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SAMPLING AND ANALYSIS PLAN
FOR
HUNTS DISPOSAL LANDFILL
CALEDONIA, WISCONSIN

JULY 1988

*** COMPANY CONFIDENTIAL ***

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PERFORMANCE OF REMEDIAL PLANNING
ACTIVITIES AT SELECTED UNCONTROLLED HAZARDOUS
SUBSTANCE DISPOSAL SITES (REM V)

U.S. EPA CONTRACT NO.: 68-01-7403

SAMPLING AND ANALYSIS PLAN

FOR

HUNTS DISPOSAL LANDFILL
CALEDONIA, WISCONSIN

DOCUMENT NO.: 002-CCJ-QA-1204

WORK ASSIGNMENT NO.: 2-5L3D

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TABLE OF CONTENTS

SAMPLING AND ANALYSIS PLAN
HUNTS DISPOSAL LANDFILL, CALEDONIA, WISCONSIN

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

Item

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

1.1 OBJECTIVES OF THE SAMPLING PROGRAM

The overall objectives of the Remedial Investigation and Feasibility Study (RI/FS) to be undertaken at the Hunts Disposal Landfill (HDL) site in Caledonia, Wisconsin, are to determine the nature and extent of the contamination problem at the site, and to develop and evaluate remedial alternatives. While the focus of the effort is to assess the extent of existing contamination, effort will also be directed towards assessing the potential for future contamination based on the wastes present at the site and the development activities occurring in the area.

The focus of the field sampling effort is to ascertain the extent of existing contamination, if any, and to assess the potential for future contamination based on the wastes present at the site. The other objective of this sampling activity is to fill in the rather limited data available on the site keeping in mind the future development activities at and near the site. The analysis from the field investigation would be basis for the development of the RI which would characterize the site.

Specific objectives, based primarily on information contained in the Work Assignment (2-5L3D), include:

- Assess the nature and extent of groundwater, surface water, and soil contamination on and adjacent to the site.
- Assess the role that contaminants from the Hunts Disposal Landfill Site play on the overall quality of water in the Root River, the on-site lake, and on the nearby groundwater supplies.
- Assess the extent of off-site migration of contaminants and their impact on potential receptors.

- o Identify potential pathways for exposure.
- o Ascertain whether the site poses a hazard to public health, welfare, or the environment.
- o Recommend the most effective, most implementable and least costly remedial alternatives.

1.2 SCOPE OF SAMPLING ACTIVITIES

The scope of the sampling activities at the HDL site includes the installation of 18 groundwater monitoring wells, and the collection and analysis of 158 investigative samples, 18 duplicates and 10 field blanks. The media/matrices to be sampled include surface water, sediment, soil, and groundwater. 176 samples will be analyzed for TCL and TAL parameters and and 10 samples will analyzed for three geotechnical parameters: permeability, porosity and grain-size. The number of sample containers actually sent to the laboratory will vary depending on the analyses being requested. However, each "sample" is designed to represent homogeneous material which reflects the environmental condition of the location sampled at the time the sample was taken.

The overall sampling effort is summarized in Table 1-1. The details of the sampling and analysis program are summarized in Table 1-2. Table 1-2 provides the specific parameters to be measured, the number and frequency of sampling, the level of QC effort for each environmental media/matrix.

TABLE 1-1

SUMMARY OF SAMPLING EFFORT

Type	Investigative	Duplicate	Field Blank
Soil			
--Surficial	35	4	---
--Soil Borings (Split-Spoon Samples)	18	2	---
--Soil Borings (Shelby-Tube Samples)	10	---	---
Groundwater			
--Monitoring Wells* (Installed and Existing)	42	6	6
--Monitoring Wells* (Existing)	3	1	1
--Residential Wells*	10	1	1
Surface Water			
--River/Lake/Pits*	20	2	2
Sediment			
--River/Lake/Pits	20	2	---
TOTALS:	158	18	10

*Duplicate matrix spike volume will be collected for one in ten samples for all organic samples. This consists of triple the sample volume for volatiles and extractable organics. Spiking will be performed by the laboratory. One trip blank will be included with each shipment container of volatile organic samples

TABLE 1-2

SUMMARY OF SAMPLING AND ANALYSIS PROGRAM - HUNTS DISPOSAL LANDFILL

SAMPLE MATRIX	FIELD PARAMETERS	LABORATORY PARAMETERS	INVESTIGATIVE SAMPLES NO.	FREQ	TOTAL	QC SAMPLES DUPLICATE NO.	FREQ	TOTAL	QC SAMPLES BLANK NO.	FREQ	TOTAL	MATRIX TOTAL
Soils (Surficial)	Qualitative organic vapor screening with HNu or OVA and HNu -Geophysical investigation. -Radiological investigation	--RAS Organics Package From CLP Including 30 Tentatively Identified Parameters/a.	35	1	35	4	1	4	-	-	-	39
		--RAS Inorganics/Metals From CLP/b.	35	1	35	4	1	4	-	-	-	39
		--RAS Inorganics Package/ Cyanide From CLP/b.	35	1	35	4	1	4	-	-	-	39
Surface water Samples	Qualitative organic vapor screening with HNu or OVA and HNu -pH -Specific Conductance -Temperature	--RAS Organics Package From CLP Including 30 tentatively identified Parameters/a.	20	1	20	2	1	2	2	1	2	24
		--RAS Inorganics Package/ Metals from CLP Unfiltered Samples/b.	20	1	20	2	1	2	2	1	2	24
		--RAS Inorganics Package/ Metals from CLP Filtered Samples/b.	20	1	20	2	1	2	2	1	2	24
		--RAS Inorganics Package/ Cyanide from CLP Unfiltered/b.	20	1	20	2	1	2	2	1	2	24
Sediments	Qualitative organic vapor screening with HNu or OVA and HNu	--RAS Organics Package From CLP Including 30 Tentatively Identified Parameters/a.	20	1	20	2	1	2	-	-	-	22
		--RAS Inorganics Package/ Metals From CLP/b.	20	1	20	2	1	2	-	-	-	22
		--RAS Inorganics Package/ Cyanide From CLP/b.	20	1	20	2	1	2	-	-	-	22
Soil Borings (Split-Spoon Samples)	Qualitative organic vapor screening with HNu or OVA and HNu	(For selected samples on head space analysis) RAS Organics Package from CLP Including 30 tentatively identified Parameters/a.	18	1	18	2	1	2	-	-	-	20
		--RAS Inorganics Package/ Metals From CLP/b.	18	1	18	2	1	2	-	-	-	20
		--RAS Inorganics Package/ Cyanide From CLP/b.	18	1	18	2	1	2	-	-	-	20

TABLE 1-2 (Continued)

SUMMARY OF SAMPLING AND ANALYSIS PROGRAM - HUNTS DISPOSAL LANDFILL

SAMPLE MATRIX	FIELD PARAMETERS	LABORATORY PARAMETERS	INVESTIGATIVE SAMPLES NO.	FREQ	TOTAL	QC SAMPLES DUPLICATE NO.	FREQ	TOTAL	BLANK NO.	FREQ	TOTAL	MATRIX TOTAL
		--Physical Gentechnical Parameter from CLP SAS/c. Grain size Permeability Porosity	10	1	10	-	-	-	-	-	-	10
Groundwater Monitoring Well Samples (3 existing and 18 newly installed wells)	Qualitative organic vapor screening with HNu or OVA and HNu (new wells only) -pH -Specific Conductance -Temperature -Bail Down/Hydraulic conductivity (new wells only)	--SAS Organics Package From CLP Including 30 Tentatively Identified Parameters/ Drinking Water Detection Limits/c.	21	2	42	3	2	6	3	2	6	54
		--RAS Inorganics Package/ Metals From CLP Filtered Samples/b.	21	2	42	3	2	6	3	2	6	54
		--RAS Inorganics Package/ Cyanide From CLP Unfiltered Samples/b.	21	2	42	3	2	6	3	2	6	54
		--SAS Inorganic Package for Total Dissolved Solids/c. Filtered Samples	21	2	42	3	2	6	3	2	6	54
		---RAS Organics Package plus SAS Fast-turnaround/c. From CLP Including 30 tentatively Identified Parameters/a.	3	1	3	1	1	1	1	1	1	5
		---RAS Inorganics Package plus SAS Fast-turnaround/c. Metals from CLP Filtered Samples/b.	3	1	3	1	1	1	1	1	1	5

TABLE 1-2 (Continued)

SUMMARY OF SAMPLING AND ANALYSIS PROGRAM - HUNTS DISPOSAL LANDFILL

SAMPLE MATRIX	FIELD PARAMETERS	LABORATORY PARAMETERS	INVESTIGATIVE SAMPLES NO.	FREQ	TOTAL	QC SAMPLES DUPLICATE NO.	FREQ	TOTAL	BLANK NO.	FREQ	TOTAL	MATRIX TOTAL
		---RAS Inorganics Package plus SAS Fast-turnaround/c. Cyanide from CLP Unfiltered samples/b.	3	1	3	1	1	1	1	1	1	5
Residential Wells	-pH -Specific Conductance -Temperature	--SAS Organic Package From CLP Including 30 Tentatively Identified Parameters/Drinking Water Detection Limits/c.	10	1	10	1	1	1	1	1	1	12
		--SAS Inorganic Package/ Metals (including Mercury) From CLP/ Drinking Water Detection Limits/ Unfiltered Samples/c.	10	1	10	1	1	1	1	1	1	12
		--SAS Inorganic Package/ Cyanide From CLP/ Drinking Water Detection Limits/ Unfiltered Samples/c.	10	1	10	1	1	1	1	1	1	12

a. Parameters to be analyzed for are listed in Table 4-2 of the QAPP.
b. Parameters to be analyzed for are listed in Table 4-3 of the QAPP.
c. Parameters to be analyzed for are listed in Appendix 3 of the SAP.

NOTE: Matrix Spike/Matrix Spike Duplicate analyses will be performed on a 1 per 10 sample basis for every aqueous sampling event. Triple the normal sample volume for organics analyses will be collected for these samples. In addition, one trip blank will be included with each shipment container of volatile organic samples.

2.0 SAMPLE LOCATIONS

2.1 SOIL SAMPLES

2.1.1 SURFICIAL SOIL

In order to characterize the extent of surface soil contamination at the site, and the extent of surface migration of contaminated materials, 35 surficial soil samples will be collected at locations on and near the site. Included in the single round of samples will be duplicate samples taken at four locations. At least one upgradient "clean" location and one "dirty" location will be chosen for duplicate sampling. These samples will be analyzed for RAS CLP organic and inorganic parameters. The final number of samples is subject to change based on new information obtained during the field investigation. Locations at which samples will be taken include:

- Areas surrounding the filled portion on the site.
- Areas adjacent to surface water bodies.
- Soil in contact with observed leachate seeps.
- Selected areas of the surface cover.
- Additional background locations outside the site boundary to be determined in the field.

2.1.2 SUBSURFACE SOIL BORINGS (SPLIT-SPOON SAMPLES)

Subsurface soil samples will be collected during the drilling of the deepest monitoring well at each well cluster. At the first deep well, the boring will be continually split-spoon sampled to a depth of approximately 60 feet to establish the geologic conditions at the site. During the

drilling of the remaining deep monitoring wells at each well nest, continuous split-spoon samples will be collected until just below the water table and at five foot intervals thereafter or where there are any changes in lithology. An experienced geologist will classify all soil samples and record pertinent drilling information.

It is estimated that two subsurface split-spoon soil samples will be retained at each of the well clusters. Thus there will be a total of 20 split-spoon samples. These samples will analyzed by the CLP for TCL organics and TAL metals. One duplicate sample will be collected and analyzed for every 10 subsurface soil samples submitted. The selection of which samples to be submitted for analysis will be based on observed lithological changes and/or on the results of HNu head space monitoring. At each of the sampling locations, one undisturbed sample (Shelby tube) will be retained for laboratory determination of grain size, permeability and porosity. The number of samples may vary based on new information obtained during the drilling of each well.

2.2 GROUNDWATER SAMPLES

2.2.1 MONITORING WELL SAMPLES

A detailed groundwater investigation will be performed in order to further assess the hydrologic characteristics of the aquifer(s) within the site area, and to obtain groundwater samples that can be considered representative of the chemical quality within the associated aquifer(s).

Presently there are three existing monitoring wells within the site study area which could play an important part in this investigation. If wells prove to be usable and accessible, these wells will be sampled and water level measurements taken. Although QA/QC during installation of these wells is currently unknown, this point will be taken into account when reviewing and analyzing the analytical data.

Assuming access to the existing monitoring well can be gained, it is estimated that a total of 18 additional monitoring wells will be installed. Sixteen of these wells will be located in eight "nests" each consisting of a shallow well and a deep well. The other two wells will be single shallow wells at the two different locations. Preliminary locations and depths of the new monitoring wells and the locations of the existing wells are shown in Figure 2-1.

For this investigation, two different well depths will be used to collect hydrogeologic data. Shallow monitoring wells will be screened from 5 to 15 feet below the ground surface. These wells will provide information on water table hydrology and will intercept any contamination that may be floating on top of the water table. "Deep" wells will be completed between the 20 and 40 foot range, depending on geology of that well location and if there are indications of contamination (from the head space analysis). These wells will give information on deeper potential contamination migration routes. All existing wells are shallow. The wells nests are situated to enable complete coverage to be given to all locations around the landfill area without intrusively drilling into the landfill. Although, generally water in the region moves laterally from west to east through the glacial material, it is anticipated that in the area of the landfill shallow groundwater is moving towards the Root River. Therefore, the well locations have been situated at various points between the landfill and the river to intercept the groundwater flowing in that direction. Well nest locations 6, 8, and 9 on Figure 2-1 are the proposed background locations situated in an areas where landfilling activities are not known to have occurred. The data from these wells will aid in segregating possible inherent area contamination from landfill related contamination. The rationale for each monitoring well location is shown in Table 2-1.

It is estimated that samples will be collected from 3 existing monitoring wells and 18 proposed monitoring wells. The sampling will be conducted no sooner than one week after the last proposed monitoring well has been developed. A second phase of groundwater sampling will be conducted after

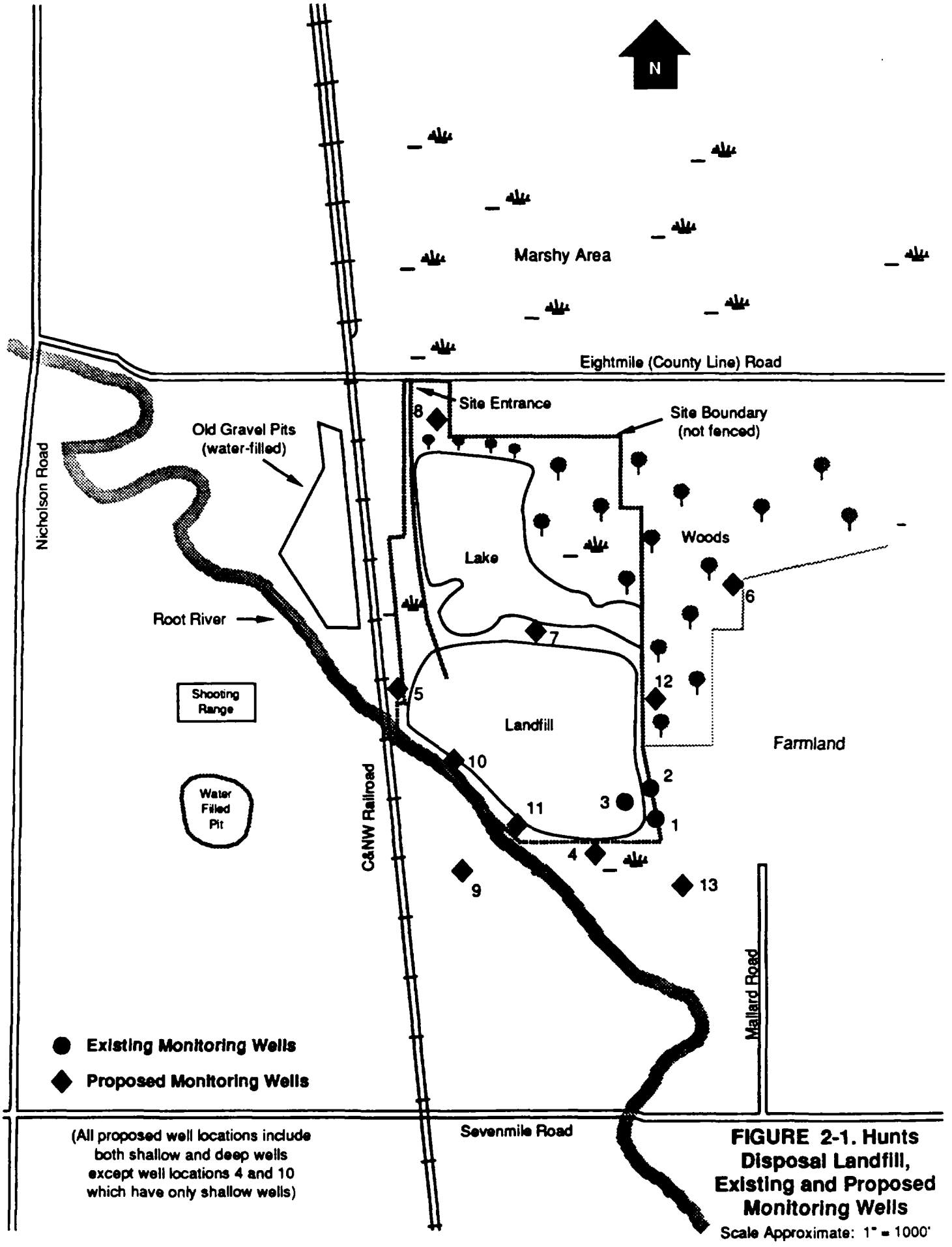

FIGURE 2-1. Hunts Disposal Landfill, Existing and Proposed Monitoring Wells

Scale Approximate: 1" = 1000'

TABLE 2-1

RATIONALE FOR PLACEMENT OF NEW GROUNDWATER MONITORING WELLS AT HUNTS DISPOSAL LANDFILL

(Refer to Figure 2-1 for location of wells; wells 1, 2 & 3 are existing monitoring wells)

Well	Placement Rationale
4, 5, 10 & 11	Placed to intercept shallow (4,5, 10 & 11) and deep (4 & 10) groundwater flow from the landfill toward the Root River.
7 & 12	Placed to intercept shallow and deep groundwater flow north from the landfill (7) and east from the landfill (12).
13	Placed to determine if groundwater contamination has migrated a significant distance southeast from the landfill. Also needed to help establish regional groundwater flow system.
6, 8, & 9	Assumed to be background locations. However, will be used to confirm this assumption and place limits on groundwater contaminant migration to the north (8), the northeast (6), and southwest below the river (9). Also needed to help establish regional groundwater flow system.

analytical results from the first round have been received and evaluated.

The 3 existing monitoring wells will be sampled during the first week of field activities with a fast turnaround request placed on the analytical results. These results will provide initial insight into current groundwater activities and will aid the field geologist in making decisions during the installation of the 18 proposed monitoring wells.

One duplicate and one field blank will be collected for every ten groundwater samples. All organic samples will be sent for full CLP analyses for volatiles, semi-volatiles, pesticides and PCBs. In addition, the protocol for obtaining low quantitation limits for drinking water samples will be applied via a SAS request. All inorganic samples will be analyzed for total metals and cyanide via RAS protocol. The number of groundwater samples may change based on new information obtained during the field investigation.

2.2.2 RESIDENTIAL WELL SAMPLES

Residential well groundwater sampling well be performed at homes in the general area of the landfill. Ten (10) homes are scheduled to be sampled. The analysis will provide an indication of the quality of drinking water within the general site area. One duplicate and one field blank will also be collected for QC purposes. All samples will be sent to the CLP for analysis under SAS protocol for low detection limits for drinking water samples. The number of samples may change based on new information obtained during field investigation. Figure 2-2 displays the locations of the ten homes to be sampled.

2.3 SURFACE WATER SAMPLES

Surface water has been identified as a potential migration pathway from the site. In addition to characterizing this pathway, sampling at on- and

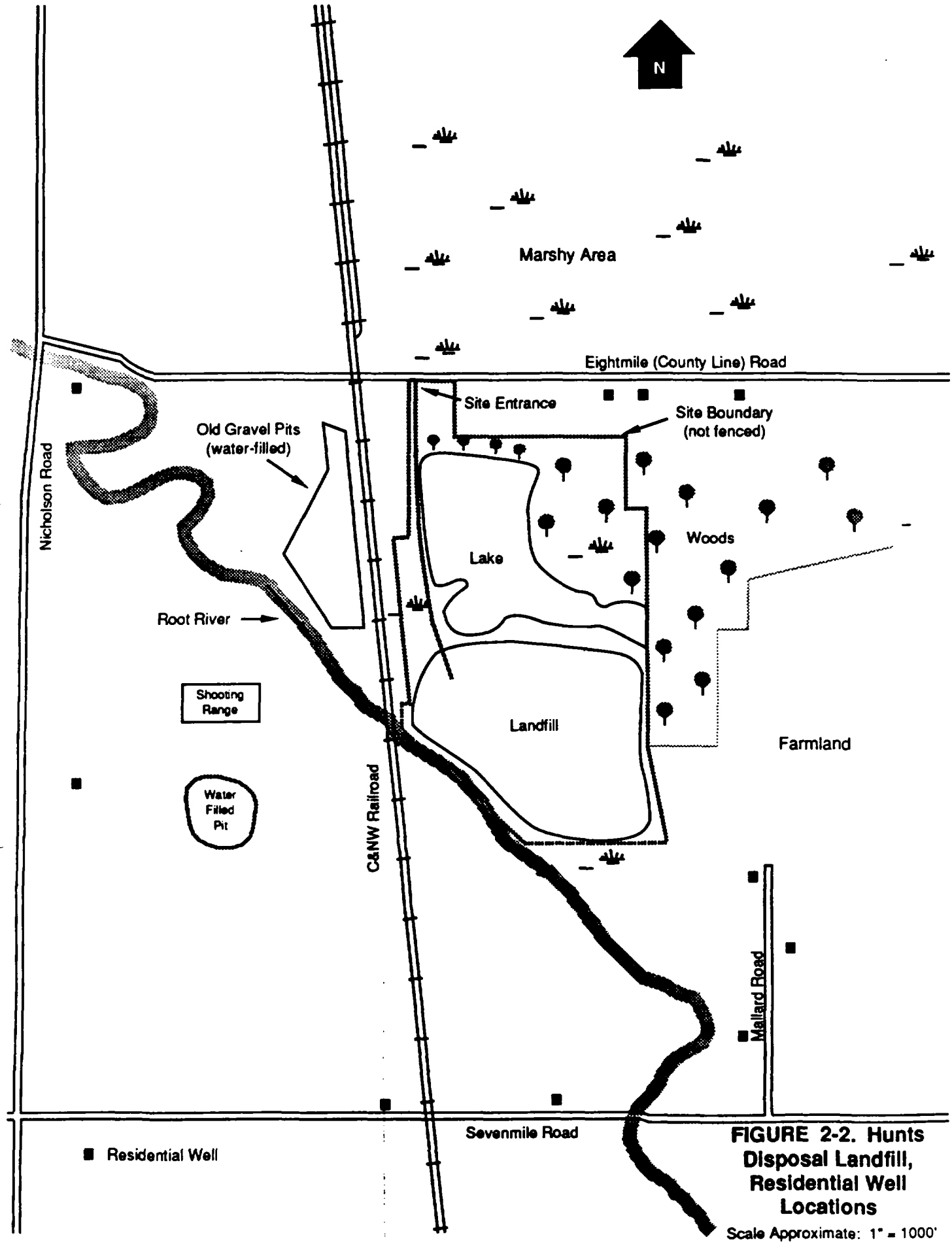

FIGURE 2-2. Hunts Disposal Landfill, Residential Well Locations

Scale Approximate: 1" = 1000'

off-site surface water locations will provide an indication of the leachability of hazardous contaminants from surficial soils and sediments should these various media exhibit similar contaminants at each location.

The Root River is the major surface drainage feature in the area of the site and, therefore, will be included in the surface water sampling activities. In addition, selected on-site standing water pools located during the field investigation will be sampled.

A total of 20 surface water samples will be taken. Stations will be located: 1) upstream of the site area, 2) immediately adjacent to the site, and 3) at selected locations in the area of the site. Surface water sampling locations are shown in Figure 2-3. All samples will be sent to the CLP for full RAS analysis for organics, metals, and cyanide. Also included will be 2 duplicate samples and 2 field blanks.

2.4 SEDIMENT SAMPLES

Depending on the physical/chemical nature of a contaminant and on the method of deposition, it is possible for the sediments underlying a contaminated body of water to exhibit levels of contamination. If the Root River or lake contain contamination, sampling the sediment would give an indication of this contamination. A total of 20 sediment samples will be collected at the same locations as the surface water samples. Also included are 2 duplicate samples. Stations will be located upstream of the site area, immediately adjacent to the site, in and along the banks of the lake, and at selected locations upstream and downstream of the site in the Root River.

Sediment sample locations are shown in Figure 2-3. All sediment samples will be sent to a CLP laboratory for full RAS analysis for organics, metals, and cyanide. Field blanks are not used for sediment samples. The number of samples is subject to change based on new information obtained during the field investigation.

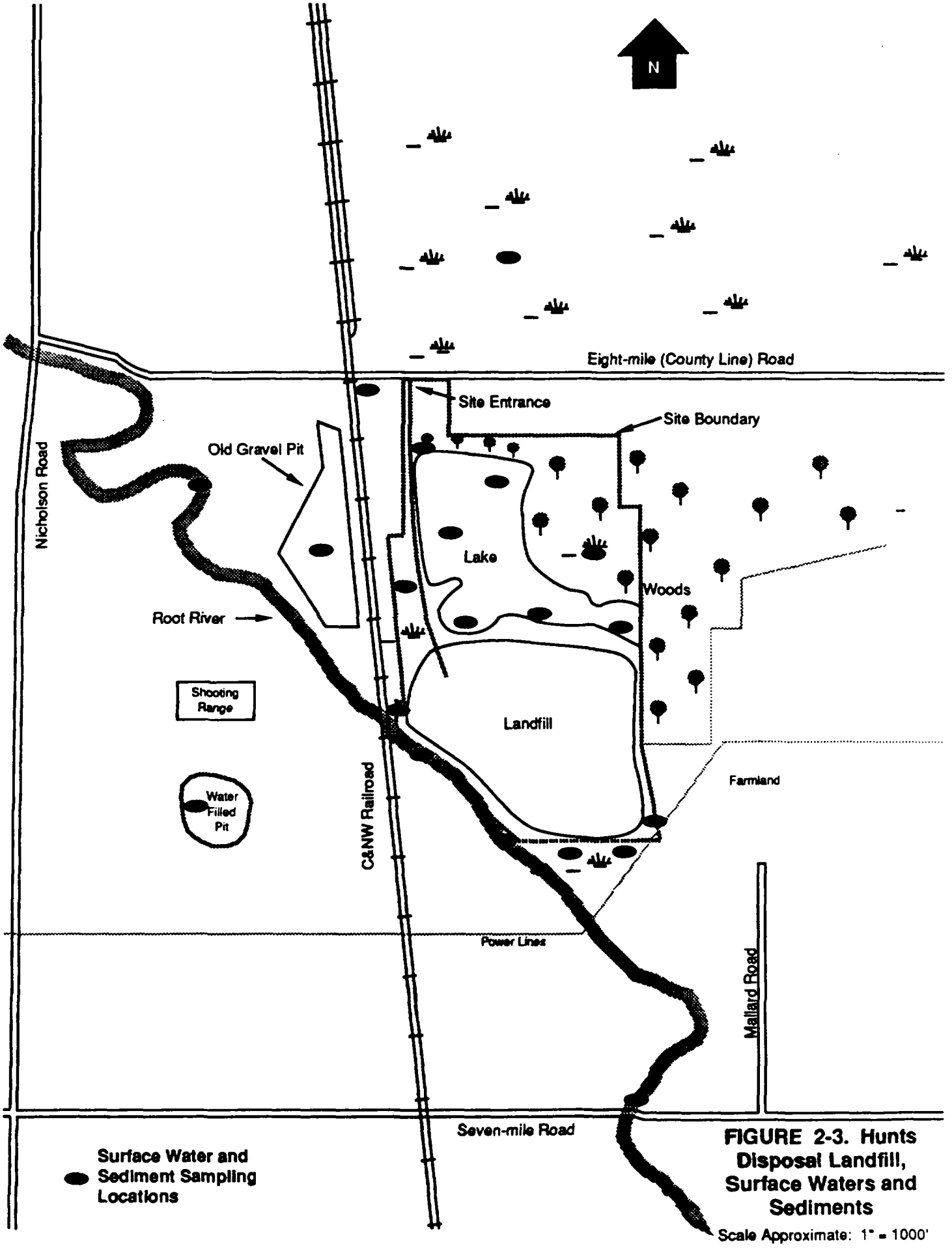

FIGURE 2-3. Hunts Disposal Landfill, Surface Waters and Sediments

2.5 DOCUMENTING SAMPLING LOCATIONS

The physical locations of all monitoring wells, borings and on-site (or immediately adjacent off-site) sampling sites will be staked, documented photographically and their locations and elevations determined by a registered surveyor. All points will be tied to the nearest United States Geological Survey (USGS) datum point and plotted on a scaled site map. Taping surveys will use existing buildings, light poles and similar fixed objects shown on the existing site map as reference points. At least three reference points will be used to locate each sampling site. The leveling survey will be tied to mean sea level datum, which may require an off-site traverse to establish an on-site benchmark.

2.6 DEVIATION FROM PLANNED SAMPLING ACTIVITIES

If through other activities at the site, the opportunity is presented to obtain types of samples not listed (e.g. waste materials), these will be collected in order to present further information concerning site conditions and materials disposed of at the site.

2.7 GEOPHYSICAL INVESTIGATION

A geophysical survey will be conducted to determine whether there are locations with a concentrated distribution of buried metal objects. The primary geophysical techniques to be used for this investigation will be magnetometer surveys and/or ground-penetrating radar.

The emphasis of the geophysical investigation will be to assess whether there are identifiable portions of the landfill in which metal objects are concentrated. If this is found to be the case, the remedial option of a partial removal could be explored further.

All final decisions concerning the ultimate area of investigation will depend to an extent on findings and interpretations obtained in the field.

2.8 RADIOLOGIC INVESTIGATION

In order to check surface gamma radiation in the area of the landfill, a walk-over site survey will be performed. Prior to performing the survey, the background gamma radiation level will be established by surveying undisturbed areas in the vicinity of the site. The survey will consist of site traverses on 200 foot spacings with a calibrated gamma ray detection meter. Readings will be observed continuously and recorded at 200 foot intervals along each traverse. Any anomalous readings will be noted. Any area measuring 2 to 3 times the background radiation level per hour will be staked out and subjected to a more detailed investigation. A beta and alpha survey will be performed after the gamma investigation and will focus on landfill areas where there has been significant erosion of cover materials.

It is anticipated that no areas will exceed the level of 2-3 times the background radiation level. If areas of high radiation are discovered, a work assignment amendment would be sought in order to initiate further studies.

3.0 SAMPLE NUMBERING SYSTEM

All samples for chemical analysis, including field duplicates, field blanks and trip blanks will be given two identification numbers: one will be the U.S. EPA Central Regional Laboratory (CRL) serial identification number, the other will be an in-house location identification number.

3.1 U.S. EPA CRL SAMPLE NUMBERING SYSTEM

Each sample must have a U.S. EPA CRL sample number regardless of the laboratory to which it is being shipped. The CRL sample number consists of nine alphanumeric characters as follows:

88 - designates fiscal year (October 1, 1987 through September 30, 1988)

R - indicates samples sent by members of the REM V Team

J - designates project manager (as assigned, A through Z)

01 - designates survey number (as assigned, 01 through 99 for each project manager A through Z)

S - indicates sample type (S = sample; D = duplicate; R = blank)

01 - designates sample number within a given survey (as assigned, 01 through 99 for each survey)

Survey and sample numbers are site-specific and are allocated in blocks for each sampling trip. Individual sample codes are assigned to specific samples by the Project Manager or sample team leader. A record of all CRL sample identification numbers will be entered in the field log book and on all other paperwork and labels. CRL numbers will also be cross-referenced to chain-of-custody and shipping documents. A description of the sample location will be entered into the field log book, including compass directions and distances from reference points.

3.2 SAMPLE LOCATION IDENTIFICATION SYSTEM

Each sample will also be assigned a location identifier. This identifier will consist of three parts:

- Project identifier--a two-letter designation used to identify the site; for Hunts Disposal Landfill these letters will be HL, followed by a one character code indicating the work phase of the RI investigation (1, 2, etc.)

- Sample type and location--a two letter designation of the sample type followed by a two-digit number for the sampling location. A list of the two-letter codes for sample types is presented in Table 3-1.

- Sample designation and sequence--a one or two character code indicating whether the sample is a duplicate (D), trip blank (TB) or field blank (FB). The second two characters will be numbers (01, 02, etc.) indicating the sequence of sample events for that location.

If a sample is considered to be a background sample, this will be indicated by the addition of two-letter characters placed at the end of the location identifier. The two characters will be BG (background).

Some examples of the sampling number system are as follows:

- HL1-SW04-S01: Hunts Disposal Landfill, work phase I, surface water sample, location 04, first sample, taken at this location.

TABLE 3-1

SAMPLE TYPE CODES

Type	Code
Air (Ambient)	AS
Water Supply (Residential Well)	RW
Soil Areas (Surficial)	SL
Soil Borings	SB
Groundwater (Monitoring Wells)	GW
Sediment (Stream and Pond)	SD
Surface Water	SW
Other	OT

- HL1-SL08-D01: Hunts Disposal Landfill, work phase I, surficial soil area sample, location 08, first duplicate sample taken at this location.

- HL2-SD02-TB02: Hunts Disposal Landfill, work phase II, sediment sample, location 02, second trip blank taken for this sample location.

- HL1-GW02-FB03: Hunts Disposal Landfill, work phase I, groundwater sample, location 02, third field blank (taken on sampling equipment prior to collecting investigative samples at this location) taken at this sample location.

- HL1-RW04-S01: Hunts Disposal Landfill, work phase I, residential well sample, location 04, first sample taken at this location.

- HL1-SW03-S01-BG: Hunt Disposal Landfill, work phase I, surface water, location 03, first sample taken at this location, background sample.

The identification system for soil borings has an amended format. An example of this format is as follows:

- HL2-SB01D-010-012: Hunts Disposal Landfill, work phase II, soil boring, location 01, duplicate sample, sample taken from the 10-foot to 12-foot depth interval.

All sample location identifiers will be recorded in the field notebook with an accurate description of the sampling location. These will also be recorded on the Sample Identification Record Form (Figure 3-1) and will be used for computer tracking and identification of each sample.

Figure 3-1

SITE NAME:________________ SAMPLE IDENTIFICATION RECORD FORM SITE NUMBER:__________

Case Number	Matrix	Lctn	CRL Number	Organic/HM Traffic Rpt.	Inorganic Traffic Rpt.	Chain of Custody	Lab Code	Date Sampled	Date Shipped	Airbill No.	SAS Number	Sample Tag Numbers	

4.0 SAMPLING EQUIPMENT AND PROCEDURES

4.1 SURFICIAL SOIL SAMPLING

Surficial soil samples will be collected from 35 locations on and near the site. The soil will be collected to a depth of 6 inches using a stainless steel scoop. Samples will be obtained by scooping the soil from a small area and placing it on a stainless steel tray. The soil will be mixed with stainless steel spoons or spatulas until a homogeneous mixture is obtained. (See Section 4.5 for details on compositing.) It will then be divided into portions and placed in sample containers. Volatile samples will be placed directly into sample containers without mixing. The stainless steel spatula, scoop, and tray will be decontaminated directly after use according to the procedures outlined in Table 4-1.

4.2 SOIL SAMPLES COLLECTED DURING DRILLING

During the installation of the eighteen new monitoring wells, split-spoon samples (soil borings samples) will be collected from the deepest well at each well location. Two samples per well will be selected and sent to the CLP for analysis unless the field geologist determines the need for additional analytical information pertaining to a particular core sample. Eight of the ten well nest locations consist of a shallow and a deep well and the remaining two shallow wells will be installed at two separate locations. Therefore, an estimated twenty soil boring samples will be analyzed.

As was previously described in Section 2.1.2.1, the boring for the first deep well will be continually split-spoon sampled to a depth of approximately 60 feet to establish the geologic conditions at the site. During the drilling of the remaining deep monitoring wells at each well nest, continuous split-spoon samples will be collected until just below the water table and at five foot intervals thereafter or where there are any apparent changes in lithology.

Each soil sample will screened for volatile organics using a head space analysis method. When the sample is brought to the surface, it will be immediately transferred to a sample jar, quickly covered with aluminum foil and put in a warm place. After the sample had warmed up to approximately 75 ^{o}F, allowing any volatile materials to collect in the head space above the soil sample, an HNu probe will be used to pierce the aluminum foil and the subsequent meter readings recorded. The field geologist will select which samples will be submitted for analysis. This decision will be based on observed lithological changes and/or the results of the HNu head space monitoring.

Soil sample containers will be filled using stainless steel spoons and spatulas. The VOA sample containers will be filled first without any mixing or compositing. Where necessary a decontaminated chisel will be used to breakup the core sample into small pieces. After the VOA sample containers are filled, the remaining sample containers will be filled. If the sample core appears highly non-homogeneous it will be necessary to composite the remaining sample according to the procedures discussed in Section 4.5 prior to filling the remaining sample containers. All sampling equipment will be decontaminated directly after use according to the procedures outlined in Table 4-1. Lithology samples will be retained in-house for geological assessment at a later time. All samples will be representative of materials encountered and will be obtained by driving a 2-inch outside diameter (OD) sample spoon with a 140-pound weight free falling 30 inches. In general, all drilling and sampling operations will conform to American Society for Testing and Materials (ASTM) standards.

TABLE 4-1

STANDARD DECONTAMINATION PROTOCOL FOR SAMPLING EQUIPMENT

STEP 1 -- Scrub equipment thoroughly with stiff-bristle brushes in a low-sudsing detergent solution.

STEP 2 -- Rinse equipment with tap water by submerging and/or spraying.

STEP 3 -- Rinse equipment with isopropanol by spraying until dripping.

STEP 4 -- Rinse equipment with distilled water by spraying until dripping.

STEP 5 -- Place equipment on aluminum foil and allow to air-dry for five to ten minutes.

STEP 6 -- Wrap equipment in aluminum foil (shiny side away from equipment surface) for handling and/or storage until next use.

All excess run-off or drippings produced during the decontamination procedure must be retained and poured into a marked 55-gallon drum, and stored onsite for future testing and disposal.

NOTES: In addition to the standard protocol, pumps and discharge lines will be decontaminated by pumping the detergent solution, tap-water rinse and distilled water rinse through the equipment. All downhole drilling equipment and materials will be decontaminated via steam cleaning unless the field geologist determines otherwise. e.g. The presence of oil or grease would require that Step 1 in the above protocol be followed prior to steam cleaning.

4.3 GROUNDWATER SAMPLING

4.3.1 MONITORING WELL SAMPLES

Groundwater samples will be collected from the 3 existing and 18 newly installed monitoring wells. Samples will be collected using the following procedures:

- The well will be inspected for above ground damage.
- The air above the water column will be screened for organic vapors with an HNu or OVA.
- The depth to the water level in the well will be measured with a weighted steel, or Fiberglas tape or with an electronic sounding device. The weight will be designed to create a popping sound on contact with the water surface. Electronic sounding devices normally emit a visible and/or audible signal upon contact with water. The depth to water and the time of measurement will be recorded.
- Based on the water level measurement and the depth of the well, the volume of standing water in the well will be calculated.
- The well will be purged using a positive displacement pump constructed of chemically inert materials. The standard procedure will be to pump until at least three well volumes have been removed.
- All downhole equipment shall be cleaned prior to sampling using the following method:
  - Rinse with clean distilled water;
  - Rinse with isopropanol and allow to air dry, and
  - Rinse at least once with clean distilled water
- Beginning with the fourth volume, periodic measurements of pH, specific conductance and temperature will be made using the procedures contained in Appendix 1.
- Purging may cease when measurements for all three parameters have stabilized ($\pm$0.25 pH units, $\pm$50 umhos/cm, and $\pm$0.5 degrees C) for three consecutive readings or after five well volumes have been removed.

If the well pumps dry before three volumes have been removed, the well will be allowed to recharge for 15 minutes and then pumped dry again.

- The sample will be obtained with a dedicated PVC bailer. The bailer will be raised and lowered in the well using a new length of polypropylene cord at each location.
- The sampling and purging equipment will be decontaminated in accordance with the standard protocol presented in Table 4-1 prior to each use.

4.3.2 RESIDENTIAL WELL SAMPLING

Residential well samples will be collected from selected residential wells in the site vicinity. Access to all of these wells will be coordinated by the U.S. EPA. Residential aeration, softening and/or other devices will be disconnected prior to sampling. The well pumps will be operated for at least 10 minutes prior to collection of the sample. Field measurement of pH, specific conductance and temperature will be performed using the procedures contained in Appendix 1.

4.4 SURFACE WATER SAMPLING

Surface water samples will be collected from 20 locations including the Root River, the lake to the north of the site and at various other areas on and near the site. The river and lake samples will be obtained midstream just below the water's surface. Additional sampling locations may be identified if field observation warrant further investigation. For all shallow surface water sampling locations, a pond sampler with either the sample bottle or an intermediate disposable sampling container will be used

to collect the sample. Intermediate disposable containers will be wide mouth glass soil sample bottles. Field measurements (temperature, pH, and conductivity) will be made in the intermediate container after sample collection is completed. The sample bottle will be sealed, marked, and labeled according to established chain-of-custody procedures. The intermediate container used for sampling will be discarded after sampling is complete at each location. Use of the sample bottle or intermediate sample container for each sampling location will eliminate the potential of a cross-contamination problem.

The sampler(s) will submerge an intermediate disposable container or sample bottle directly into the water at midstream. The sampling container will be evacuated. Additional water will be allowed to enter the container and the sample will be collected from the newly entering water. In the river and stream, where two locations have an upstream-downstream relationship, the downstream location will be sampled first so that disturbances to water and sediment resulting from sample collection at one location do not affect the subsequently sampled location. In each instance, the container's mouth should be positioned so that it faces upstream. Field measurement of pH, specific conductance and temperature will be performed using the procedures contained in Appendix 1. At least 2 of the 20 surface water samples will be collected at a depth from the lake and/or river. A Kemmerer sampler will be utilized to collect the sample and convey it to the surface. There, the appropriate sample containers will be filled, with the VOA containers filled first. Information concerning flow in the Root River will be obtained from available data sources.

4.5 SEDIMENT SAMPLES

Sediment samples will be collected at 20 locations in and around the area of the landfill. Stations will be upstream of the site area, immediately adjacent to the site, in and along the banks of the lake and at selected locations in the Root River. Samples taken from the banks of the lake and

in those areas of shallow water, will be collected using either a 4-inch diameter bucket auger or stainless steel hand trowels and spoons. Samples taken at depth from the Root River and lake will be collected using a gravity core sampler. The top 6 to 24 inches of solid material at each sampling location will be collected. The VOA portion of each sediment sample will not be composited. Instead a small portion of undisturbed sediment taken directly from the hand auger or sampler will be placed in each VOA sample container. The remaining sample will be placed in a stainless steel mixing bowl or tray. When enough material has been collected to fill all sample containers, the sample will be composited and the remaining sample containers filled appropriately.

The compositing procedure is designed to ensure an acceptable degree of mixing. Using a decontaminated stainless steel spoon or spatula, sample material will be broken up into one-half inch diameter pieces or smaller. The soil particles will then be stirred (using spoons or spatulas), so that all of the soil at the bottom of the tray or bowl is displaced to the top and vice versa. This action will be repeated at least three times (the motion is similar to gently tossing a salad). The end result of compositing is to acquire a soil mixture that appears to have the same properties throughout such as color, grain size distribution and density/plasticity.

All sampling equipment, including spatulas and spoons will be decontaminated in accordance with the standard decontamination protocol presented in Table 4-1 prior to each use.

4.6 MONITORING WELL INSTALLATION

Eighteen monitoring wells will be installed at ten separate locations in the site study area. The final configuration may vary based on additional information gained during the field activities. The well installation

procedure will be designed to provide additional information concerning the stratigraphy and lithology of the area, aquifer continuity and direction(s) of groundwater flow.

4.6.1 Two-Well Nests

Eight of the ten monitoring well locations will have a two-well nest installed using the following procedures with the deeper well installed first:

- The working end of the drilling rig and all equipment, tools and materials will be steam cleaned prior to drilling at each location. Provisions will be made to keep the equipment, tools and materials from coming into contact with surficial soils during drilling and well installation.
- The borehole will be advanced using hollow stem auger drilling methods. The depth of the well will be determined in the field but will generally be about 20-40 feet below the water table.
- Samples will be collected using 2-inch split-spoon samplers. Samples will be collected continuously until the water table is reached and at 5-foot intervals to the bottom of the boring displaying apparent changes in lithology. As each sample is recovered, it will be qualitatively screened for organic vapors using an OVA or HNu instrument. The instrument readings and soil description will be entered into a sampling logbook. The boring will be logged by a geologist or geotechnical engineer and the samples retained for future reference and possible geotechnical index testing.
- Drilling and sampling will proceed until indicated by the on-site geologist.
- The well will be constructed of 2-inch diameter, schedule 40 polyvinyl chloride pipe with flush-threaded joints and a five-foot screened interval at the bottom. The screen will be continuously slotted with openings of 0.010 inches.

- The annular space around the screen will be backfilled with a silt-free flint sand to a height at least two feet above the top of the screen. A three-foot seal of compressed pure bentonite pellets will be placed above the sand pack, and the remaining annular space will be filled with a cement-bentonite grout placed with a tremie pipe.

- A six-inch diameter, locking protective casing will be installed at the surface with a concrete anchor and run-off diversion apron. Locks will be provided. Vehicle-bumper posts will be installed around the well if it is located in a traffic area.

- The well will be developed by air surging or surge block until at least five well volumes have been removed and clear water is obtained during pumping. Well development will be performed by the drilling contractor under the supervision of the field geologist. Upon completion of development, a bail down recovery test, as described in Subsection 4.9, will be performed to document the sensitivity of the well and provide data for calculating the hydraulic conductivity of the screened interval.

The shallow wells at these locations (two-well nests) will be installed using similar procedures except as follows:

- Samples will not be collected unless drill cuttings or monitoring instruments show contamination or conditions which vary from the deeper boring at the location.

- The depth of the boring will be determined in the field and will be screened at depths selected by the onsite geologist.

- The screened interval will span the water table surface.

- The screened interval will be ten feet in length.

- Extra care will be taken to ensure that the annulus of the well is completely sealed against surface runoff.

The details of well construction for two-well nests are shown on Figure 4-1.

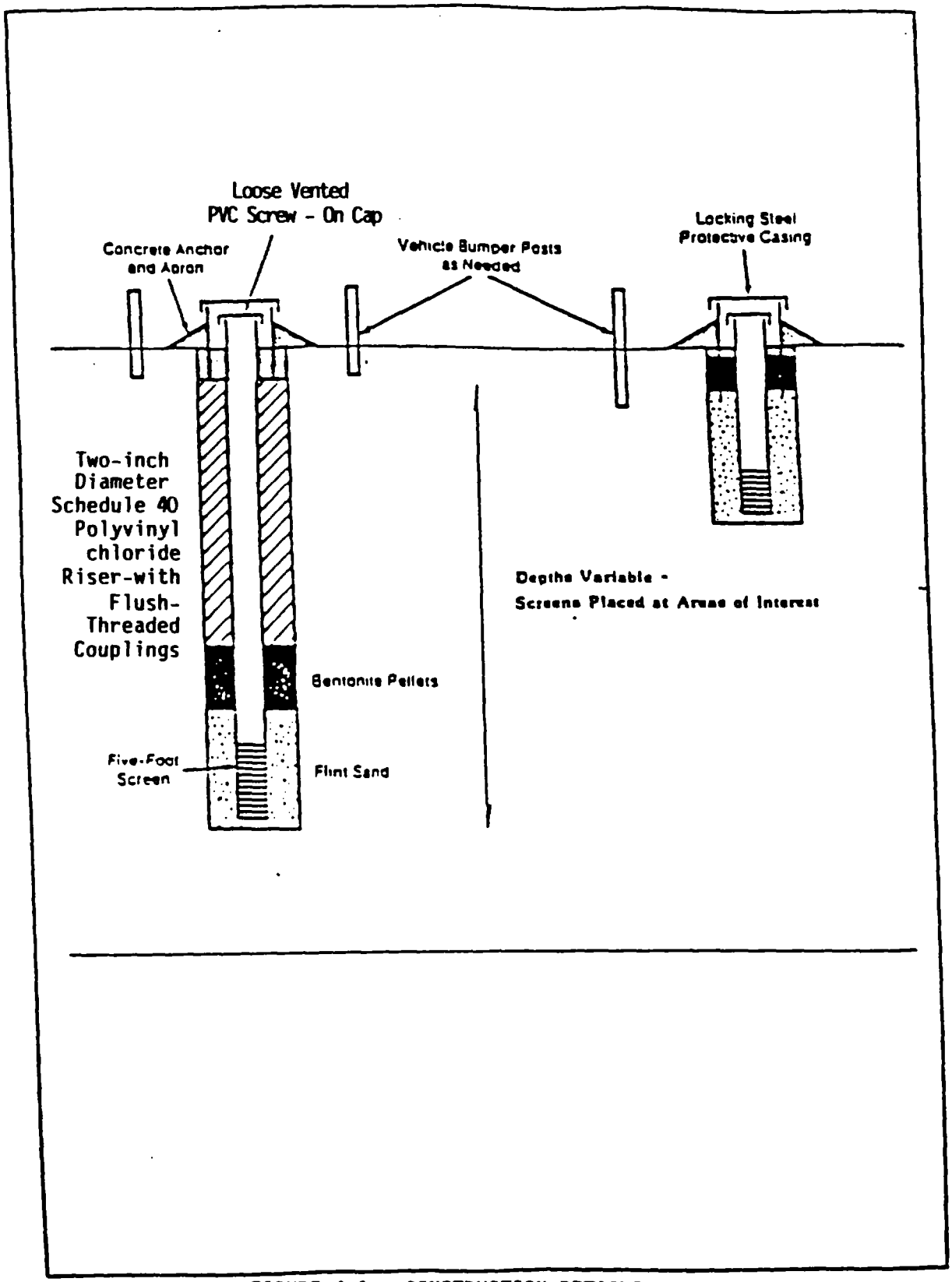

FIGURE 4-1 CONSTRUCTION DETAILS
TWO-WELL NEST

4.6.2 Single-Well Installations

Monitoring wells at these locations will have only one well screened at the depth of interest. There will be two locations with this configuration. Proposed monitoring well locations are presented in Figure 2-1 of this document.

The single wells will be installed using the following procedures:

- The working end of the drilling rig and all equipment, tools and materials will be steam cleaned prior to drilling at each location. Provisions will be made to keep the equipment, tools and materials from coming into contact with surficial soils during drilling and well installation.

- The borehole will be advanced using hollow stem auger drilling methods.

- Samples will be collected using 2-inch split-spoon samplers. Samples will be collected continuously until the water table is reached and at 5 foot intervals to the bottom of the boring, or where there are any apparent changes in lithology. As each sample is recovered, it will be qualitatively screened for organic vapors using an OVA or HNu instrument. The instrument readings and soil description will be entered into a sampling log-book. The boring will be logged by a geologist or geotechnical engineer and the samples retained for future reference and possible geotechnical index testing.

- The well will be constructed of 2-inch diameter, schedule 40 polyvinyl chloride pipe with flush-threaded joints and five-foot screened intervals at the bottom. The screen will be continuously slotted with opening of 0.010 inches.

- The annular space around the screen will be backfilled with a silt-free flint sand to a height at least two feet above the top of the screen. A three-foot seal of compressed pure bentonite pellets will be placed above the sand pack.

- A six-inch diameter, locking protective casing will be installed at the surface with a concrete anchor and runoff diversion apron. The riser will be covered with a loosely fitting, PVC screw-on cap. Locks will provided. Three vehicle-bumper posts will be installed around the well if it is in a traffic area.

- The well will be developed by air surging or surge block until at least five well volumes have been removed and clear water is obtained during pumping. Upon completion of development, a bail-down recovery test, as described in Subsection 4.9, will be performed to document the sensitivity of the well and provide data for calculating the hydraulic conductivity of the screened interval.

The details of well construction for the single-well installations are shown on Figure 4-2.

4.7 QUALITATIVE ORGANIC VAPOR SCREENING OF SOIL SAMPLES

The purpose of the organic vapor screening activity is to obtain a preliminary indication of the magnitude and distribution of volatile contaminants in the subsurface. This procedure will be performed on all split-spoon samples taken during drilling. (The samples that will be sent for laboratory analysis have been predetermined by depth so that an attenuation profile can be obtained). Screening data may also be used to adjust the depths of monitoring wells. Equipment needed for this screening will be an HNu or an HNu in conjunction with an OVA. However, the HNu alone should be adequate for a qualitative screening. General procedures for use of the equipment for the detection of volatiles associated with

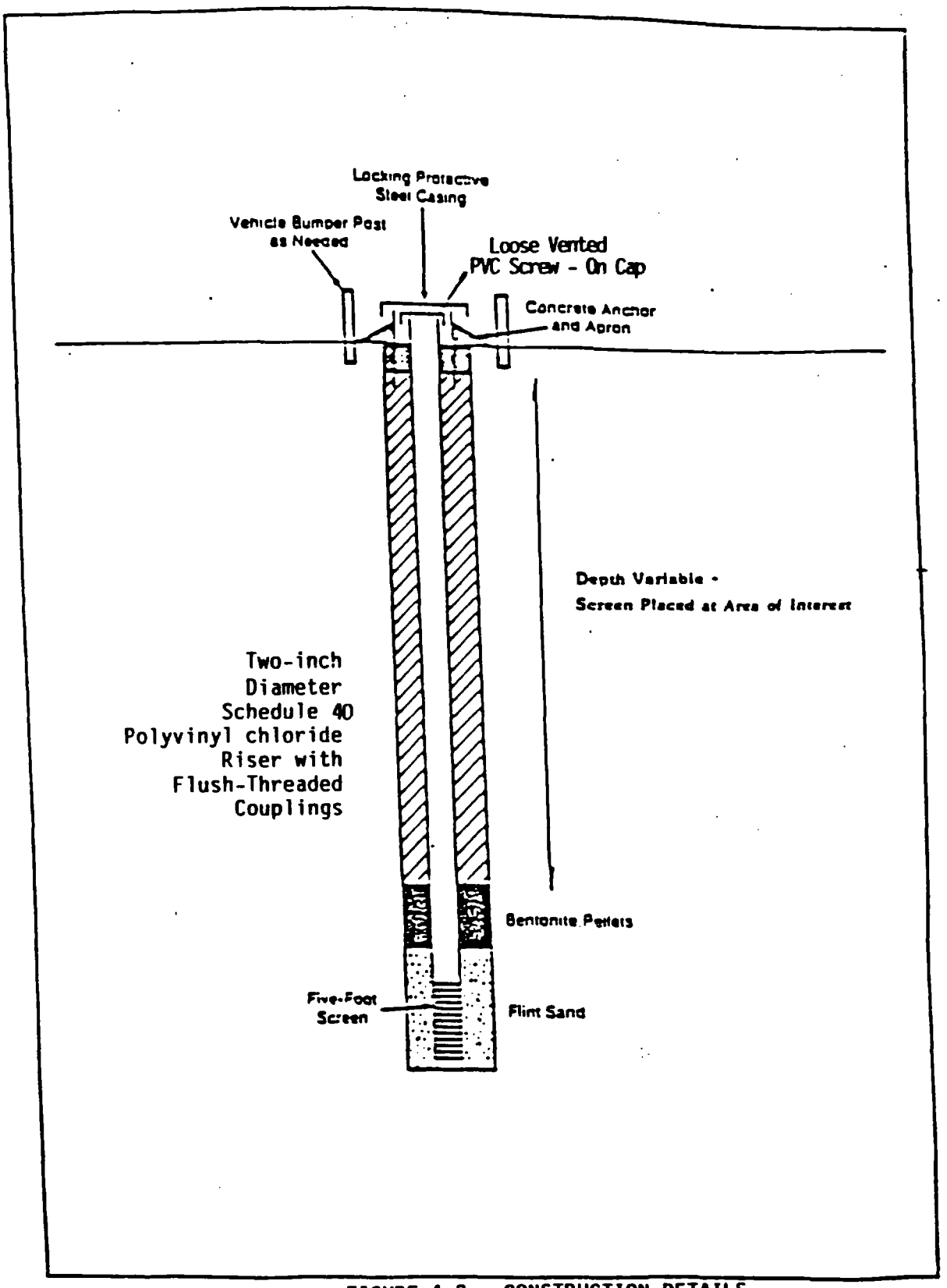

FIGURE 4-2 CONSTRUCTION DETAILS
SINGLE WELL LOCATIONS

split-spoon samples is as follows:

- Verify that the OVA or HNu have been calibrated before field use and that the equipment is functioning properly. (For calibration and operating information refer to "Instruction & Service Manual, MI 2R900AC, Century Systems, Portable Organic Vapor Analyzer, Model OVA-128" and Instruction Manual for Model PI 101, Photoionization Analyzer, HNu Systems, 1975).

- As the split-spoon is opened, pass the air intakes along the sample at a distance of about one-half inch, noting the location and magnitude of any readings. Record all readings in the field log notebook.

- If the OVA is used for the initial screening, and it is believed that methane is interfering with readings, attempt a second reading using the HNu. If hydrogen sulfide is believed to be interfering with HNu readings, attempt to verify H_2S presence with an appropriate indicator tube.

- Record the highest reading on each instrument for each six-inch interval of sample recovered, identifying interferences and the basis of measurement.

- Before the borehole is advanced or the next sample is taken, place the air intakes in the hollowstem, noting any readings and interferences as above.

In addition to the general procedures noted above, headspace analyses will also be performed. A description of headspace screening procedures is presented in Table 4-2.

TABLE 4-2

QUALITATIVE FIELD SCREENING FOR VOLATILE ORGANICS

1. Scope and Application

This method is applicable for qualitative screening at the sampling location for volatile organics.

2. Summary of Method

The vapor in the head space above the samples is measured with an OVA or HNu for a meter deflection, which indicates the presence of organics.

3. Apparatus

(A) Organic Vapor Analyzer (OVA) or Photoionization Detector (HNu)
(B) Sealed Jar
(C) Aluminum Foil

4. Sample Handling and Preparation

Collect samples as specified in the QAPP and place in an 8-oz. jar until half full. Place aluminum foil over the jar mouth to achieve as tight a seal as possible. Screw the jar lid in place and allow the sample to warm to ambient temperature (approximately 75°F), by setting it out in the sun or by placing it in a heated room.

5. Procedure

After the sample has warmed, which allows volatile organics to enter the head space, poke the OVA/HNu probe through the foil. A deflection upscale indicates the presence of volatile organics. Adjust the scale if necessary.

4.8 BAILDOWN TESTING OF WELLS

The basic concept of a baildown test is that the rate of rise of the water level in a well after an "instantaneous" withdrawal of a "slug" of water is a function of aquifer hydraulic conductivity. Thus by measuring water levels at various times following withdrawal of the slug, the hydraulic conductivity can be calculated. The basic requirements are to quickly displace a large slug of water and to quickly and accurately measure the water level in the well after the displacement. Analysis of test data will use appropriate computational methods such as that presented by Bouwer, H. and R.C. Rice, 1977, "A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells", Water Resources Research, vol. 12, no. 3, pp. 423-428.

Baildown testing of monitoring wells installed at the Hunts Landfill will be performed as follows:

- Not less than 24 hours after development of the well, an initial measurement of static water level will be made.
- A volume of water will then be displaced as rapidly as possible using a solid slug inserted or withdrawn from the well.
- Using a pressure transducer attached to recording equipment, water level measurements will be made at gradually increasing time intervals until the water level returns to near the static level.
- The data will be plotted in the field (water level vs. log time) using semi-log paper to determine if the data are sufficient to establish a reasonable straight-line relationship.

4.9 STORAGE AND DISPOSAL OF DRILLING AND SAMPLING WASTES

The sampling and drilling activities are expected to generate solid and liquid "wastes". The activities, the anticipated type and amount of waste, and the planned handling of the wastes are summarized below.

- o Surface water sampling: No wastes anticipated.
- o Sediment sampling: solids, any excess sediment collected in sampler will be returned to area of origin; liquids -- none.
- o Water supply well sampling: no wastes anticipated.
- o Soil area sampling: solids, any excess soil collected will be returned to holes created by sample collection; liquids -- none.
- o Monitoring well installation: solids, approximately 1 cubic foot of cuttings per 10 linear feet of borehole will be retained in drums for future disposal. Liquids, up to 0.16 gallons per linear foot of well volume of water removed during well development, will be temporarily retained in drums until head space analysis can be performed on a representative sample. An HNu will be used for this analysis. If the reading is between background and 5 ppm, the contents of the drum will be emptied in the area of collection. Otherwise the drums will be stored onsite for future testing and disposal.
- o Groundwater sampling: solids -- none; liquids, up to 0.16 gallons per lineal foot of well volume of water purged from wells prior to sampling will be temporarily retained in drums. The procedure similar to that described previously for monitoring well installation liquids will be followed.
- o Decontamination Procedures: All run-off and drippings from the decontamination of equipment and contaminated vehicles will be retained and pumped into 55 gallon drums. These drums will be stored onsite for future testing and disposal.

5.0 SAMPLE ANALYSIS AND HANDLING

5.1 ANALYSIS PROGRAM

The analysis program for the samples collected during implementation of this plan is summarized in Table 1-2. All soil samples and surface water samples collected for chemical analyses will be analyzed under RAS organic protocol which uses GC screening followed by GC/MS analysis for the quantitation of 126 TCL parameters. They will also be analyzed for 24 TAL parameters under RAS inorganic protocol. Residential well water will be analyzed for 126 TCL parameters and 24 TAL parameters under SAS protocol for low quantitation limits. Groundwater organic samples will also be analyzed for 126 TCL parameters under SAS protocol for low quantitation limits but RAS inorganic protocol will be utilized during the analysis of the 24 TAL parameters. All samples are expected to be low concentration samples and all analyses will be performed by assigned CLP facilities.

5.2 SAMPLE CONTAINERS AND PRESERVATION

5.2.1 Medium Hazard Samples

Medium hazard samples collected for chemical analysis by the CLP will be packed and shipped in containers appropriate for the intended testing and in accordance with the U.S. EPA protocols listed in Table 5-1.

5.2.2 Low Hazard Samples

Low hazard samples collected for chemical analysis by the CLP and CRL will be contained and preserved as appropriate for the intended testing and in accordance with U.S. EPA protocols listed in Table 5-2. If required, samples will be placed on ice immediately after collection to maintain a temperature of 4 degrees centigrade.

TABLE 5-1

REQUIRED SAMPLE VOLUME, CONTAINERS AND PRESERVATION FOR SOLID SAMPLES TESTED BY THE CLP

Low and Medium Concentration

Analysis	Container	Preservation	Maximum Holding Time	Volume of Sample
Acid extractables, Base/neutral extractables, Pesticides/PCBs	One 8-oz. glass wide mouth bottle with Teflon-lined cap	Iced to 4°C	5 days to extraction 40 after extraction	Fill 3/4 full
Volatiles	Two 120-ml glass wide mouth vials with Teflon-lined caps	Iced to 4°C	7 days	Fill completely
Metals and Cyanide	One 8-oz. wide mouth bottle	Iced to 4°C	6 months (metals) 14 days (cyanide) 26 days (mercury)	Fill 3/4 full

NOTE: All organic samples must be protected from light.
One volatile trip blank (ultra-pure HPLC grade water poured directly into two 40-ml vials) will be supplied per VOA shipment container.

TABLE 5-2

REQUIRED SAMPLE VOLUME, CONTAINERS AND PRESERVATION FOR AQUEOUS SAMPLES TESTED BY THE CLP

Low Concentration

Analysis	Container	Preservation	Maximum Holding Time	Volume of Sample
ORGANIC				
Acid extractable, Base/neutral extractable, Pesticides/PCBs (Low Level)	Two 80-oz. glass amber bottles with Teflon-lined caps[1/]	Iced to 4°C	7 days until extraction 40 days after extraction	Fill to neck of bottle
Volatiles (Low Level)	Two 40-ml volatile organic analysis (VOA) vials with Teflon-lined caps[2/]	Iced to 4°C	7 days	Fill completely, No air bubbles
INORGANIC				
Metals (Low Level)	One 1-liter high density polyethylene bottle	1:1 HNO_3 to pH pH < 2 Iced to 4°C	6 months 26 days (mercury)	Fill to shoulder of bottle
Cyanide (Low Level)	One 1-liter high density polyethylene bottle	6N NAOH to pH pH ≥ 12 Iced to 4°C	14 days	Fill to shoulder of bottle

NOTE: [1/] Three 1-liter glass amber bottles with Teflon-lined caps are required for drinking water samples.

[2/] Four 40-ml VOA vials with Teflon-lined caps are required for drinking water samples.

[3/] All medium level samples must be sealed in dividual paint cans for shipment.

NOTE: All organic samples must be protected from light.

TABLE 5-2 (Continued)

REQUIRED SAMPLE VOLUME, CONTAINERS AND PRESERVATION FOR AQUEOUS SAMPLES TESTED BY THE CLP

Medium Concentration

Analysis	Container	Preservation	Maximum Holding Time	Volume of Sample
ORGANIC				
Acid extractable, Base/neutral extractable, Pesticides/PCBs (Medium Level)[1/]	Four 32-oz. wide mouth glass jars with Teflon-lined caps	Iced to 4°C	7 days until extraction 40 days after extraction	Fill to neck of bottle
Volatiles (Medium Level)[1/]	Two 40-ml volatile organic analysis (VOA) glass vials with Teflon-lined caps	Iced to 4°C	7 days	Fill completely, No air bubbles
INORGANIC				
Metals (Medium Level)[1/]	One 16-oz. wide mouth glass jar bottle	1:1 HNO_3 to pH pH < 2 Iced to 4°C [2/]	6 months 26 days (mercury)	Fill to shoulder of bottle
Cyanide (Medium Level)[1/]	One 16-oz. wide mouth glass jar bottle	6N NAOH to pH pH ≥ 12 Iced to 4°C [2/]	14 days	Fill to shoulder of bottle

NOTE: [1/] All medium level samples must be sealed in individual paint cans for shipment.

[2/] If samples are considered medium level due solely to elevated concentrations of organics, then the inorganic samples will be preserved as normal. However, if inorganic concentrations are also known to be elevated, no preservatives will be added to either total metals or cyanide samples.

NOTE: All organic samples must be protected from light

TABLE 5-2 (Continued)

REQUIRED SAMPLE VOLUME, CONTAINERS AND PRESERVATION FOR AQUEOUS SAMPLES TESTED BY THE CLP

Low and Medium Concentration

Analysis	Container	Preservation	Maximum Holding Time	Volume of Sample
INORGANIC (Continued)				
Dissolved Metals* (Low Level)	One 1-liter high density polyethylene bottle (Filtered on site)	1:1 HNO_3 to pH pH < 2 Iced to 4°C	6 months 26 days (mercury)	Fill to shoulder of bottle
Total Dissolved Solids* (Low Level)	One 1-liter high density polyethylene bottle (Filtered on site)	Iced to 4°C	7 days	Filled to shoulder of bottle
INORGANIC				
Dissolved Metals* (Medium Level)	One 32-oz. wide mouth glass jar (filtered on site) (Filtered on site)	1:1 HNO_3 to pH pH < 2 Iced to 4°C	6 months 26 days (mercury)	Fill to shoulder of bottle
Total Dissolved Solids* (Medium Level)	One 32-oz. wide mouth glass jar (filtered on site) (Filtered on site)	Iced to 4°C	7 days	Filled to shoulder of bottle

* Applicable to groundwater samples only.

NOTE: All Organic Samples must be protected from light.
Water samples collected for Matrix Spike/Matrix Spike Duplicate require triple the volume specified for volatile organics and extractables. In addition, one volatile trip blank (ultra-pure HPLC grade water poured directly into two 40-ml vials) will be supplied per VOA shipment container.

If residual chlorine or sulfides are suspected to be present in the groundwater, the following tests will be performed on the cyanide water sample before the sample is preserved with 10N sodium hydroxide:

- A drop of sample will be tested with potassium iodide-starch test paper (KI-starch paper); a blue color indicates the presence of oxidizing agents and the need for treatment. Ascorbic acid will then be added, a few crystals at a time, until a drop of sample produces no color on the indicator paper. Then an additional 0.6g of ascorbic acid will be added for each liter of sample volume.
- A drop of sample will be tested on lead acetate paper previously moistened with acetic acid buffer solution. Darkening of the paper will indicate the presence of S^{2-}. If S^{2-} is present it will be removed by the addition of powered cadmium carbonate until a drop of the treated solution does not darken the lead acetate test paper. The solution will then be filtered before sodium hydroxide preservative is added to the sample (stabilization pH $\geq$ 12).

Monitoring well groundwater samples collected for RAS inorganics metals analysis will be filtered in the field as soon as possible after collection and prior to the addition of nitric acid preservative. Filtering will be done with a pressure filtration device and 0.45 micron filter paper. Procedure for filtration of samples is contained in Appendix 2. Residential well samples collected for metals analysis will not be filtered prior to acid preservation. Both filtered and unfiltered surface water samples for metals analysis will be collected and sent to the CLP.

5.3 SAMPLE PACKAGING AND SHIPMENT

Following sampling, the exterior of all sample bottles will be initially decontaminated (if necessary) near the sampling location by wiping outer surface with a moist cloth prior to transportation to the Contamination Reduction Zone where the Support Technician will complete decontamination of bottles. Filled sample bottles should not be sprayed with water during decontamination because this water could contact the sample if container is not tightly sealed. A sampling team member will help the Field Data Coordinator (FDC) prepare documentation and package the bottles for shipment according to the following procedures:

- Where required, check to make sure that the sample is properly preserved; tighten cap securely and seal with tape; mark liquid levels if bottles are partially full.
- Make sure traffic report labels, CRL number labels, and custody tags are securely attached to the sample container; place each container in a ZipLoc Baggie, ensuring that labels can be read.
- For medium concentration samples, place sample container in a metal paint can. Fill the excess space with vermiculite or equivalent absorbent material. Mark the sample number and proper DOT hazard classification on each can. Unknown samples will be classified as "Flammable Solid N.O.S. UN 1325." Seal paint cans using 3 clips to affix lid.

- Place containers in a cooler lined with two inches of vermiculite or equivalent absorbent material. For low concentration samples, maintain temperature at $4^{\circ}C$ with cold packs or ice sealed in plastic bags. Fill remaining space in cooler with additional packing material.

- Put chain-of-custody forms and sample documentation forms in a ZipLoc Baggie and tape to inside of cooler lid.

- Close cooler and seal shut with strapping tape; if cooler has a drain port, seal it shut with tape; place one custody seal across closure at front of cooler and across hinge area at back of cooler.

- Affix airbill with shipper's and consignee's addresses to top of cooler; if samples are liquid, place "This End Up" labels appropriately.

- For medium concentration samples, label coolers with proper DOT hazard classification markings.

The Field Manager should contact the REM V Sampling Coordinator to confirm sample shipment dates to the CLP for Routine Analytical Service (RAS) analyses, and two weeks in advance for Special Analytical Service (SAS) analyses. The Field Manager will notify the Sampling Coordinator of any last minute changes in the sampling schedule. Upon shipment of samples to the CLP, the FDC will call the Sampling Coordinator (before 5:30 p.m. central time on the day of the shipment or early the following morning). The Sampling Coordinator must be notified by 2:00 p.m. Friday for shipments to the CLP for Saturday delivery/pick-up. The Sampling Coordinator be provided with the following information.

- Case and/or SAS numbers.
- Name of laboratory(s).
- Date of shipment.
- Carrier, airbill number.
- Number and matrices of samples shipped.
- Information regarding changes or delays pertaining to the activity.

All samples will be shipped via Federal Express for next day delivery. Organic samples will be shipped within 24 hours of collection and inorganic samples within 48 hours of collection.

5.4 QUALITY CONTROL REQUIREMENTS

All sampling activities will include the procedures as described in the following paragraphs. The anticipated QC effort associated with specific sampling activities is shown in Table 1-2.

Field Duplicates

For water and soil samples, one duplicate (of the same type and container size) will be collected for every 10 samples (or portion thereof) during each sampling activity. Duplicate samples will be collected by alternately filling two sets of sample bottles or air tubes from the same sample unit (e.g., bail of water, scoop of sediment, spoon of soil, flowing water source pump) for each set of parameters.

Trip Blanks

For all sample media, a trip blank for volatile organic analysis (VOA) will be included in each sample shipment containing samples for volatile organic analysis. The trip blank will consist of two 40-ml VOA vials and will be prepared in the field by a member of the field team. Preparation of the trip blank entails the pouring of ultra-pure (HPLC grade) water into the two 40-ml vials (leaving no head space), and carefully securing the caps to ensure the absence of air bubbles. This procedure will occur outside in a location away from the area of contamination and away from exhaust fumes, cigarette smoke or any form of aerosol sprays. The trip blank will be documented on a Traffic Report form and on a Chain-Of-Custody form for a shipment being sent to the Contract Laboratory Program.

Field Blanks

For every 10 aqueous samples (or portion thereof) collected during sampling activities, one field blank will be collected. The field blank will be prepared by pouring reagent grade distilled water over freshly decontaminated unused sampling equipment. The VOA vials will be filled first by collecting the water in the vials as it runs off the equipment. Then the remaining sample liquid will be collected in large decontaminated stainless steel buckets. When enough sample volume has been collected all extractable and inorganic sample containers will be filled. Each field blank will be documented on a Traffic Report Form and on a Chain-Of-Custody Record Form and will be sent to the CLP for Routine Analytical Services as designated by the IFB. Field documentation of each field blank will be handled by the relevant field personnel.

Matrix Spikes and Matrix Spike Duplicates

For soil and water samples, one sample out of every 10 (or portion thereof) collected for volatile organic analysis and extractable organic analysis during each sampling activity will be labeled as a matrix spike duplicate (MSD). The matrix spike duplicate sample must be collected at triple the volume normally collected for this parameter. The MSD will be documented on the Traffic Report Form and on a Chain-Of-Custody Record Form for samples sent to CLP. Matrix spike analysis by the CLP will be performed as designated by the IFB and does not require documentation from field personnel. No trip blanks or field blanks will be used for MSD analysis.

6.0 SAMPLE DOCUMENTATION AND TRACKING

6.1 FIELD RECORDS

Field observations and other pertinent information pertaining to the collection of samples will be recorded in bound log books using black waterproof ink. Standard formats will be developed so that data relating to the collection of each type of sample and to the installation of monitoring wells are consistently recorded. The data to be recorded will include date, time, samplers, location, sample number, custody tag number, weather, instrument readings and visual description of sample, in addition to other data specific to each sample type. The standard formats are presented in Tables 6-1 through 6-7. In addition to written records, photographs will be taken as needed to further clarify sampling activities.

6.2 CHAIN-OF-CUSTODY PROCEDURES

All samples will be collected and handled in accordance with established Chain-of-Custody procedures. These procedures are summarized below.

- All information required on the custody tag, including the signatures of all sampling team members and a predesignated location description, will be filled out in the field.
- Prior to relinquishing samples for packaging and shipment, one member of the sampling team will transfer all data contained on the custody tags to a Chain-of-Custody Record, which responsible team members will sign.
- The individual who prepared the Chain-of-Custody Record will relinquish the samples to the sample handling technician, who will prepare all CLP traffic reports and affix appropriate traffic report labels to the sample containers.
- The technician will package the samples for shipment making sure that all traffic reports, Chain-of-Custody Records and documentation paper work is enclosed.

TABLE 6-1

HUNTS DISPOSAL LANDFILL
SURFACE WATER SAMPLING

LOGGED BY:_____

DATE:_____ LOCATION:_____

FIELD SAMPLE NO.:_____

SAMPLERS:_____
_____

WEATHER:_____
_____

TIME COLLECTION BEGAN:_____HRS.
TIME COLLECTION ENDED:_____HRS.

INTERMEDIATE BOTTLE USED: YES - NO

LOCATION DESCRIPTION:_____
_____
_____

SAMPLE DESCRIPTION:_____
_____
_____

FIELD MEASUREMENTS:

pH:_____ STANDARD UNIT

SPEC. COND.:_____umhos/cm

TEMPERATURE:_____oC

CUSTODY TAG NUMBERS:
ORGANICS: _____
INORGANICS:_____
CYANIDE: _____

REMARKS:_____
_____
_____
_____

TABLE 6-2

HUNTS DISPOSAL LANDFILL
SOIL/SEDIMENT SAMPLING

LOGGED BY:_____

DATE:_____ LOCATION:_____

FIELD SAMPLE NO.:_____

SAMPLERS:_____
_____

WEATHER:_____
_____

TIME COLLECTION BEGAN:_____HRS.
TIME COLLECTION ENDED:_____HRS.

DEPTH INTERVAL:_____INCHES

LOCATION DESCRIPTION:_____
_____
_____

SOIL DESCRIPTION:_____
_____
_____

CUSTODY TAG NUMBERS:
ORGANICS: _____
INORGANICS:_____
CYANIDE: _____
DIOXIN: _____

REMARKS:_____
_____
_____
_____

TABLE 6-3

HUNTS DISPOSAL LANDFILL
WELL INSTALLATION

LOGGED BY:_____

LOCATION:_____ UNIT:_____

INSTALLERS:_____
_____
_____

WEATHER:_____
_____

LOCATION DESCRIPTION:_____
_____
_____

TIME DRILLING BEGAN:
DATE:_____ _____HRS.
TIME DRILLING ENDED:
DATE:_____ _____HRS.
TIME INSTALLATION BEGAN:
DATE:_____ _____HRS.
TIME INSTALLATION ENDED:
DATE:_____ _____HRS.
TIME DEVELOPMENT BEGAN:
DATE:_____ _____HRS.
TIME DEVELOPMENT ENDED:
DATE:_____ _____HRS.

TOTAL DEPTH OF BORING:
_____FEET

WELL CONSTRUCTION:
SCREEN LENGTH:_____FEET
SLOT TYPE: MILLED-CONTINUOUS
SLOT SIZE:_____INCHES
WELL DIAMETER:_____INCHES
RISER LENGTH:_____FEET
RISER MATERIAL:_____
COUPLING METHOD:_____

DEPTH TO TIP OF SCREEN:
_____FEET

ANNULUS BACK FILLINGS (FEET):

DEPTH OF SENSING ZONE:
_____FEET

PROTECTIVE CASING:
DIAMETER:_____INCHES
LENGTH:_____FEET
STICK-UP:_____FEET
LOCKING: YES - NO

TABLE 6-3 (continued)

CASING FLUSHED CLEAN: YES - NO

WELL DEVELOPMENT:

INITIAL WATER DEPTH:

VOLUME IN WELL:

VOLUME REMOVED

SURGE AND PUMP CYCLES: 1-2-3-4-5

FINAL DISCHARGE CLEAR: YES - NO

BAILDOWN RECOVERY TEST:

INITIAL WATER DEPTH:_____FEET

WELL DIAMETER:_____INCHES

WATER VOLUME REMOVED:_____GALS.

DURATION OF BAILDOWN:_____MINS.

RECOVERY MEASUREMENTS:

TIME(MIN):	DEPTH(FEET)
0	
1/2	
1	
2	
5	
10	
20	
50	
100	

REMARKS:_____

TABLE 6-4

HUNTS DISPOSAL LANDFILL
WELL INSTALLATION - FIELD SAMPLING

LOGGED BY:_____

BORING
LOCATION:_____

FIELD SAMPLE NO.:_____
TIME SAMPLE COLLECTED:_____HRS.
SAMPLE TYPE: SPLIT SPOON - SHELBY TUBE
DEPTH INTERVAL:_____

BLOW COUNTS / RECOVERY (INCHES)
_____ / _____

SAMPLE DESCRIPTION:_____
_____

ORGANIC VAPOR SCREENING

SAMPLE	OVA(PPM)	HNu(PPM)
TOP		
MIDDLE		
BOTTOM		

WATER QUALITY SAMPLES:

FIELD SAMPLE NO.:_____
TIME SAMPLE COLLECTED:___HRS
DEPTH:_____FEET

SAMPLE DESCRIPTION:_____
_____
_____

FIELD MEASUREMENTS:
pH_____STANDARD UNITS
SPEC. COND._____umhos/cm
TEMPERATURE:_____oC

ORGANIC VAPOR SCREENING
OVA(PPM)_____
HNu(PPM)_____

REMARKS:_____
_____
_____

REMARKS:_____
_____
_____

TABLE 6-5

HUNTS DISPOSAL LANDFILL
GROUNDWATER SAMPLING

LOGGED BY:_____

DATE:_____ LOCATION:_____

FIELD SAMPLE NO.:_____

SAMPLERS:_____
_____

WEATHER:_____

INITIAL WATER DEPTH:_____FEET
TOTAL WELL DEPTH:_____FEET

WATER VOLUME IN WELL:_____GALS.

TIME PURGING BEGAN:_____HRS.
TIME PURGING ENDED:_____HRS.

DID WELL GO DRY?: YES - NO

WATER VOLUME PURGED:_____GALS.

LOCATION DESCRIPTION:_____
_____

TIME COLLECTION BEGAN:_____HRS.
TIME COLLECTION ENDED:_____HRS.

SAMPLE DESCRIPTION:_____
_____
_____

FIELD MEASUREMENTS:
pH:_____STANDARD UNITS

SPEC. COND.:_____umhos/cm

TEMPERATURE:_____oC

FILTERED: YES____ NO____
CUSTODY TAG NUMBERS:
ORGANICS: _____
INORGANICS:_____
CYANIDE: _____

REMARKS:_____
_____
_____

TABLE 6-6

HUNTS DISPOSAL LANDFILL
AIR SAMPLING (IF NECESSARY)

LOGGED BY:_____

DATE:_____ LOCATION:_____

CUSTODY TAG NUMBERS:
VOA FRACTION:_____

FIELD SAMPLE NO.:_____

SAMPLERS:_____
_____

WEATHER:_____
_____

TIME COLLECTION BEGAN:_____HRS.
TIME COLLECTION ENDED:_____HRS.

OBSERVED FLOW RATE:_____
OBSERVED FLOW RATE:_____

LOCATION DESCRIPTION:_____
_____

CALIBRATION INFORMATION:
METHOD USED:_____
MEASURED FLOW RATE:_____
OBSERVED FLOW RATE:_____

READINGS:

EXPLOSIMETER/OXYGEN METER:
_____%LEL

HNu: _____
_____
_____

REMARKS:_____
_____
_____
_____

OVA:_____
_____
_____

TABLE 6-7

HUNTS DISPOSAL LANDFILL
SOIL CORING SAMPLING

LOGGED BY:_____

DATE:_____ LOCATION:_____

SAMPLERS:_____
_____
_____

FIELD SAMPLE NO.:_____
DEPTH INTERVAL:_____

TIME SAMPLE COLLECTED:____HRS

WEATHER:_____
_____

SAMPLE DESCRIPTION:_____
_____
_____

TIME SAMPLING BEGAN:_____HRS.
TIME SAMPLING ENDED:_____HRS.

ORGANIC VAPOR SCREENING:
OVA:_____PPM
HNu:_____PPM

LOCATION DESCRIPTION:_____
_____

SAMPLE	OVA(PPM)	HNu(PPM)
TOP		
MIDDLE		
BOTTOM		

CUSTODY TAG NUMBERS:
ORGANICS: _____
INORGANICS: _____
CYANIDE: _____
DIOXIN: _____

REMARKS:_____
_____
_____

[FOR EACH SAMPLE]

- If samples are stored temporarily prior to shipment, they will be kept cool and placed in a secured storage area. Coolers will be sealed and custody seals affixed just prior to shipment.

The sample handling technician will maintain lists cross-referencing site sample numbers, custody tag numbers, traffic report numbers, analyses to be performed, custody seal numbers, shippers' airbill numbers, and consigned laboratories in a bound log book using black ink. (For detailed guidance on completing Chain-of-Custody and sample tracking paperwork, refer to "Sampling Handbook, U.S. EPA TAT, Region V, Revised 1985.")

6.3 DOCUMENTING SAMPLE LOCATIONS

Representative photographs of sampling stations with respect to surrounding area and relative to objects used to locate the station will be taken. The picture number and roll number will be logged in the field book to identify which sampling site is depicted in the photograph. The film roll number will be identified by taking a photograph of an information sign on the first frame of the roll. This sign would have the job and film roll number written on it so as to identify the pictures contained on the roll.

For example: Roll Number 1
Frame Number 1 of 36
1 Dec 1987 - Dec 1987

General locations of the sampling sites will be documented photographically, while detailed locations will be determined by taping. Sampling locations will be located by taping using at least three permanent reference points (i.e., the site grid matrix, telephone poles, fire hydrants, manhole covers, etc.). Depths will be measured with reference to ground surface.

6.4 SAMPLE DOCUMENTATION FORMS

Sample documentation required by the U.S. EPA are numbered and must be accounted for. If a document is voided, do not destroy it: save and return it to the REM V sample coordinator. Copies of the multiple-copy forms must accompany samples to the laboratory.

The other copies must be sent to the Sampling Coordinator immediately following sampling shipment. The protocol to be followed for shipping the samples and required documentation is summarized below:

A) Chain-of-Custody Form

1. One form per shipping container (cooler).
2. Carrier service does not need to sign form if custody seals remain intact.
3. Use for all samples.

B) Chain-of-Custody Seals

1. Two seals per shipping container to secure the lid and provide evidence that samples have not been tampered with.
2. Cover seals with clear tape.
3. Record seal numbers on Chain-of-Custody Form.
4. Use for all samples.

C) Organic and Inorganic Traffic Reports

1. For low and medium samples, one form required for each sample undergoing RAS organic or inorganic analysis by CLP.
2. Preprinted stickers on forms should be affixed to the appropriate sample containers.
3. These numbers are recorded on the Chain-of-Custody Forms.

4. If the updated multi-sample Traffic Reports are used, each sample requires an individual Traffic Report Sticker with a unique imprinted Traffic Report Number.

D) Sample Tags

1. Each sample container must have a Sample Tag affixed to it with string or wire.

2. Traffic Report Number and Case Number are recorded in the "Remarks" section of the tag.

3. Sample Tag Numbers are recorded on the Chain-of-Custody Forms.

4. Use for all samples.

E) SAS Packing List

1. One form is required for each "All SAS" sample request being analyzed by the CLP. If the sampling activity extends over several days, more than one form is used.

2. SAS samples are numbered using the SAS Sample Number followed by a hyphen and progressive numerical designation starting with 1.

3. Adhesive sample labels must be provided by the sampler and marked with appropriate SAS Sample Number.

Other Sample Documentation Required

A) CLP Sample Data Report

1. Must be completed for all CLP samples

2. For samples sent to CLP Laboratories, these forms are sent to Sampling Coordinator to be forwarded to the RSCC.

3. The forms are necessary for the U.S. EPA to track the samples and ensure data validation.

B) Sample Identification Record Form

1. Will provide a means of recording crucial sample shipping and tracking information.

2. Will contain information as follows to be entered into the REM V analytical database:

   a) Case Number
   b) CRL Number
   c) Sample Matrix
   d) Site Number
   e) Sample Local Code
   f) Sample Round
   g) Sample Type (blank, replicate)
   h) Number of Bottles
   i) Traffic Report Numbers
   j) Chain-of-Custody Number
   k) Lab Code
   l) Date Sampled
   m) Date Shipped
   n) Airbill Number
   o) Sample Tag Number

3. This form must be maintained for each sample shipment and forwarded to the Sampling Coordinator upon sample shipment.

All paperwork accompanying the samples being shipped to the CLP laboratories will be sealed in a plastic bag that is taped to the inside of the cooler lid. Copies of the Chain-of-Custody Forms and other paperwork will be retained for the field files.

The Sample Handling Coordinator will maintain lists cross-referencing site sample numbers, custody tag number, traffic report numbers, analyses to be performed, custody seal number, shippers' airbill numbers, and consigned laboratories in a bound log book using black ink and on the Sample Identification Record Forms (see Figure 3-1). For more details on sampling paperwork, refer to "User's Guide to the Contract Laboratory Program, U.S. EPA, Revised December, 1986".

7.0 SAMPLING TEAM ORGANIZATION

The sampling team will consist of five individuals with the following roles and responsibilities:

- Field Manager -- responsible for overall execution of the sampling plan; will direct drilling activities for the soil borings and monitoring well installations; will direct a two-man sampling team during other sampling activities.

- Site Health and Safety Coordinator (SHSC) -- responsible for implementation of the site safety plan as contained in the Site Evaluation Form (SEF); will operate OVA and HNu instruments for screening of soil samples during drilling activities; will direct a two-man sampling team during some of the other sampling activities.

- Sample Collector -- primarily involved in sample collection, may assist with decontamination and/or sample handling; will have the "dirty hands" during drilling activities and when sampling with the field manager or site safety officer.

- Decontamination Technician -- primarily involved in decontamination of sampling equipment and sampling team personnel, may assist with sample collection and/or sample handling; will have the "dirty hands" when sampling with the field manager or site safety officer.

- Sample Handling Coordinator -- primarily involved in sample packaging and processing of sample custody and tracking paper work, may assist with decontamination; will remain at the command post and coordinate procurements and communications.

The site manager will participate in all of the activities listed above.

8.0 SAMPLING SCHEDULE

Table 8-1 provides a description for the overall schedule for the major field activities at the HDL site. The proposed schedule is dependent on a timely review and approval of the QAPP by U.S. EPA Quality Assurance Office, and the timely return of validated analytical data. The "miscellaneous" sampling event listed for the August-September time period will be used for the collection of samples that may be considered necessary following review of earlier data.

TABLE 8-1

SCHEDULE FOR FIELD ACTIVITIES AT THE HDL SITE*

August	o	Site Survey; Establishment of Site Grid Network
	o	Radiologic Investigation
	o	Geophysical Investigation
August - October	o	Initial Mobilization/Site Setup
	o	Monitoring Well Installation
	o	Soil Sampling
	o	Surface Water and Sediment Sampling
	o	Existing Monitoring Well Sampling
	o	Residential Well Sampling
October - November	o	Monitoring Well Sampling
	o	Other Miscellaneous Sampling as Needed

* All dates are for the 1988 calendar year

APPENDIX 1

Procedures for Field Measurement of pH, Specific Conductance and Temperature of Water Samples

Field Measurement of pH in Water

1. Scope and Application

This method is applicable to samples of surface water, water supplies and groundwater with measurement occurring at the sampling location.

2. Summary of Method

The pH of water is determined using a portable, field pH meter with a temperature-compensated combination electrode.

3. Apparatus

A) Haake Buchler pH Meter Stick
B) 100 ml disposable beakers

4. Reagents

A) pH referenced buffer solutions:

1) pH = 4.00 $\pm$.01
2) pH = 7.00 $\pm$.01
3) pH = 10.00 $\pm$.01

B) distilled water

5. Sample Handling and Preparation

Sample aliquots for pH measurement should be obtained directly from the sampling point in 100 ml disposable beakers. Groundwater samples being tested during well purging can be obtained from the pump discharge line.

6. Calibration

Calibrate the meter/electrode using two reference solutions that bracket the expected pH of the sample. Reference solutions should be at room temperature. Immerse the electrode in pH 7.00 solution and adjust the meter as needed. Remove and rinse the electrode and repeat using the second buffer solution. Repeat adjustments until readings are within 0.05 pH units of the reference values.

7. Procedure

Immerse the electrode in the water while gently agitating. After about one-half minute, record the pH reading to the nearest 0.05 units -- provided the meter readings are not fluctuating more than +0.03 units. Be sure that temperature compensation has been provided for. Remove and thoroughly rinse the electrode with distilled water. Repeat the measurement procedure until four readings have been obtained.

8. Interferences

Prolonged immersion of the electrode in turbid solutions can lead to plugging of the liquid junction and erratic meter readings. The electrode should be cleaned by gently blotting with a lab tissue and rinsing with distilled water.

9. Verification of Accuracy

Following the last of the four replicate measurements, immerse the rinsed electrode in each of the reference buffer solutions used to calibrate the meter/electrode prior to sample measurements. If the readings are not within 0.05 units of the reference values, recalibrate the meter/electrode and re-do the measurement of the sample just tested.

10. Assessment of Precision

Calculate the mean and standard deviation of the four replicate measurements. If the standard deviation is greater than 0.1 units, re-do the measurement of the sample just tested including calibration and verification.

11. Reporting

Report the average value of the replicate measurements to the nearest 0.1 units.

Field Measurement of Specific Conductance and Temperature

1. Scope and Application

This method is applicable to samples of stormwater, surface water, water supplies and ground water measurement occurring at the sampling point.

2. Summary of Methods

The specific conductance and temperature of water is determined using a portable, field conductivity meter having manual temperature compensation.

3. Apparatus

A) YSI Model 33 S-C-T Meter with weighted probe
B) 100 ml disposable beakers

4. Reagents

A) 0.01 N KCL reference solution
B) Distilled Water

5. Sample Handling and Preparation

Sample aliquots for specific conductance and temperature should be obtained directly from the sampling point in 100 ml disposable beakers. Ground water samples being tested during well purging can be obtained from the pump discharge line.

6. Calibration

Calibrate the thermometer in the probe against the thermometer in the field laboratory. Readings should be within ±1 degree C. Calibrate the specific conductance meter using the 0.01 N KCl reference solution. The specific conductance of this solution is 1413 umhos/cm at 25 degrees C. Adjust the meter as needed. Temperature calibration should be performed weekly. Specific conductance calibrate should be performed daily during the period of use.

7. Procedure

Check battery condition by turning selector dial to "Red Line". Adjust meter as needed. Immerse the probe in the beaker while gently agitating. Turn selector dial to "Temperature" and record temperature of water. Turn selector dial to "Conductivity" at the scale range appropriate to sample conductance. Record specific conductance to three significant digits. Remove and thoroughly rinse the probe with distilled water. Repeat temperature and specific conductance measurements until four sets of readings have been obtained.

8. Assessment of Precision

Calculate the mean and standard deviation of the four specific conductance measurements. If the standard deviation is greater than 5% of the mean, re-do the measurement of the sample just tested.

9. Reporting

Report the average values of the replicate measurements to the nearest 1 degree C for temperature and to three significant digits for specific conductance.

APPENDIX 2

PROCEDURES FOR FILTRATION OF GROUNDWATER SAMPLES

APPENDIX 2

PROCEDURES FOR FILTRATION OF GROUNDWATER SAMPLES

1.0 INTRODUCTION

The sampler should carefully review any proposed procedures for filtering samples on site. Filtration of samples in which volatile organic constituents are of interest is not recommended, since filtration may strip these constituents from the sample. However, filtration of samples in which metals are the constituents of concern may be applicable depending on the proposed analytical method. If total recoverable methods are to be used, the sample should not be filtered. However, if measurement of dissolved metals is desired, the sample should be filtered on site.

Dissolved metal samples are filtered to remove particulate matter which may have been drawn through the well screen from the surrounding geologic materials. These particulates may have adsorbed constituents that, once a preservative (particularly acid) is added, may become dissolved in the sample. Thus, if samples truly representative of in-situ groundwater quality are desired, filtering should be required. However, if the goal is simply to detect the subsurface presence of a constituent, filtering may not be recommended. Analyzing unfiltered samples may, accordingly be particularly suitable for detection monitoring. However, establishment of a suitable background may become a problem because water quality measurements my be strongly influenced by the design and construction of individual wells and the grain size distribution of the formation in which the intake of each well is located. The sampler will need to determine which method is most appropriate for each particular program. In some cases both filtered and unfiltered samples may be collected and compared.

If minerals precipitation is observed during filtration or if the chemical species of interest are suspected to be significantly present in colloidal form, a unfiltered acidified sample should also be collected and subsequently analyzed for the same parameters as the filtered sample. The containers for the filtered and unfiltered samples must be so labeled and appropriately identified in the field notes.

2.0 PROCEDURE

If filtration is required, the use of a 0.45 micron filter is generally considered appropriate. Occasionally well or surface waters may contain concentrations of Total Suspended Solids (TSS) which are high enough to result in the clogging of 0.45 micron filters. To avoid clogging, commercially available prefilters should be used in addition to the 0.45 micron filters. All filters used should be made of materials compatible with the chemical characteristics of the groundwater samples.

Filtration of groundwater samples will be performed when appropriate, as summarized in the table below.

Analysis	Sample Collection	
	Filtered	Non-Filtered
Volatile	No	Yes
Total Metals or Ions	No	Yes
Dissolved Metals or Ions	Yes (acidify after filtration)	Sometimes

3.0 REFERENCE

U.S EPA, 1983. Test Methods for Evaluating Solid Waste. SW-846.

U.S. EPA, 1983. Methods for the Chemical Analysis of Water and Wastes. March 1983. EPA-600/4-79-020.

Geotrans, Inc., 1983. RCRA Permit Writer's Manual: Ground Water Protection (40 CFR Part 264, Subpart F), EPA Contract no. 68-01-6464.

Scalf, M.R., McNabb, J.F., Dunlap, W.J., Crosby, R.L., Fryberger, J., 1981. Manual of Ground-Water Sampling Procedures. NWWA/EPA Series.

APPENDIX 3

HUNTS DISPOSAL LANDFILL

SPECIAL ANALYTICAL SERVICES REQUESTS

APPENDIX 3.1

SAS REQUEST FOR FAST TURNAROUND ANALYSIS OF GROUNDWATER SAMPLES

FOR

FULL RAS ORGANICS

U.S. Environmental Protection Agency
CLP Sample Management Office
P.O. Box 818, Alexandria, Virgina 22313
PHONE: (703)/557-2490 or FTS/557-2490

SAS Number

SPECIAL ANALYTICAL SERVICES
Client Request

☐ Regional Transmittal ☐ Telephone Request

A. EPA Region/Client: REGION V/CCJM

B. RSCC Representative: JAN PELS

C. Telephone Number: (312) 353-2720

D. Date of Request: 6th June 1988

E. Site Name: HUNTS DISPOSAL LANDFILL

Please provide below a description of your request for Special Analytical Services under the Contract Laboratory Program. In order to most efficiently obtain laboratory capability for your request, please address the following considerations, if applicable. Incomplete or erroneous information may result in delay in the processing of your request. Please continue response on additional sheets, or attach supplementary information as needed.

1. General description of analytical service requested: Fast turnaround analysis of water samples for RAS organics (volatiles, semi-volatiles and pesticides/PCBs).

2. Definition and number of work units involved (specify whether whole samples or fractions; whether organics or inorganics; whether aqueous or soil and sediments; and whether low, medium, or high concentration):

   A total of 5 low concentration water samples -- 3 investigative, 1 duplicate and 1 field blank. All analyzed for full RAS organic analysis.

3. Purpose of analysis (specify whether Superfund (Remedial or Enforcement), RCRA, NPDES, etc.):

   Superfund Remedial

4. Estimated date(s) of collections: 11th July thru 15th July 1988

5. Estimated date(s) and method of shipment: 11th July thru 15th July 1988

6. Number of days analysis and data required after laboratory receipt of samples:

   7 days to analysis -- Final report and data due within 15 days of sample receipt.

7. Analytical protocol required (attach copy if other than a protocol currently used in this program:

   CLP protocol for RAS organics IFB WA87-J001/J002/J003 and K236/K237/K238.

8. Special technical instruction (if outside protocol requirements, specify compound names, CAS numbers, detection limits, etc.):

   CLP protocol for RAS organics

9. Analytical results required (if known, specify format for data sheets, QA/QC reports, Chain-of-Custody documentation, etc.). If not completed, format of results will be left to program discretion.

   As per IFB

10. Other (use additional sheets or attach supplementary information, as needed):

11. Name of sampling/shipping contact: Mona Sutherland

    Phone: (312) 621-3944

I. DATA REQUIREMENTS

Parameter	Detection Limit	Precision Desired (±% or Conc.)
As per IFB		

II. QC REQUIREMENTS

Audits Required	Frequency of Audits	Limits* (±% or Conc.)
As per IFB		

III. ACTION REQUIRED IF LIMITS ARE EXCEEDED:

Take corrective action.

Contact Jay Thakkar or Chuck Elly

(312) 886-1972 (312) 353-9087

Please return this request to the Sample Management Office as soon as possible to expedite processing of your request for special analytical services. Should you have any questions or need any assistance, please call the Sample Management Office.

00206/07

APPENDIX 3.2

SAS REQUEST FOR FAST TURNAROUND ANALYSIS OF GROUNDWATER SAMPLES

FOR

FULL RAS INORGANICS

U.S. Environmental Protection Agency
CLP Sample Management Office
P.O. Box 818, Alexandria, Virgina 22313
PHONE: (703)/557-2490 or FTS/557-2490

SAS Number

SPECIAL ANALYTICAL SERVICES
Client Request

☐ Regional Transmittal ☐ Telephone Request

A. EPA Region/Client: REGION V/CCJM

B. RSCC Representative: JAN PELS

C. Telephone Number: (312) 353-2720

D. Date of Request: 6th June 1988

E. Site Name: HUNTS DISPOSAL LANDFILL

Please provide below a description of your request for Special Analytical Services under the Contract Laboratory Program. In order to most efficiently obtain laboratory capability for your request, please address the following considerations, if applicable. Incomplete or erroneous information may result in delay in the processing of your request. Please continue response on additional sheets, or attach supplementary information as needed.

1. General description of analytical service requested: Fast turnaround analysis of water samples for RAS inorganic (including mercury) and cyanide.

2. Definition and number of work units involved (specify whether whole samples or fractions; whether organics or inorganics; whether aqueous or soil and sediments; and whether low, medium, or high concentration):

   A total of 5 low concentration water samples: 3 investigative, 1 duplicate and 1 field blank. All analyzed for full RAS inorganic analysis and cyanide.

3. Purpose of analysis (specify whether Superfund (Remedial or Enforcement), RCRA, NPDES, etc.):

   Superfund Remedial

4. Estimated date(s) of collections: 11th July thru 15th July 1988

5. Estimated date(s) and method of shipment: 11th July thru 15th July 1988

6. Number of days analysis and data required after laboratory receipt of samples:

   7 days to analysis -- Final report and data due within 15 days of sample receipt.

7. Analytical protocol required (attach copy if other than a protocol currently used in this program:

   CLP Protocol for RAS inorganics IFB WA87-K025/K026/K027 and K201

8. Special technical instruction (if outside protocol requirements, specify compound names, CAS numbers, detection limits, etc.):

   CLP Protocol for RAS inorganics

9. Analytical results required (if known, specify format for data sheets, QA/QC reports, Chain-of-Custody documentation, etc.). If not completed, format of results will be left to program discretion.

   As per IFB

10. Other (use additional sheets or attach supplementary information, as needed):

11. Name of sampling/shipping contact: Mona Sutherland

    Phone: (312) 621-3944

I. DATA REQUIREMENTS

Parameter	Detection Limit	Precision Desired (±% or Conc.)
As per IFB		

II. QC REQUIREMENTS

Audits Required	Frequency of Audits	Limits* (+% or Conc.)
As per IFB		

III. ACTION REQUIRED IF LIMITS ARE EXCEEDED:

Take corrective action.

Contact Jay Thakkar or Chuck Elly

(312) 886-1972 (312) 353-9087

Please return this request to the Sample Management Office as soon as possible to expedite processing of your request for special analytical services. Should you have any questions or need any assistance, please call the Sample Management Office.

00206/08

APPENDIX 3.3

SAS REQUEST FOR ANALYSIS OF DRINKING WATER

AND GROUNDWATER SAMPLES

FOR

FULL ORGANICS WITH LOW DETECTION LIMITS

U.S. Environmental Protection Agency
CLP Sample Management Office
P.O. Box 818, Alexandria, Virgina 22313
PHONE: (703)/557-2490 or FTS/557-2490

SAS Number

SPECIAL ANALYTICAL SERVICES
Client Request

[X] Regional Transmittal [ ] Telephone Request

A. EPA Region/Client: REGION V/CCJM

B. RSCC Representative: JAN PELS

C. Telephone Number: (312) 353-2720

D. Date of Request: 6th June 1988

E. Site Name: HUNTS DISPOSAL LANDFILL

Please provide below a description of your request for Special Analytical Services under the Contract Laboratory Program. In order to most efficiently obtain laboratory capability for your request, please address the following considerations, if applicable. Incomplete or erroneous information may result in delay in the processing of your request. Please continue response on additional sheets, or attach supplementary information as needed.

1. General description of analytical service requested: Analysis of drinking water/residential wells and groundwater - for volatiles, semi-volatiles and pesticide/PCBs with low quantitation limits.

2. Definition and number of work units involved (specify whether whole samples or fractions; whether organics or inorganics; whether aqueous or soil and sediments; and whether low, medium, or high concentration):

   A total of 41 low concentration water samples - 10 residential well investigative, 1 duplicate and 1 field blank; 21 groundwater investigative, 3 duplicates and 3 blanks

3. Purpose of analysis (specify whether Superfund (Remedial or Enforcement), RCRA, NPDES, etc.):

   Superfund Remedial

4. Estimated date(s) of collections: 12th September - 23rd September, 1988: Re-analysis of groundwater only: 14th November - 25th November 1988

5. Estimated date(s) and method of shipment: 12th September - 23rd September, 1988: Re-analysis of groundwater only: 14th November - 25th November 1988

6. Number of days analysis and data required after laboratory receipt of samples:

   7 days to analysis -- Final report due within 30 days of sample receipt.

7. Analytical protocol required (attach copy if other than a protocol currently used in this program:

   Organic Analysis IFB WA85-J664

8. Special technical instruction (if outside protocol requirements, specify compound names, CAS numbers, detection limits, etc.):

   1. Exceptions to Organic IFB - Attachment I

   2. Required low level quantitation limits - Attachment II

   3. Requirements for determining quantitation limits: Easily recognizable spectra for all compounds using 10 ng injection for ABNs and 1.5 ug/l for VOAs.

   4. Initial calibrations: %RSD for RFs should be <40 for each VOA and ABN compound before beginning analyses.

   5. Continuing calibration: Run daily calibration standard before running analyses. %D should be <25 for all compounds in both VOAs and ABNs. If any %Ds are greater than 25%, the standard should be reinjected. If still out, rerun 3 point curve. Exception: %D for bromomethane, chloroethane, chloromethane and vinyl chloride must be ≤35.

9. Analytical results required (if known, specify format for data sheets, QA/QC reports, Chain-of-Custody documentation, etc.). If not completed, format of results will be left to program discretion.

   All deliverables included in the IFB are required including instrument quantitation limit determinations. The lab will notify the Region prior to diluting any sample. If Regional approval is given to dilute, all of

the data will be submitted; data for each dilution will be reported on separate OADS forms.

10. Other (use additional sheets or attach supplementary information, as needed):

11. Name of sampling/shipping contact: Mona Sutherland

Phone: (312) 621-3944

I. DATA REQUIREMENTS

Parameter	Detection Limit	Precision Desired (±% or Conc.)
Organics	See Attachment II	Attachment I

II. QC REQUIREMENTS

Audits Required	Frequency of Audits	Limits* (% or Conc.)
Organics - As in IFB	As in IFB	Attachment I

III. ACTION REQUIRED IF LIMITS ARE EXCEEDED:

Contact Chuck Elly or Jay Thakkar

(312) 353-9087 (312) 886-1971

Please return this request to the Sample Management Office as soon as possible to expedite processing of your request for special analytical services. Should you have any questions or need any assistance, please call the Sample Management Office.

Attachment I

VOA - Increase sample volume up to 20 ml to meet quantitation limits.
Initial Calibration: 5ug/L, 10ug/L, 20ug/L for all compounds except for acrolein and acrylonitrile, which should be run at 200ug/L, 300ug/L, 500ug/L; vinyl chloride, chloromethane, bromomethane, acetone, 2-butanone, 2-hexanone, and vinyl acetate, which should be run at 50ug/L, 100ug/L, 150ug/L.

Continuing Calibration: 10ug/L except all those compounds that have a detection limit ≥ 3.0ug/L but <10ug/L which are to be run at 20ug/L.
Acrolein and acrylonitrile should be run at 300ug/L.
Vinyl chloride, chloromethane, bromomethane, acetone, 2-butanone, 2-hexanone, and vinyl acetate should be run at 50ug/L.

Surrogates: As in IFB but at 10 ug/L with percent recovery 80 - 120%.
Matrix spike: As in IFB but at 10 ug/L with percent recovery 80 - 120%.
All RFs must be ≥0.05.

ABN - Extract the entire liter bottle, rinse cap & bottle, and add to sample. Decrease extract volume to help meet quantitation limits.

Initial Calibration: 20, 50, and 100 total nanograms.

Continuing Calibration: 20 nanograms except for the following-

Benzoic acid, 2,4 - dinitrophenol, 2,4,5-trichlorophenol, all three nitroaniline isomers, 4-nitrophenol, 4,6-dinitro-2-methylphenol and pentachlorophenol which are to be injected at 50 nanograms.

* Surrogates: 20 ppb BN compounds with % recoveries as listed in IFB.
40 ppb Acid compounds with % recoveries as listed in IFB.
* Matrix Spike: 20 ppb BN compounds with % recoveries as listed in IFB.
40 ppb Acid compounds with % recoveries as listed in IFB.
All RFs must be ≥0.05.

Pesticide/PCB - Extract the entire liter bottle, rinse cap & bottle, and add to sample. Decrease extract volume to help meet quantitation limits.

Calibration: As in IFB using an attenuation setting capable of achieving the quantitation limits in Attachment II. 72 hour run sequence as in IFB.

Surrogates: Use 20% of the IFB amounts with % recoveries as listed in IFB.

Matrix Spike: Use 20% of the IFB amounts with % recoveries an listed in IFB.

NOTE: The IFB limits for the RPDs for the matrix spike/matrix spike duplicate results apply for all of the organics analyses.
For corrective action when surrogates are outside the SAS required recovery limits, see the IFB for re-extraction/re-analysis requirements.
* The surrogate and matrix spike amounts listed are the concentrations in the liter of sample.

5. Estimated date(s) and method of shipment: 12th September - 16th September 1988

6. Number of days analysis and data required after laboratory receipt of samples:

Laboratory should report results within 30 days of receipt of samples.

7. Analytical protocol required (attach copy if other than a protocol currently used in this program:

Inorganic analysis as per SOW785, IFB WA-85-J838, with the exceptions listed in Attachments II & III. ICP emission spectroscopy, mercury, and cyanide analyses follow the SOW mentioned above for sample preparation and analysis protocol with the instrument detection limits end matrix spike levels given in Attachment II and the QC audits as described in Attachment III. GFAA analyses may be run undigested if the samples are free of particulates. If particulates are present the samples are to be digested as per SOW mentioned above. The ICP digest is to be used for Sb analyses if digestion is required. A detailed set of instructions for conducting the GFAA analyses are included in Attachment III. Special instrument detection limits and matrix spike levels are listed on Attachment II.

8. Special technical instruction (if outside protocol requirements, specify compound names, CAS numbers, detection limits, etc.):

1.) Check the pH of each sample (wide range pH paper is acceptable). If the pH values are outside of the specified limits of SOW785, contact Region V for instruction.

2.) Instrument Detection Limits (IDL) of Attachment II are to be met prior to any sample analysis.

3.) Spike Ca, Mg, Na and K and all other parameters as per Attachment II. The Spikes for these four analytes shall be a separate aliquot unless documentation is provided that no contamination results for the other

analytes. The GFAA protocol is specified in Attachment III. The frequency and limits of certain audits are changed from that given in SOW785 for all analyses as per Attachment III.

9. Analytical results required (if known, specify format for data sheets, QA/QC reports, Chain-of-Custody documentation, etc.). If not completed, format of results will be left to program discretion.

   All of the deliverables included in SOW785 are required. Also, provide current quarterly XI, XII, XIII for each case. Submit Form VIII separate for each separate parameter analyzed by MSA. Form VIII must be modified to include the slope of each addition as well as the correlation coefficient. Use footnotes on Form 1 for reporting results, except use IDL of Attachment II for detection limit.

10. Other (use additional sheets or attach supplementary information, as needed):

11. Name of sampling/shipping contact: Mona Sutherland

    Phone: (312) 621-3944

I. DATA REQUIREMENTS

Parameter	Detection Limit	Precision Desired (±% or Conc.)
ICP Metal	See Attachment II	10% RPD or Duplicate
Furnace Metals	See Attachment II	Difference ≤ SAS IDL
		of Attachment II
Mercury, Cyanide	See Attachment II as	
	per SOW785	

II. QC REQUIREMENTS

Audits Required	Frequency of Audits	Limits* (±% or Conc.)
For ICP - AES, Hg,	See 9.A of Attach-	
and CN.	ment III	
GFAA (undigested) As,	See 9.B of Attach-	
Cd, Pb, Sb, Se, Tl.	ment III	
GFAA (undigested) As,	See 9.C of Attach-	
Cd, Pb, Sb, Se, Tl.	ment III	

III. ACTION REQUIRED IF LIMITS ARE EXCEEDED:

Take corrective action and repeat analysis.

Contact Jay Thakkar or Chuck Elly

(312) 886-1972 (312) 353-9087

Please return this request to the Sample Management Office as soon as possible to expedite processing of your request for special analytical services. Should you have any questions or need any assistance, please call the Sample Management Office.

ATTACHMENT II

Instrument Detection Limit and Spiking Level for Drinking Water

Compound	Required Instrument Detection Limit[1] ug/L			Required Matrix Spike Concentrations ug/L		
	GFAA	ICP	Other	GFAA	ICP	Other
Metal:						
1. Aluminum		100			2000	
2. Antimony [2]	5			20	500	
3. Arsenic	5			20		
4. Barium		50			2000	
5. Beryllium		5			50	
6. Cadmium [2]	0.5			2	50	
7. Calcium [3]		1000			50,000	
8. Chromium		10			200	
9. Cobalt		10			500	
10. Copper		10			250	
11. Iron		100			1000	
12. Lead [2]	2			20	500	
13. Magnesium [3]		1000			25,000	
14. Manganese		10			200	
15. Mercury			0.2			1.0
16. Nickel		20			400	
17. Potassium [3]		2000			20,000	
18. Selenium	2			10		
19. Silver		5			50	
20. Sodium [3]		1000			50,000	
21. Thallium	2			20		
22. Vanadium		10			500	
23. Zinc		20			200	
4. Cyanide			10			100

[1] Instrument Detection Limits (IDL) must be met before any samples are analyzed. The Lab may submit their quarterly Form XI with each case if all IDLs meet the detection limits.

[2] ICP analysis results may only be reported for Sb, Cd and Pb, if the concentration is $\geq$ 10 times the IDL of instrument used. If ICP results are reported, all ICP audits are required including matrix spike.

[3] Report Ca, Mg, Na and K on separate Form V for Matrix Spike if a separate aliquot is used for this spike.

ATTACHMENT III

Special instructions for GFAA and QC requirements for all analyses.

1. Sample aliquots are preserved in the field as follows:

   a) One liter preserved with 5ml/l of 50% HNO_3 to pH<2 for all metals (excluding Hg).

   b) One liter sample preserved with 0.5% HNO_3 V/V and 0.05% $K_2Cr_2O_7$ W/V for Mercury.

   c) One liter of sample preserved with 5ml/l of 6N NaOH to pH $\geq$ 12 for cyanide determination.

2. Analysis of the six metals (specified in Attachment II) by graphite furnace atomic absorption (GFAA) must use the method of standard additions for quantitation.

3. All of the samples for GFAA metals can be analyzed without digestion if the samples are clean and without any particulates. In this case, a calibration blank, duplicate, ICVS, and CCVS shall be analyzed without digestion.

4. If any of the samples contain particulate or significant suspended solids, sample aliquots, preparation blank, duplicate, matrix spikes and lab control samples are to be digested per page D-2 of SOW785. The samples digested for ICP analysis are to be used for antimony determination.

5. No identified field blank may be used as a laboratory duplicate or matrix spike sample

ATTACHMENT III

6.1 Zeeman, Smith/Hieftje background correction or equivalent (not D_2) is required for Arsenic, Selenium and Antimony or any element with structured background interferences.

6.2 The matrix modifiers of SOW785 are mandatory for As & Se.

6.3 L'vov platform is allowed.

6.4 Any matrix modifers for Sb, Cd, Pb and Tl must be approved by the Region V Central Regional Laboratory's Contract Project Management Section prior to use and documented with the raw data.

6.5 Each sample or QC audit is to be determined by the MSA using the sample or QC audit and then three consecutive spikes.

6.6 Each calibration blank and QC audit solution must contain the same nitric acid concentration as the sample (or diluted samples). All solutions analyzed must have their matrix concentrations fully documented in the raw data.

6.7 Each analytical determination must have the resulting absorbance clearly recorded and documented in the order of determined.

6.8 The data for each MSA determination must show; slope (signal/conc.), intercept and correlation coefficent (r). The results must be reported on Form VIII for all samples and QC audits in order of analysis. Form VIII must be modified to include the above mentioned slope.

6.9 Samples and QC audits will be tested in the following order for the method of standard addition quantitation.

a) calibration blank and + 3 spikes
b) ICVS (provided by EMSL-LV) +3 spikes
c) 5 samples, each with 3 spikes
d) calibration blank + 3 spikes
e) CCVS + 3 spikes
f) succeeding sets of 5 samples, cal. blank, and CCVS.

7. Report the correlation coefficient for all MSA analyses. $r \geq 0.995$ is required for all sample and audit analyses. A correlation coefficent (r) ≥ 0.998 is recommended for the calibration blank or problems will occur with the sample analysis. If $r<0.995$ or the slope is <35% of the initial calibration blank, reanalyze the sample once. If the standard addition again fails these criteria, dilute the sample and reanalyze. If the standard addition again fails, flag the data with a "+".

8. Care must be taken to avoid exceeding the linear range for all GFAA analyses. This problem is especially severe with Cd and Pb. Dilution of the samples may be necessary to avoid this problem.

Q.C. REQUIREMENTS

9. A ICP Metals, Mercury and Cyanide

Audits Required	Frequency of Audits	Limits
ICVS, CCVS, ICP serial dilution; ICP ICS, Distilled CN standard	as per SOW 785	as per SOW 785
Calibration Blank	Beginning of Run and 1 in 10 thereafter	≤ IDL
Preparation Blank	1 in 10 samples	< SAS IDL of Attachment II
Duplicate	1 in 10 samples	10% RPD or Difference is ≤ SAS IDL, 15% For Hg & CN
Matrix Spike (ICP)	1 in 10 samples	85 - 115% Recovery
Matrix Spike(ICP-Ca,Mg, Na, K)*	1 in 10 samples	85 - 115% Recovery
Matrix spike (Hg & CN)	1 in 10 samples	80 - 120%
Digested Lab Control Sample	1 per sample set	85 - 115%

*May be combined with other spike (cf item 8 of SAS)

9.B G.F.A.A. Undigested Samples

Audits Required	Frequency of Audits	Limits
1) Duplicate	1 in 10 samples	Difference of < SAS IDL of Attachment II or ≤ 10% RPD
2) Calibration Blank	Initially and after every 5 samples	≤ IDL
3) ICVS and CCVS	Initially ICVS,and CCVS after every 5 samples	90% - 110%

9.C GFAA Digested Samples

Audits Required	Frequency of Audits	Limits
1) Calibration Blank	Initially and after every 5 samples	≤ IDL
2) Preparation Blank (Digested)	1 in 10 samples	< SAS IDL of Attachment II
3) Duplicates (Digested)	1 in 10 samples	Difference of < SAS IDL or 10% RPD
4) Matrix Spike (Digested)	1 in 10 samples	85 - 115% Recovery
5) Lab Control Sample (Digested)	1 per set of samples	85 - 115% Recovery
6) ICVS, CCVS	Initially ICVS, and CCVS after every 5 samples	90 - 110% Recovery

APPENDIX 3.5

SAS REQUEST FOR THE DETERMINATION OF TOTAL DISSOLVED SOLIDS (TDS) IN GROUNDWATER SAMPLES

U.S. Environmental Protection Agency
CLP Sample Management Office
P.O. Box 818, Alexandria, Virgina 22313
PHONE: (703)/557-2490 or FTS/557-2490

SAS Number

SPECIAL ANALYTICAL SERVICES
Client Request

[X] Regional Transmittal [ ] Telephone Request

A. EPA Region/Client: REGION V/CCJM

B. RSCC Representative: JAN PELS

C. Telephone Number: (312) 353-2720

D. Date of Request: 6th June 1988

E. Site Name: HUNTS DISPOSAL LANDFILL

Please provide below a description of your request for Special Analytical Services under the Contract Laboratory Program. In order to most efficiently obtain laboratory capability for your request, please address the following considerations, if applicable. Incomplete or erroneous information may result in delay in the processing of your request. Please continue response on additional sheets, or attach supplementary information as needed.

1. General description of analytical service requested: Analysis of total dissolved (180°C) in groundwaters. Results are reported as mg/l dissolved solids.

2. Definition and number of work units involved (specify whether whole samples or fractions; whether organics or inorganics; whether aqueous or soil and sediments; and whether low, medium, or high concentration):

   Two rounds of groundwater sampling. Each round will have a total of 23 low concentration water samples -- 19 investigative, 2 duplicates and 2 field blanks.

3. Purpose of analysis (specify whether Superfund (Remedial or Enforcement), RCRA, NPDES, etc.):

   Superfund Remedial

4. Estimated date(s) of collections: 12th September - 16th September 1988.

   Re-analysis: 14th November - 25th November 1988.

5. Estimated date(s) and method of shipment: 12th September - 16th September 1988. Re-analysis: 14th November - 25th November 1988.

6. Number of days analysis and data required after laboratory receipt of samples:

   Laboratory should report results within 30 days of receipt of samples.

7. Analytical protocol required (attach copy if other than a protocol currently used in this program:

   1.) EPA Method 160.1, 1983 ed., or

   2.) Method 209B, "Standard Methods," 16th ed. Samples will be kept at $4^{o}C$ until sample analysis and validation of results. Holding time is 7 days from date of sample collection.

8. Special technical instruction (if outside protocol requirements, specify compound names, CAS numbers, detection limits, etc.):

   1.) Use standard aliquots of 100 ml; however, do not use sample aliquots yielding more than 200 mg residue. If residue is greater than 200 mg, repeat the analysis using a smaller sample aliquot.

   2.) If the pH value is less than 4.0, raise the pH of the aliquot (using NaOH titrant) to between pH 4 and 8, and subtract the weight of sodium added from the weight of the residue.

   3.) Residue will be weighted either to constant weight pursuant to Section 7.6 of Method 160.1. The final weight is to be used for calculations. Constant weight is defined as: (a.) less than 0.5 mg or less than 4% weight loss from the previous weight, whichever is smaller, or (b.) dried overnight (12 hours drying time) with a single weight used for calculations.

9. Analytical results required (if known, specify format for data sheets, QA/QC reports, Chain-of Custody documentation, etc.). If not completed, format of results will be left to program discretion.

   Identify the QC reference sample lot numbers used and their true values

with 95% confidence intervals. Bench records of tare weights, final weights, additional weights to determine constant weights, volumes filtered, blanks, duplicate samples, and reference samples will be provided with copies of work sheets used to calculate results. Dates and time of: (1.) determination of tare weights, (2.) sample filtration, and (3.) determination of residue weights and constant residue weights will be part of bench records. All records of analysis must be legible and sufficient to recalculate all sample concentrations and QA results.

10. Other (use additional sheets or attach supplementary information, as needed):

11. Name of sampling/shipping contact: Mona Sutherland

Phone: (312) 621-3944

I. DATA REQUIREMENTS

Parameter	Detection Limit	Precision Desired (±% or Conc.)
TDS	20 mg/l	Difference in duplicate sample aliquots shall not exceed 2 mg for residues. Duplicate differences shall not exceed 10% for sample values greater than 200 mg/l.
Note: These are minimum requirements. Report the acutal detection limits used based on allowable methodology options.		

II. QC REQUIREMENTS

DO NOT USE ANY DESIGNATED FIELD BLANKS FOR QA AUDITS.

Audits Required	Frequency of Audits	Limits* (+% or Conc.)
1. 1 set of EPA QC Mineral Reference Samples* -- 2 concentration levels.	1 per sample set	85-115% Recovery
2. Lab Duplicate	At least 1 per group of 10 or fewer samples	±(10% or 2 mg of residue)
3. Lab Blanks (100 ml of filtered reagent water	At least 1 per group of 10 or fewer samples	-20 mg/l to +20 mg/l

*Alternate reference samples must be approved by Region V RSCC prior to analysis.

III. *ACTION REQUIRED IF LIMITS ARE EXCEEDED:

Take corrective action and retest samples.

Contact Charles T. Elly or Jay Thakkar

(312) 353-9087 (312) 886-1972

Please return this request to the Sample Management Office as soon as possible to expedite processing of your request for special analytical services. Should you have any questions or need any assistance, please call the Sample Management Office.

ATTACHMENT II (1of4)

TABLE 1 (ALL UNITS ARE MICROGRAMS/LITER)

PARAMETER	CAS #	QUANTITATION LIMITS
BENZENE	71-43-2	1.5
BROMODICHLOROMETHANE	75-27-4	1.5
BROMOFORM	75-25-2	1.5
BROMOMETHANE	74-83-9	10
CARBON TETRACHLORIDE	56-23-5	1.5
CHLOROBENZENE	108-90-7	1.5
CHLOROETHANE	75-00-3	1.5
2-CHLOROETHYL VINYL ETHER	110-75-8	1.5
CHLOROFORM	67-66-3	1.5
CHLOROMETHANE	74-87-3	10
DIBROMOCHLOROMETHANE	124-48-1	1.5
1,1-DICHLOROETHANE	75-34-3	1.5
1,2-DICHLOROETHANE	107-06-2	1.5
1,1-DICHLOROETHENE	75-35-4	1.5
TOTAL 1,2-DICHLOROETHENES	156-60-5	1.5
1,2-DICHLOROPROPANE	78-87-5	1.5
cis-1,3-DICHLOPROPROPENE	10061-01-5	2
trans-1,3-DICHLOROPROPENE	10061-02-6	1
ETHYL BENZENE	100-41-4	1.5
METHYLENE CHLORIDE (*)	75-09-2	1
1,1,2,2-TETRACHLOROETHANE	79-34-5	1.5
TETRACHLOROETHENE	127-18-4	1.5
TOLUENE (*)	108-88-3	1.5
1,1,1-TRICHLOROETHANE	71-55-6	1.5
1,1,2-TRICHLOROETHANE	79-00-5	1.5
TRICHLOROETHENE	79-01-6	1.5
VINYL CHLORIDE	75-01-4	10
ACROLEIN	107-02-8	100
ACETONE (*)	67-64-1	75
ACRYLONITRILE	107-13-1	50
CARBON DISULFIDE	75-15-0	3
2-BUTANONE	78-93-3	(50)
VINYL ACETATE	108-05-4	15
4-METHYL-2-PENTANONE	108-10-1	(3)
2-HEXANONE	519-78-6	(50)
STYRENE	100-42-5	1
m-XYLENE	108-38-3	2
o-XYLENE **	95-47-6	
p-XYLENE **	106-42-3	2.5

* COMMON LABORATORY SOLVENT
BLANK LIMIT IS 5x METHOD DETECTION LIMIT

** THE o-XYLENE AND p-XYLENE ARE REPORTED AS A TOTAL OF THE TWO

ATTACHMENT II (2of4)

TABLE 1 (ALL UNITS ARE MICROGRAMS/LITER)

PARAMETER	CAS #	QUANTITATION LIMIT
BIS(2-CHLOROETHYL)ETHER	111-44-4	1.5
PHENOL	108-95-2	2
2-CHLOROPHENOL	95-57-8	2
1,3-DICHLOROBENZENE	541-73-1	2
1,4-DICHLOROBENZENE	106-46-7	2
1,2-DICHLOROBENZENE	95-50-1	2.5
BENZYL ALCOHOL	100-51-6	2
BIS(2-CHLOROISOPROPYL) ETHER	39638-32-9	2.5
2-METHYLPHENOL	95-48-7	1
HEXACHLOROETHANE	67-72-1	2
N-NITROSODIPROPYLAMINE	621-64-7	1.5
NITROBENZENE	98-95-3	2.5
4-METHYLPHENOL	106-44-5	1
ISOPHORONE	78-59-1	2.5
2-NITROPHENOL	88-75-5	2
2,4-DIMETHYLPHENOL	105-67-9	2
BIS(2-CHLOROETHOXY)METHANE	111-91-1	2.5
2,4-DICHLOROPHENOL	120-83-2	2
1,2,4-TRICHLOROBENZENE	120-82-1	2
NAPHTHALENE	91-20-3	2
4-CHLOROANILINE	106-47-8	2
HEXACHLOROBUTADIENE	87-68-3	2.5
BENZOIC ACID	65-85-0	(30)
2-METHYLNAPTHALENE	91-57-6	2
4-CHLORO-3-METHYLPHENOL	59-50-7	1.5
HEXACHLOROCYCLOPENTADIENE	77-47-4	2
2,4,6-TRICHLOROPHENOL	88-06-2	1.5
2,4,5-TRICHLOROPHENOL	95-95-4	1.5
2-CHLORONAPTHALENE	91-58-7	1.5
ACENAPTHYLENE	208-96-8	1.5
DIMETHYL PHTHALATE	131-11-3	1.5
2,6-DINITROTOLUENE	606-20-2	1
ACENAPHTHENE	83-32-9	1.5
3-NITROANILINE	99-09-2	2.5
DIBENZOFURAN	132-64-9	1
2,4-DINITROPHENOL	51-28-5	(15)
2,4-DINITROTOLUENE	121-14-2	1

NOTE: Limits are for reagent water.

ATTACHMENT II (3of4)

TABLE 1 (CONTINUED) (ALL UNITS ARE MICROGRAMS/LITER)

PARAMETER	CAS #	QUANTITATION LIMIT
FLUORENE	86-73-7	1
4-NITROPHENOL	100-02-7	1.5
4-CHLOROPHENYL PHENYL ETHER	7005-72-3	1
DIETHYL PHTHALATE	84-66-2	1
4,6-DINITRO-2-METHYLPHENOL	534-52-1	(15)
N-NITROSODIPHENYLAMINE *	86-30-6	
DIPHENYLAMINE *	122-39-4	1.5
4-NITROANILINE	100-01-6	3
4-BROMOPHENYL PHENYL ETHER	101-55-3	1.5
HEXACHLOROBENZENE	118-74-1	1.5
PENTACHLOROPHENOL	87-86-5	2
PHENANTHRENE	85-01-8	1
ANTHRACENE	120-12-7	2.5
DI-n-BUTYL PHTHALATE	84-74-2	2
FLUORANTHENE	206-44-0	1.5
PYRENE	129-00-0	1.5
BUTYL BENZYL PHTHALATE	85-68-7	3.5
CHRYSENE **	218-01-9	
BENZO(a)ANTHRACENE **	56-55-3	1.5
BIS(2-ETHYLHEXYL) PHTHALATE	117-81-7	1
DI-n-OCTYL PHTHALATE	117-84-0	1.5
BENZO(b)FLUORANTHENE ***	205-99-2	
BENZO(k)FLUORANTHENE ***	207-08-9	1.5
BENZO(a)PYRENE	50-32-8	2
INDENO(1,2,3-cd)PYRENE	193-39-5	3.5
DIBENZO(a,h)ANTHRACENE	53-70-3	2.5
BENZO(g,h,i)PERYLENE	191-24-2	4
2-NITROANILINE	88-74-4	1

* THESE TWO PARAMETERS ARE REPORTED AS A TOTAL
** THESE TWO PARAMETERS ARE REPORTED AS A TOTAL
*** THESE TWO PARAMETERS ARE REPORTED AS A TOTAL

VALUES IN PARENTHESES ARE ESTIMATES. ACTUAL VALUES ARE BEING DETERMINED AT THIS TIME.

NOTE: Limits are for reagent water.

APPENDIX 3.6

SAS REQUEST FOR THE DETERMINATION OF PERMEABILITY, GRAIN SIZE AND POROSITY IN SHELBY-TUBED SOIL BORING SAMPLES

U.S. Environmental Protection Agency
CLP Sample Management Office
P.O. Box 818, Alexandria, Virgina 22313
PHONE: (703)/557-2490 or FTS/557-2490

SAS Number

SPECIAL ANALYTICAL SERVICES
Client Request

☐ Regional Transmittal ☐ Telephone Request

A. EPA Region/Client: REGION V/CCJM

B. RSCC Representative: JAN PELS

C. Telephone Number: (312) 353-2720

D. Date of Request: 6th June 1988

E. Site Name: HUNTS DISPOSAL LANDFILL

Please provide below a description of your request for Special Analytical Services under the Contract Laboratory Program. In order to most efficiently obtain laboratory capability for your request, please address the following considerations, if applicable. Incomplete or erroneous information may result in delay in the processing of your request. Please continue response on additional sheets, or attach supplementary information as needed.

1. General description of analytical service requested: Analysis of undisturbed soil samples from borings for permeability, grain size and porosity.

2. Definition and number of work units involved (specify whether whole samples or fractions; whether organics or inorganics; whether aqueous or soil and sediments; and whether low, medium, or high concentration):

   A total of 10 undisturbed Shelby tube soil core samples. Concentration analysis not applicable; however, samples will be shipped as low concentration.

3. Purpose of analysis (specify whether Superfund (Remedial or Enforcement), RCRA, NPDES, etc.):

   Superfund Remedial

4. Estimated date(s) of collections: 1st August - 2nd September 1988

5. Estimated date(s) and method of shipment: 1st August - 2nd September 1988

   Federal Express Next Day Delivery

6. Number of days analysis and data required after laboratory receipt of samples:

   Laboratory should report results within 30 days of receipt of samples.

7. Analytical protocol required (attach copy if other than a protocol currently used in this program:

   Falling Head Permeability, "Laboratory Soils Testing," Engineer Manual EM 1110-2-1906, Department of the Army, Office of the Chief of Engineers, Washington, D.C. 20314.

   Measurement is to be made on undisturbed samples in Shelby tubes following procedures outlined on Page VII - 16, Permeability Tests with Sampling Tubes.

8. Special technical instruction (if outside protocol requirements, specify compound names, CAS numbers, detection limits, etc.): Use only the method specified above. Obtain approval of CPMS, CRL, prior to use of any other method. Analysis is to be run on a 6.0 inch section cut from the central portion of the tube.

9. Analytical results required (if known, specify format for data sheets, QA/QC reports, Chain-of-Custody documentation, etc.). If not completed, format of results will be left to program discretion.

   Report all raw data and parameter values used in making computations of permeability (Section 4e(2) of attached method).

10. Other (use additional sheets or attach supplementary information, as needed):

11. Name of sampling/shipping contact: Mona Sutherland

    Phone: (312) 621-3944

I. DATA REQUIREMENTS

Parameter	Detection Limit	Precision Desired (+% or Conc.)
Permeability	10^{-10} cm/sec	Duplicates within 10%

II. QC REQUIREMENTS

Audits Required	Frequency of Audits	Limits* (±% or Conc.)
Duplicate	2 for sets ≤10	±10%
	1 per 10 for sets >10	

III. ACTION REQUIRED IF LIMITS ARE EXCEEDED:

Call Region V CRL if problems exist

Jay Thakkar or Chuck Elly

(312) 886-1972 (312) 353-9087

Please return this request to the Sample Management Office as soon as possible to expedite processing of your request for special analytical services. Should you have any questions or need any assistance, please call the Sample Management Office.

Alexandria

REPRINT WITH CORRECTED COPY INCORPORATED.

ENGINEER MANUAL

EM 1110-2-1906

30 November 1970

Alexandria "Cab Copy"

ENGINEERING AND DESIGN

LABORATORY SOILS TESTING

HEADQUARTERS, DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS

4. FALLING-HEAD PERMEABILITY TEST WITH PERMEAMETER CYLINDER. a. Use. The falling-head test with the permeameter cylinder should in general be used for determining the permeability of remolded samples of cohesionless soils having a permeability less than about 10×10^{-4} cm per sec.

b. Apparatus. The apparatus and accessory equipment should consist of the following:

(1) A permeameter cylinder similar to that shown schematically in Figure 3b, or modified versions thereof. The permeameter cylinder should be constructed of a transparent plastic material. The inside diameter of the cylinder should be not less than about 10 times the diameter of the largest soil particles. The use of two piezometer taps, as shown by Figure 3b, connected to a standpipe and discharge level tube eliminates the necessity for taking into account the height of capillary rise which would be necessary in the case of a single standpipe of small size. The height of capillary rise for a given tube and condition can be measured simply by standing the tube upright in a beaker full of water. The size of standpipe to be used is generally based on experience with the equipment used and soils tested. In order to accelerate testing, air pressure may be applied to the standpipe to increase the hydraulic gradient.

(2) Perforated metal or plastic disks and circular wire screens, 35 to 100 mesh, cut for a close fit inside the permeameter.

(3) Glass tubing, rubber or plastic tubing, stoppers, screw clamps, etc., necessary to make connections as shown in Figure 3b.

(4) Filter materials such as Ottawa sand, coarse sand, and gravel of various gradations.

(5) Deaired distilled water, prepared according to paragraph 3b(6).

(6) Manometer board or suitable scales for measuring levels in piezometers or standpipe.

(7) Timing device, a watch or clock with second hand.

(8) Centigrade thermometer, range 0 to 50 C, accurate to 0.1 C.

(9) Balance, sensitive to 0.1 g.

(10) Oven (see Appendix I, WATER CONTENT - GENERAL).

(11) Scale, graduated in centimeters.

c. Placement and Saturation of Specimen. Placement and saturation of the specimen shall be done as described in paragraph 3c. Identifying information for the sample and test data shall be entered on a data sheet similar to Plate VII-2.

d. Procedure. The procedure shall consist of the following steps:

(1) Measure and record the height of the specimen, L, and the cross-sectional area of the specimen, A.

(2) With valve B open (see Fig. 3b), crack valve A and slowly bring the water level up to the discharge level of the permeameter.

(3) Raise the head of water in the standpipe above the discharge level of the permeameter. The difference in head should not result in an excessively high hydraulic gradient during the test. Close valves A and B.

(4) Begin the test by opening valve B. Start the timer. As the water flows through the specimen, measure and record the height of water in the standpipe above the discharge level, h_o, in centimeters, at time t_o, and the height of water above the discharge level, h_f, in centimeters, at time t_f.

(5) Observe and record the temperature of the water in the permeameter.

(6) Repeat the determination of permeability, and if the computed values differ by an appreciable amount, repeat the test until consistent values of permeability are obtained.

e. Computations. The computations consist of the following steps:

(1) Compute the test void ratios as outlined in paragraph 3e(1).

(2) Compute the coefficient of permeability, k, by means of the following equation:

$$k = 2.303 \frac{a}{A} \frac{L}{t} \left(\log \frac{h_o}{h_f} \right) R_T$$

where a = inside area of standpipe, sq cm

A = cross-sectional area of specimen, sq cm

L = length of specimen, cm

t = elapsed time ($t_f - t_o$), sec

h_o = height of water in standpipe above discharge level at time t_o, cm

h_f = height of water in standpipe above discharge level at time t_f, cm

R_T = temperature correction factor for viscosity of water obtained from Table VII-1, degrees C (attached)

If a single standpipe of small diameter is used as shown in Figure 2, the height of capillary rise, h_c, should be subtracted from the standpipe readings to obtain h_o and h_f.

f. Presentation of Results. The results of the falling-head permeability test shall be reported as described in paragraph 3f.

5. PERMEABILITY TESTS WITH SAMPLING TUBES. Permeability tests may be performed directly on undisturbed samples without removing them from the sampling tubes. The sampling tube serves as the permeameter cylinder. The method is applicable primarily to cohesionless soils which cannot be removed from the sampling tube without excessive disturbance. The permeability obtained is in the direction in which the sample was taken, i.e. generally vertical. The permeability obtained in a vertical direction may be substantially less than that obtained in a horizontal direction.

Permeability tests with sampling tubes may be performed under constant-head or falling-head conditions of flow, depending on the estimated permeability of the sample (see paragraph 2a). The equipment should be capable of reproducing the conditions of flow in the constant-head or falling-head tests. It is important that all disturbed material or material containing drilling mud be removed from the top and bottom of the sample. The ends of the sample should be protected by screens held in place by perforated packers. The test procedure and computations are

the same as those described previously for each test.

6. PERMEABILITY TEST WITH PRESSURE CHAMBER. In the permeability test with a pressure chamber, see Figure 7, a cylindrical specimen is confined in a rubber membrane and subjected to an external hydrostatic pressure during the permeability test. The advantages of this type of test are: (a) leakage along the sides of the specimen, which would occur if the specimen were tested in a permeameter, is prevented, and (b) the specimen can be tested under conditions of loading expected in the field. The test is applicable primarily to cohesive soils in the undisturbed, remolded, or compacted state. Complete saturation of the specimen, if it is not fully saturated initially, is practically impossible. Consequently, this test should be used only for soils that are fully saturated, unless values of permeability are purposely desired for soils in an unsaturated condition. The permeability test with the pressure chamber is usually performed as a falling-head test.

The permeability specimens for use in the pressure chamber generally should be 2.8 in. in diameter, as rubber membranes and equipment for cutting and trimming specimens of this size are available for triaxial testing apparatus (see Appendix X, TRIAXIAL COMPRESSION TESTS). A specimen length of about 4 in. is adequate. (The dimensions of a test specimen may be varied if equipment and supplies are available to make a suitable test setup.) The pressure in the chamber should not be less than the maximum head on the specimen during the test. The other test procedure and computations are the same as those described for the falling-head test. The linear relation between permeability and void ratio on a semilogarithmic plot as shown in Figure 6 is usually not applicable to fine-grained soils, particularly when compacted. Other methods of presenting permeability-void ratio data may be desirable.

7. PERMEABILITY TESTS WITH BACK PRESSURE.

a. Description. Gas bubbles in the pores of a compacted or undisturbed specimen of fine-grained soil will invalidate the results of the

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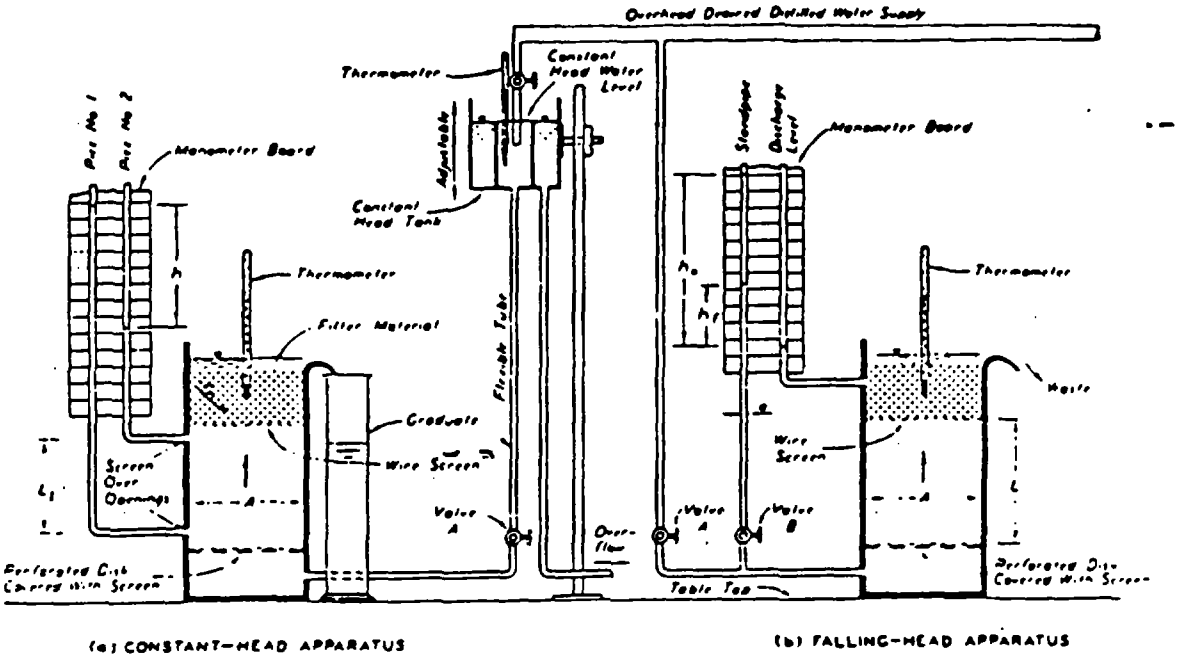


Figure 3. Schematic diagram of constant-head and falling-head permeability apparatus

Table VII-1

Correction Factor, R_T, for Viscosity of Water at Various Temperatures

Temperature Degrees C	Tenths of Degrees									
	0	1	2	3	4	5	6	7	8	9
0.0	1.783	1.777	1.771	1.765	1.759	1.753	1.747	1.741	1.735	1.729
1.0	1.723	1.717	1.711	1.705	1.699	1.694	1.688	1.682	1.676	1.670
2.0	1.664	1.659	1.654	1.648	1.643	1.638	1.632	1.627	1.622	1.616
3.0	1.611	1.606	1.601	1.596	1.590	1.585	1.580	1.575	1.570	1.565
4.0	1.560	1.555	1.550	1.545	1.540	1.535	1.531	1.526	1.521	1.516
5.0	1.511	1.507	1.502	1.498	1.493	1.488	1.484	1.479	1.475	1.470
6.0	1.465	1.461	1.457	1.452	1.448	1.443	1.439	1.435	1.430	1.426
7.0	1.421	1.417	1.413	1.409	1.404	1.400	1.396	1.392	1.388	1.383
8.0	1.379	1.375	1.371	1.367	1.363	1.359	1.355	1.351	1.347	1.343
9.0	1.339	1.336	1.332	1.328	1.324	1.320	1.317	1.313	1.309	1.305
10.0	1.301	1.298	1.294	1.290	1.287	1.283	1.279	1.276	1.272	1.269
11.0	1.265	1.262	1.258	1.255	1.251	1.248	1.244	1.241	1.237	1.234
12.0	1.230	1.227	1.223	1.220	1.217	1.213	1.210	1.207	1.203	1.200
13.0	1.197	1.194	1.190	1.187	1.184	1.181	1.178	1.175	1.171	1.168
14.0	1.165	1.162	1.159	1.156	1.153	1.150	1.147	1.144	1.141	1.138
15.0	1.135	1.132	1.129	1.126	1.123	1.120	1.117	1.114	1.111	1.108
16.0	1.106	1.103	1.100	1.097	1.094	1.091	1.089	1.086	1.083	1.080
17.0	1.077	1.075	1.072	1.069	1.067	1.064	1.061	1.059	1.056	1.053
18.0	1.051	1.048	1.045	1.043	1.040	1.038	1.035	1.033	1.030	1.027
19.0	1.025	1.022	1.020	1.017	1.015	1.012	1.010	1.007	1.005	1.002
20.0	1.000	0.998	0.995	0.993	0.990	0.988	0.986	0.983	0.981	0.979
21.0	0.976	0.974	0.972	0.969	0.967	0.965	0.962	0.960	0.958	0.955
22.0	0.953	0.951	0.949	0.947	0.944	0.942	0.940	0.938	0.936	0.933
23.0	0.931	0.929	0.927	0.925	0.923	0.920	0.918	0.916	0.914	0.912
24.0	0.910	0.908	0.906	0.904	0.901	0.899	0.897	0.895	0.893	0.891
25.0	0.889	0.887	0.885	0.883	0.881	0.879	0.877	0.875	0.873	0.871
26.0	0.869	0.867	0.866	0.864	0.862	0.860	0.858	0.856	0.854	0.852
27.0	0.850	0.848	0.847	0.845	0.843	0.841	0.839	0.837	0.836	0.834
28.0	0.832	0.830	0.828	0.826	0.825	0.823	0.821	0.819	0.818	0.816
29.0	0.814	0.812	0.810	0.809	0.807	0.805	0.804	0.802	0.800	0.798
30.0	0.797	0.795	0.793	0.792	0.790	0.788	0.787	0.785	0.783	0.782
31.0	0.780	0.778	0.777	0.775	0.774	0.772	0.770	0.769	0.767	0.766
32.0	0.764	0.763	0.761	0.759	0.758	0.756	0.755	0.753	0.752	0.750
33.0	0.749	0.747	0.746	0.744	0.743	0.741	0.739	0.738	0.736	0.735
34.0	0.733	0.732	0.731	0.729	0.728	0.726	0.725	0.723	0.722	0.720
35.0	0.719	0.718	0.716	0.715	0.713	0.712	0.711	0.709	0.708	0.706
36.0	0.705	0.704	0.702	0.701	0.699	0.698	0.697	0.695	0.694	0.693
37.0	0.691	0.690	0.689	0.687	0.686	0.685	0.683	0.682	0.681	0.679
38.0	0.678	0.677	0.675	0.674	0.673	0.672	0.670	0.669	0.668	0.666
39.0	0.665	0.664	0.663	0.661	0.660	0.659	0.658	0.656	0.655	0.654
40.0	0.653	0.652	0.650	0.649	0.648	0.647	0.646	0.644	0.643	0.642
41.0	0.641	0.639	0.638	0.637	0.636	0.635	0.634	0.632	0.631	0.630
42.0	0.629	0.628	0.627	0.626	0.624	0.623	0.622	0.621	0.620	0.619
43.0	0.618	0.616	0.615	0.614	0.613	0.612	0.611	0.610	0.609	0.608
44.0	0.607	0.606	0.604	0.603	0.602	0.601	0.600	0.599	0.598	0.597
45.0	0.596	0.595	0.594	0.593	0.592	0.591	0.590	0.588	0.587	0.586
46.0	0.585	0.584	0.583	0.582	0.581	0.580	0.579	0.578	0.577	0.576
47.0	0.575	0.574	0.573	0.572	0.571	0.570	0.569	0.568	0.567	0.566
48.0	0.565	0.564	0.564	0.563	0.562	0.561	0.560	0.559	0.558	0.557
49.0	0.556	0.555	0.554	0.553	0.552	0.551	0.550	0.549	0.548	0.548

Computed from Table 170 - Smithsonian Physical Tables - 8th Edition
Correction factor, R_T, is found by dividing the viscosity of water at the test temperature by the viscosity of water at 20 C.

4. Estimated date(s) of collections: 1st August - 2nd September 1988

5. Estimated date(s) and method of shipment: 1st August - 2nd September 1988

   Federal Express Next Day Delivery

6. Number of days analysis and data required after laboratory receipt of samples:

   No known technical holding time requirement. Analyze and report within 30 days from VTSR.

7. Analytical protocol required (attach copy if other than a protocol currently used in this program:

   Standard Method for Practice Size Analysis of Soils -- Sieve and Hydrometer Analysis, ASTM/D422-63.

8. Special technical instruction (if outside protocol requirements, specify compound names, CAS numbers, detection limits, etc.): Use only the methods specified above. Sieve and hydrometer analyses shall be performed on the portion of each sample that is not used for permeability. Obtain approval of CPMS, CRL prior to use of any other method. Rewrite SAS request to reflect new methodology.

9. Analytical results required (if known, specify format for data sheets, QA/QC reports, Chain-of-Custody documentation, etc.). If not completed, format of results will be left to program discretion.

   Report all raw data, including container tare weights, hydrometer readings (along with any correction factor associated with the hydrometer used), and liquid temperatures. Report particle size results as percent finer than the specified particle diameter.

10. Other (use additional sheets or attach supplementary information, as needed):

    DO NOT SUBCONTRACT WITHOUT PRIOR REGIONAL APPROVAL

11. Name of sampling/shipping contact: Mona Sutherland

    Phone: (312) 621-3944

I. DATA REQUIREMENTS

Parameter	Detection Limit	Precision Desired (±% or Conc.)
PARTICLE SIZE -	2%	Duplicates within 10%
% Finer than		

II. QC REQUIREMENTS

Audits Required	Frequency of Audits	Limits* (±% or Conc.)
Lab Duplicate	2 for sets ≤10	±10%
	1 per 10 for sets >10	

III. ACTION REQUIRED IF LIMITS ARE EXCEEDED:

1.) Reanalyze

2.) Call Region V CRL if problems exist

Jay Thakkar or Chuck Elly

(312) 886-1972 (312) 353-9087

Please return this request to the Sample Management Office as soon as possible to expedite processing of your request for special analytical services. Should you have any questions or need any assistance, please call the Sample Management Office.

ATTACHMENT II (4of4)

TABLE 1 (ALL UNITS ARE MICROGRAMS/LITER)

PARAMETER	CAS #	QUANTITATION LIMIT
ALDRIN	309-00-2	0.005
alpha BHC	319-84-6	(0.010)
beta BHC	319-85-7	(0.005)
delta BHC	319-86-8	(0.005)
gama BHC(LINDANE)	58-89-9	0.005
CHLORDANE	57-74-9	(0.020)
4,4'-DDD	72-54-8	(0.020)
4,4'-DDE	72-55-9	(0.005)
4,4'-DDT	50-29-3	0.020
DIELDRIN	60-57-1	0.010
ENDOSULFAN I	959-98-8	0.010
ENDOSULFAN II	33213-65-9	0.010
ENDOSULFAN SULFATE	1031-07-8	(0.10)
ENDRIN	72-20-8	0.010
ENDRIN ALDEHYDE	7421-93-4	(0.030)
ENDRIN KETONE	53494-70-5	(0.030)
HEPTACHLOR	76-44-8	0.030
HEPTACHLOR EPOXIDE	1024-57-3	0.005
4,4'-METHOXYCHLOR	72-43-5	0.020
TOXAPHENE	8001-35-2	(0.25)
PCB-1242	53469-21-9	(0.10)
PCB-1248	12672-29-6	(0.10)
PCB-1254	11097-69-1	(0.10)
PCB-1260	11096-82-5	(0.10)

VALUES IN PARENTHESES ARE ESTIMATES. ACTUAL VALUES ARE CURRENTLY BEING DETERMINED.

NOTE: Limits are for reagent water.

APPENDIX 3.4

SAS REQUEST FOR ANALYSIS OF DRINKING WATER SAMPLES

FOR

FULL INORGANICS WITH LOW DETECTION LIMITS

U.S. Environmental Protection Agency
CLP Sample Management Office
P.O. Box 818, Alexandria, Virgina 22313
PHONE: (703)/557-2490 or FTS/557-2490

SAS Number

SPECIAL ANALYTICAL SERVICES
Client Request

[X] Regional Transmittal [ ] Telephone Request

A. EPA Region/Client: REGION V/CCJM

B. RSCC Representative: JAN PELS

C. Telephone Number: (312) 353-2720

D. Date of Request: 6th June 1988

E. Site Name: HUNTS DISPOSAL LANDFILL

Please provide below a description of your request for Special Analytical Services under the Contract Laboratory Program. In order to most efficiently obtain laboratory capability for your request, please address the following considerations, if applicable. Incomplete or erroneous information may result in delay in the processing of your request. Please continue response on additional sheets, or attach supplementary information as needed.

1. General description of analytical service requested: Analysis of residential well water for metals and cyanide using detection limits lower than SOW785 (See Attachment II). Six elements are to be determined by GFAA using the method of standard additions. GFAA analysis of samples free of particulates may be conducted on the undigested sample.

2. Definition and number of work units involved (specify whether whole samples or fractions; whether organics or inorganics; whether aqueous or soil and sediments; and whether low, medium, or high concentration):

   A total of 12 low concentration water samples - 10 investigative, 1 duplicate and 1 field blank.

3. Purpose of analysis (specify whether Superfund (Remedial or Enforcement), RCRA, NPDES, etc.):

   Superfund Remedial

4. Estimated date(s) of collections: 12th September - 16th September 1988

APPENDIX 4.1

HNu PORTABLE PHOTOIONIZATION ANALYZER
MODEL PI 101

HNu INSTRUCTION MANUAL

FOR

MODEL PI 101

PHOTOIONIZATION ANALYZER

00201/28

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SECTION 1

INTRODUCTION TO THE hNu PHOTO-IONIZER

1.1 PERSONNEL

The hNu Photo-ionizer Model PI 101 is extremely simple to operate. After a few hours of training, virtually everyone on the program can be taught to use the hNu efficiently. However, since the interpretation of its readings is often complex, personnel with specialized training and/or knowledge in its operation must be present to evaluate the data obtained from it.

1.2 THEORY OF OPERATION

The hNu is a portable, non-specific vapor/gas detector employing the principle of photoionization to detect a wide variety of chemical compounds, both organic and inorganic. The hNu contains a source of ultraviolet (UV) light within its sensor chamber. Ambient air is drawn into the chamber with the aid of a small fan. If the ionization potential (IP) of any molecule present in the ambient air is lower than the energy of the UV light source, that molecule will absorb a photon and become ionized. The following equation is the principal reaction:

$$RH + h\nu \rightarrow RH^{+} + e^{-}$$

where, RH = trace gas

$h\nu$ = A photon with an energy $\geq$ IP of RH

The chamber contains a pair of electrodes with a positive potential applied to one electrode. The field thus created drives any ions formed by the absorption of UV light to the collector electrode, where the current (proportional to concentration) is measured.

The IP of the normal constituents of ambient air, i.e., O_2, N_2, CO, CO_2 and H_2O, are all higher than any available UV lamp source. Therefore, the instrument does not respond to those components.

The range of the instrument is from approximately 0.1 to 2000 ppm, depending on the span setting and the chemical nature of molecular species present within the sensor chamber.

1.3 INSTRUMENT OPERATION

1.3.1 Specifications

- o Range: 0.1 to 2000 ppm (benzene) Linear Range: 0.1 to 600 ppm
- o Sensitivity: 0 to 2 ppm, maximum for 100 division scale
- o Response Time: 3 seconds to 90% full scale
- o Operating Temperature: Ambient to 40°C.
- o Operating Humidity: To 95% relative humidity

1.3.2 Description

The unit consists of a Readout/Control Assembly and a Sensor/Probe. The Probe connects the Readout/Control Assembly via an electrical cord and 12-pin jack (front panel mounted). The Sensor/Probe can be disassembled and stored in the instrument's cover (See Figure 1-1).

1.3.3 Controls (refer to Figure 1-2)

Following are the controls on the Readout/Control Assembly:

- o Six-Position Function Switch: Selects functions according to the following:
  - o OFF: Complete power shutdown.
  - o BATT: Verifies the condition of the battery.
  - o STANDBY: Energizes entire unit except UV lamp. Used to zero instrument and to conserve power.
  - o Ranges 0 to 20, 0 to 200, 0 to 2000: Direct reading span of the meter face, in ppm.
- o ZERO Potentiometer: Electronically zeroes the instrument.
- o SPAN Potentiometer: Increases or decreases the sensitivity of the instrument with respect to full scale deflection. Used to calibrate instrument with specific span gas.

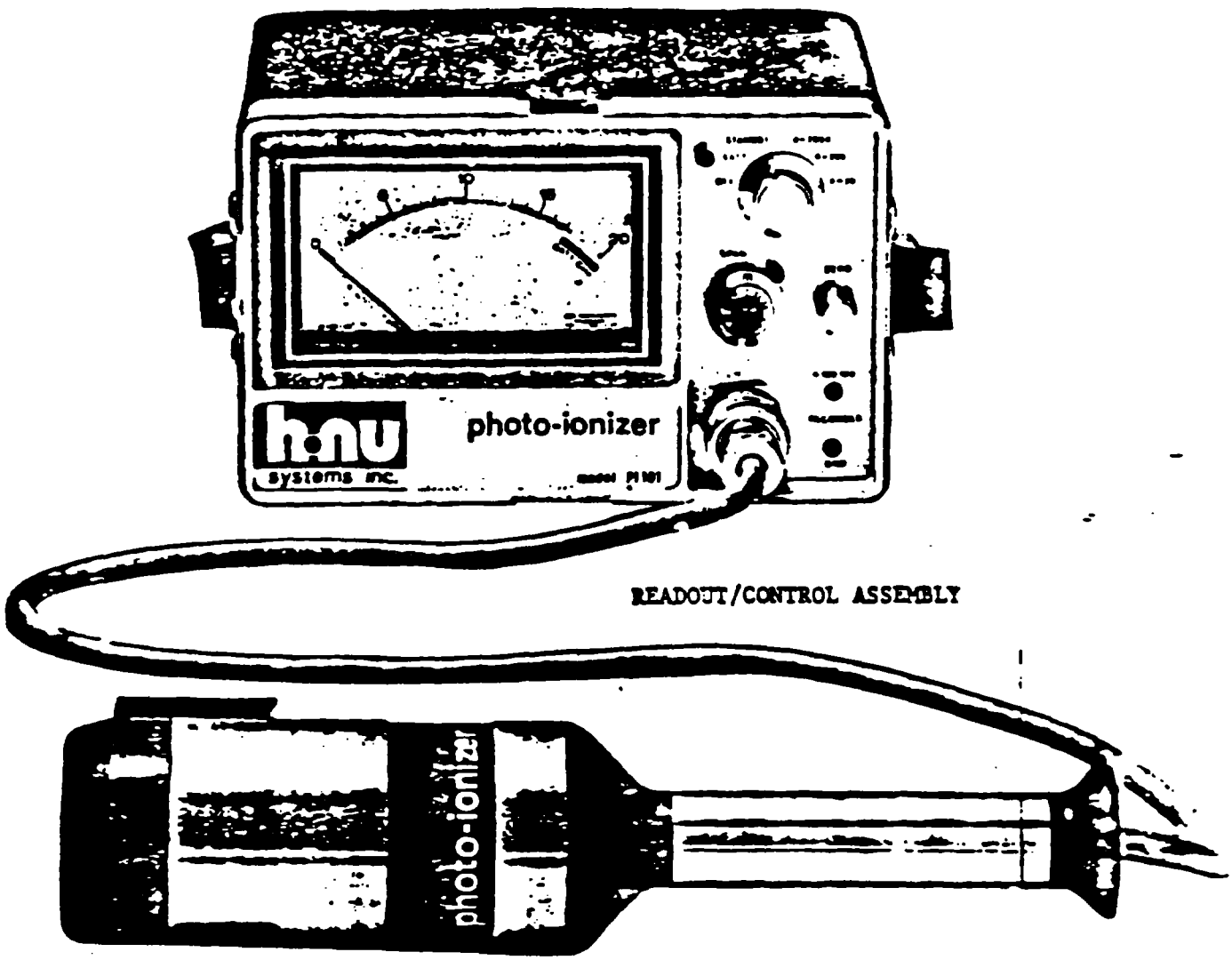


Figure 1-1 hNu PORTABLE PHOTO-IONIZER, MODEL PI 101

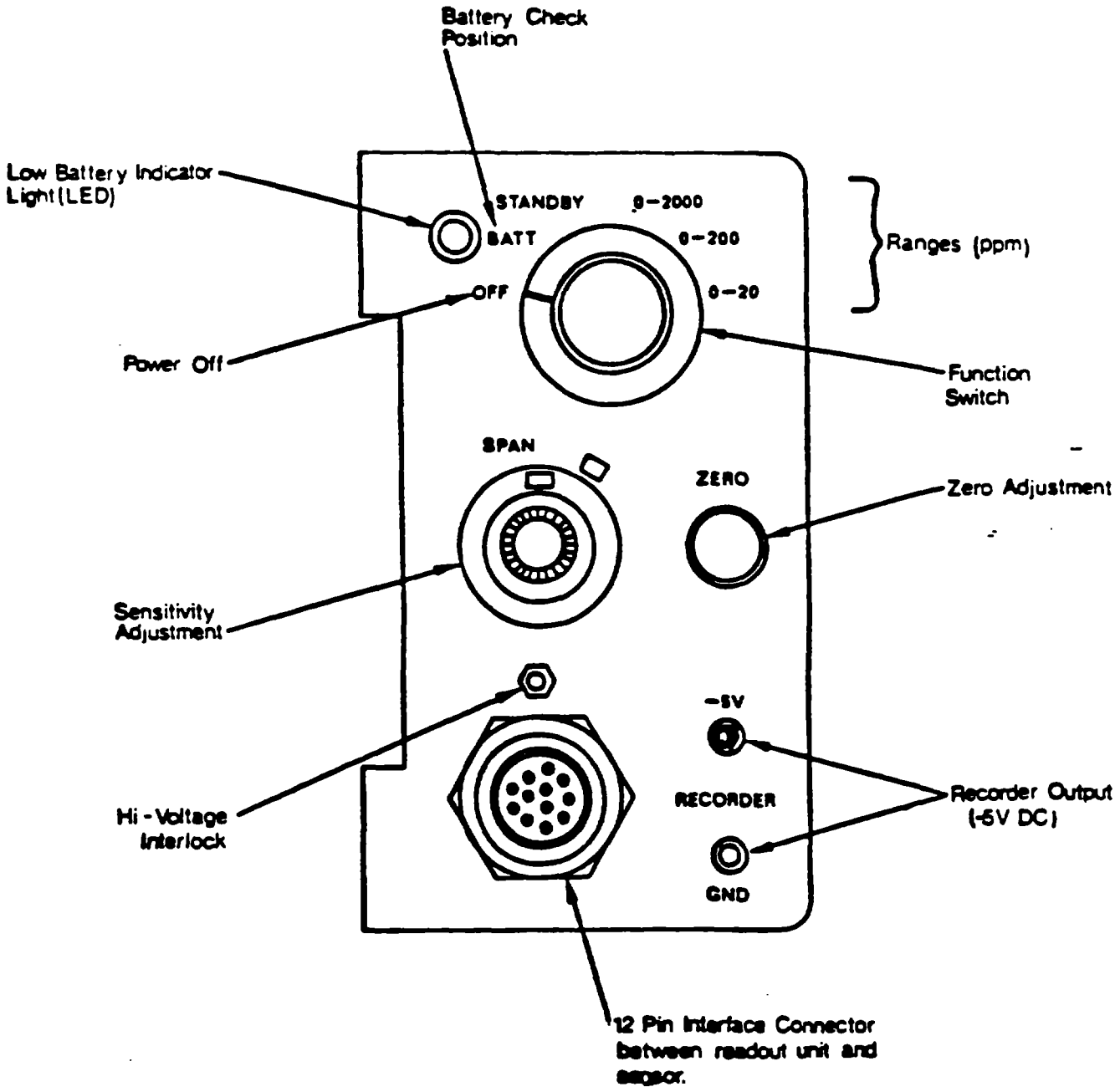


Figure 1-2 hNu CONTROL PANEL SCHEMATIC

- o RECORDER Output Jacks: 0 to -5 VDC signal output for recorder.

- o RECORDER Power Jack: Provides 12 VDC to drive recorder.

1.3.4 Battery Charging

To charge the battery, plug the charger into the jack on the side of the instrument case. The battery is fully charged after 14 hours of charging. Disconnect 120 VAC power before disconnecting the charger plug. A full charge provides about 10 continuous hours of operation. The instrument will always be left on charge when not in use.

The instrument is equipped with an automatic cut-off circuit which turns off the power if the battery voltage drops below 11 VDC. This prevents accidental damage to the electronics if it is inadvertently left on. Note that the unit can be operated with the charger on, unless it is in a hazardous (explosive) environment; however, it must be charged in a non-hazardous (non-explosive) area.

1.3.5 Operation

Start-up

The start-up procedure is as follows:

(1) Connect Sensor Probe to Readout/Control Assembly.

(2) Turn function switch to BATT and verify condition of the battery.

(3) Turn function switch to STANDBY and utilizing ZERO potentiometer, set meter to zero. Hold Sensor/Probe next to your ear to verify that the fan is working.

(4) Set SPAN control to 9.8 or to desired setting. (See Section 2.4 "Instrument Span.")

(5) Select appropriate range. For most survey operations on the FIT Project, the setting used is 0 to 20 ppm. A violet-colored glow from the UV lamp source should be observable at the sample

inlet of the Probe/Sensor unit. (Avoid looking directly in since eye damage can result.)

(6) Verify instrument operation. A convenient method is to gently blow into the Probe. There should be a 1 to 2 ppm deflection.

Shut-down

To shut the unit off:

(1) Turn function switch to OFF.

(2) Disconnect Sensor/Probe.

1.4 INSTRUMENT SPAN

The SPAN potentiometer increases or decreases the sensitivity of the instrument. (Counter-clockwise rotation increases the sensitivity.) At the recommended span setting of 9.8, it quantitatively responds to benzene, if benzene is the sole chemical species present. At this setting it will also respond, but not quantitatively, to all molecules with an IP of less than the energy of the UV lamp. The response to a molecule other than benzene (at the 9.8 setting) may be greater or less than that of benzene (on a volume/volume basis), depending on the molecule's type and structure. If a quantitative response to a specific chemical compound is desired, then the instrument span must be calibrated with that compound.

1.5 IONIZATION POTENTIALS

Since the hNu is used as both a safety and a survey device on the FIT Project, each unit is supplied with the 10.2 and the 11.7 ev UV sources. This allows the instrument to be used to detect a wide variety of chemical species. A list of the IP of many chemical compounds appears in Appendix C. Qualitative identification of compounds is not possible.

1.6 CALIBRATION

Primary calibration of the hNu is accomplished at the factory. For FIT applications, the calibration standard used is benzene and the SPAN potentiometer reading is 9.8. Primary calibration is normally stable for a long time. Routine calibration is most easily accomplished by using a

manufacturer-supplied cylinder of calibration gas (provided to each region). A sample of the calibration gas is drawn into the instrument and the SPAN potentiometer is adjusted until the instrument is reading the exact concentration of the calibration gas. Small deviations from the span setting over time are normal. Deviations of greater than ± 5% indicate that the lamp window may need cleaning or, if that does not eliminate the deviation, the unit needs servicing. It is FIT Project policy that routine calibration be performed prior to each field use. This will also serve as an operational check to ensure that the instrument is responding properly. Records of routine calibration should be placed on file.

1.7 DATA

Any quantitative data obtained with the hNu must be reported as the equivalent value of its span gas. That is, with the span set to 9.8, a reading of 20 ppm would be reported as "20 ppm, benzene equivalent, span = 9.8." If a span setting of other than 9.8 is used, the data must be referenced to that particular span and/or calibration gas.

1.8 MAINTENANCE

The following subsections describe the minimum routine maintenance necessary. The instrument contains only one moving part and consumes no gases or reagents.

1.8.1 Cleaning UV Light Source Window

The only routine maintenance procedure specified by the manufacturer is cleaning the light source window every few weeks. This procedure is accomplished as follows:

(1) Turn the function switch to the OFF position and disconnect the Sensor/Probe from the Readout/Control Unit.

(2) Remove the exhaust screw found near the base of the probe. Grasp the end cap in one hand and the Probe shell in the other and gently pull to separate the end cap and lamp housing from the shell.

(3) Loosen the screws on the top of the end cap and separate the end cap and ion chamber from the lamp and lamp housing. Care must be taken so that the ion chamber doesn't fall out of the end cap and the lamp doesn't slide out of the lamp housing. Turn the end cap over in your hand and tap on the top of it; the ion chamber should fall out in your hand.

(4) Place one hand over the top of the lamp housing and tilt slightly; the light source will slide out of the housing. The lamp window may now be cleaned with the manufacturer-supplied cleaning compound.

(5) Following the completion of cleaning, reassemble the unit by first sliding the lamp back into the lamp housing. Then place the ion chamber on top of the lamp housing, checking to make sure that the contacts are properly aligned.

(6) Place the end cap on top of the ion chamber and replace the two screws. The screws should be tightened only enough to seal the "O" ring. DO NOT OVERTIGHTEN. Line up the pins on the base of the lamp housing with pins inside the probe shell. Gently slide the housing assembly into the shell; it only fits one way.

(7) Replace the exhaust screw.

Figure 1-3 hows the component parts of the Probe Assembly.

1.8.2 "Fogging" of UV Light Source Window

During cold weather operations, condensation may form on the UV light source window, resulting in reduced levels of response. Field operators can follow the procedure outlined in Section 1.8.1 for removing the lamp to clear it of condensation. Consideration should also be given to more frequent cleaning when the instrument is used under very dusty conditions, such as on a landfill in dry weather.

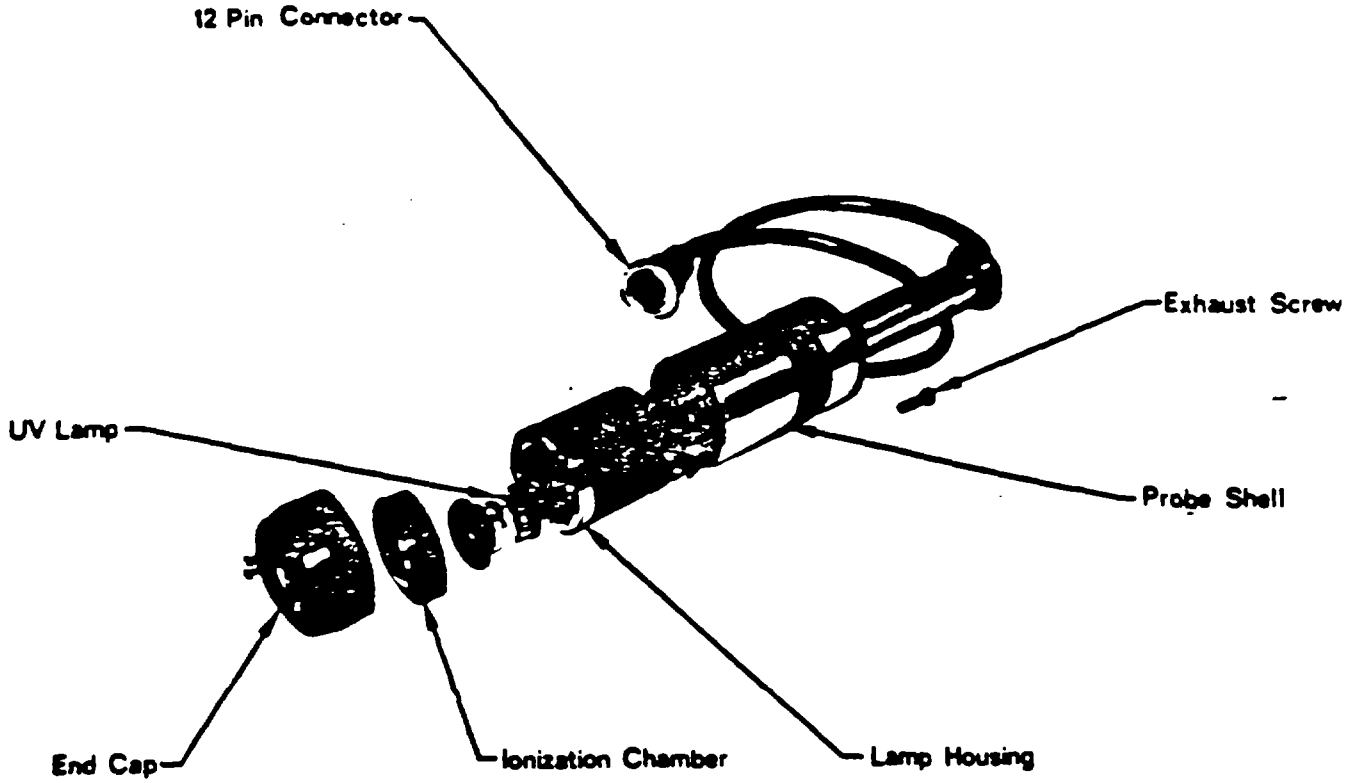


Figure 1-3 COMPONENT PARTS OF THE hNu PROBE ASSEMBLY

1.9 TROUBLESHOOTING

If any malfunctions are noted during the start-up and operational check of the hNu prior to field use, refer to Appendix D for some basic troubleshooting guidance. Any problems which cannot be resolved quickly by the field operator should be referred to the factory for correction. (See the resource list at the end of the manual for the address and telephone number.)

1.10 SAFETY AND SHIPPING

The hNu can be carried on any aircraft as luggage; however, do not check it unless it has been carefully packaged. Commercial airlines will not insure it unless it is shipped in its original container.

The hNu has Factory Mutual (FM) Certification for operation in Class 1, Division 2 of the National Electrical Code. Therefore, the hNu should not be used in environments which are above 10% of the lower explosive limit (LEL), since the circuitry in the probe assembly is relatively open and could be an ignition source. This action level for % of the LEL agrees with that for site evacuation during FIT operations.

SECTION 2

SPECIAL APPLICATIONS OF THE OVA AND hNu

2.1 INTRODUCTION

Section 5 described general applications for use of the OVA and hNu. Most of the regional FITs have or will have the opportunity for more specialized use of the OVA and/or hNu. The special applications may include monitoring for vapors or gases and/or actual field analysis.

2.2 MONITORING

The use of the OVA and hNu for monitoring purposes involves simply focusing the site ambient air characterization process on a specific activity. The objective is to ensure that the personnel involved in the activity are not endangered by the changes in air quality caused by the activity. The following subsections address some specific monitoring applications. FIT personnel who are trained OVA/hNu operators are encouraged to expand these monitoring applications on the basis of personal field experience.

2.2.1 Hydrogeologic Investigations

At sites where volatile organic wastes are buried, the installation of bore holes and monitoring wells can expose personnel to a respiratory hazard. Often, the preliminary air characterization of the site and other data, such as the presence or absence of wastes on the site surface, may indicate that there is no respiratory hazard. However, the drill bit may penetrate contaminant-saturated soils or highly contaminated groundwater. Depending upon the temperature and other conditions, dangerous concentrations of volatiles may be present in the area immediately above the bore hole. The personnel in the immediate vicinity of the bore hole are at greatest risk. The OVA in the survey mode or the hNu may be used to monitor the potential for exposure by periodically placing the sampling probe of the instrument directly at the top of the bore hole (drive casing). As is the case with ambient air monitoring, there can be no "action levels" since the readings will be total concentrations. Project personnel must use their best professional judgement,

incorporating other conditions, in order to decide whether the use of SCBA is warranted or whether engineering controls such as fans can be used to reduce the possibility of exposure.

The hNu is better suited for this type of monitoring for several reasons. First, it will not respond to naturally occurring methane. Second, it is less cumbersome and readily operated by a wider variety of personnel. Third, if an hNu and OVA are available, the hNu can be used to monitor the drilling operation while the OVA is being used in an on-location laboratory for field analysis. The probe of the OVA or hNu can also be used in the drilling area to "sniff" soil core samples as they are brought up in a split-spoon sampler. Care should be taken to identify occasional readings caused by exhaust gases from the drilling rig.

2.2.2 Remedial Response

A variety of remedial response activities can result in altering ambient air quality. Use of the OVA and hNu to monitor air quality can provide real-time data which can be used to evaluate respiratory protection needs. The following list is representative of the types of work which, if carried out at sites where volatile organics were the principal compounds, might require OVA or hNu monitoring:

- Overpacking or pump transfer of leaking drums
- Transfer of individual drum contents to bulk tanks for removal and disposal
- Staging/containment operations of leaking drums
- Excavation of buried leaking drums
- Excavation of contaminated soil for removal and disposal
- Emergency or planned containment operations, e.g., construction of leachate collection ditches
- Emergency treatment operations, e.g., air-stripping of contaminated groundwater

- o Emergency/on-site disposal operations, e.g., on-site incineration, detonation where risk/cost prohibits off-site removal

2.3 FIELD ANALYSIS

The OVA in the GC mode of operation and, to a limited degree, the hNu can be used in the field to perform preliminary analyses of various air, water, or soil samples. The data generated can be of significant value in making field decisions, responding rapidly to an immediate threat, reducing analytical costs, and selecting future sampling locations. The following is a list of several of these field analytical applications:

- o Preliminary volatile organic analyses of soil, surface water, or groundwater samples obtained during site inspections

- o Analysis of soil core samples for volatile organics during monitoring well installations

- o Analysis of drilling wash water samples during monitoring well installation to prevent accidental contamination of clean wells

- o Preliminary analysis of air samples to establish best locations for integrated sample stations

- o Rapid preliminary analysis of tap water samples for volatile organics

Once samples have been obtained, the field analytical procedure is essentially common for all types of sample media. Section 6 details the procedures for preliminary field analysis, or, sample screening.

Section 3

RESOURCE LIST

Below are the names, addresses and telephone numbers of individuals who may be able to answer questions or provide help for problems encountered during the use of the OVA and hNu:

hNu

George Marquardt, CH2M HILL
2300 NW Walnut Blvd.
Corvallis, Oregon 97339
(503) 752-4271

Mark Boedighimer, CH2M HILL
2300 NW Walnut Blvd.
Corvallis, Oregon 97339
(503) 752-4271

hNu Systems, Inc.
Service Department
(617) 964-6690, Ext. 42

Geoff Hewitt, General Sales Manager
hNu Systems, Inc.
160 Charlemont
Newton Highlands, MA 02161
(617) 964-6690

GLT81/9

SECTION 3

RESOURCE LIST

Below are the names, addresses and telephone numbers of individuals who may be able to answer questions or provide help for problems encountered during the use of the OVA and hNu:

3.1 OVA

Don Woods, E & E, Region V
223 West Jackson Boulevard
Chicago, IL 60606 (312) 663-9415

Dr. James Farr, E & E, Region X
108 South Washington Street
Seattle, WA 98104 (206) 624-9537

Dr. Thomas Spittler, EPA Region I
60 Westview Street
Lexington, MA (617) 861-6700

OVA Repair/Maintenance
Foxboro-Wilkes
140 Water Street
S. Norwalk, CT 06856 (203) 853-1616

Larry Robinson

3.2 hNu

Don Woods, E & E, Region V
223 West Jackson Boulevard
Chicago, IL 60606 (312) 663-9415

hNu Systems, Inc.
Service Department
(617) 964-6690, Ext. 42

Geoff Hewitt, General Sales Manager
hNu Systems, Inc.
160 Charlemont
Newton Highlands, MA 02161 (617) 964-6690

3.3 PROJECT COORDINATION

Jack Wilson, Deputy AZPM-FIT
1700 N. Moore Street
Rossyln Center, Suite 1930
Arlington, VA 22209 (703) 522-6065

h•nu systems inc.

APPENDIX A

INSTRUCTION MANUAL

FOR

MODEL PI 101

PHOTOIONIZATION ANALYZER

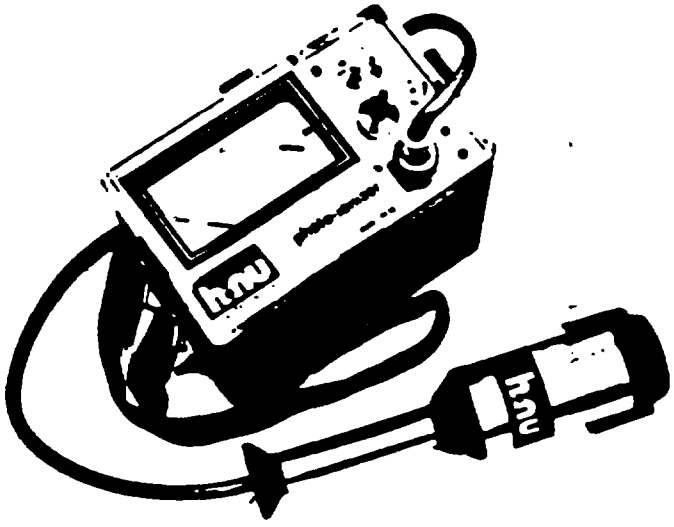


TABLE OF CONTENTS

NOTE

This manual contains operation, service, and maintenance information for HNU Model 101 Photoionization Analyzers equipped with the 10.2 eV lamp and calibrated for direct reading in ppm vol/vol of benzene.

Specific information relative to units equipped with an 11.7 eV or 9.5 eV lamp or calibrated on species other than benzene is contained in the addendum at the back of the manual.

ERRATA

Page

25 Figure 7 Electrical Block Diagram of Photoionization Analyzer

Readout Assembly: Point 19
Fan Voltage (DC)

44 Table XVIII Relative Sensitivities for Various Gases

Species	Photoionization Sensitivity
Ethylene	1.0

52 Power Supply PC Board

Pads	Voltage
18	+19.4V

SECTION 1

INTRODUCTION

The model PI 101 has been designed to measure the concentration of trace gases in many industrial or plant atmospheres. The analyzer employs the principle of photoionization for detection. This process is termed photoionization since the absorption of ultraviolet light (a photon) by a molecule leads to ionization via:

$$RH + h\nu \rightarrow RH^{+} + e^{-}$$

where RH = trace gas

$h\nu$ = a photon with an energy $\geq$ Ionization Potential of RH

The sensor consists of a sealed ultraviolet light source that emits photons which are energetic enough to ionize many trace species (particularly organics) but do not ionize the major components of air such as O_2, N_2, CO, CO_2, or H_2O. A chamber adjacent to the ultraviolet source contains a pair of electrodes. When a positive potential is applied to one electrode, the field created drives any ions, formed by absorption of UV light, to the collector electrode where the current (proportional to concentration) is measured.

To minimize adsorption of various sample gases, the ion chamber is made of an inert fluorocarbon material, is located at the sampling point, and a rapid flow of sample gas is maintained through the small ion chamber volume.

The analyzer will operate either from a rechargeable battery for more than 10 hours or continuously from the AC battery charger. A solid state amplifier board in the probe and a removable power supply board in the readout module enable rapid servicing of the unit in the field.

The useful range of the instrument is from a fraction of a ppm to about 2,000 ppm. For measurement at levels above 2,000 ppm, dilution of the sample stream with clean air is recommended. Some typical specifications for the model PI 101 Photoionization Analyzer are given in Table 1.

TABLE 1

SPECIFICATIONS FOR MODEL PI 101

PHOTOIONIZATION ANALYZER

performance (benzene referred)

range 0.1 to 2000 ppm
detection limit 0.1 ppm
sensitivity (max) 0-2 ppm FSD over 100 division meter scale
repeatability ± 1% of FSD
linear range 0.1 to 600 ppm
useful range 0.1 to 2000 ppm
response time < 3 sec to 90% of full scale
ambient humidity to 95% RH
operating temperature ambient to 40°C*

physical

size:	probe 6.3 DIA x 28.5L (cm)	(2-1/2 x 11-1/4")
	readout 21W x 13D x 16.5H (cm)	(8-1/4 x 5-3/16 x 6-1/2")
	stowed 21W x 13D x 24H (cm)	(8-1/4 x 5-3/16 x 9-1/2")
	cable 80 cm long (32")	

weight: probe .55 kg (20 ounces)
readout 3.2 kg (7 pounds)
total (shipping) 5.4 kg (12 pounds)

controls and functions

mode switch Off, Battery Check, Standby (zero), 0-2000, 0-200, 0-20 ppm
low battery indicator light
zero (10 turn ± 300% FSD max)
span (10 turn counting dial 1.0 to 10 times nominal sensitivity)
readout 4-1/2" (11.3 cm) meter Taut Band movement graduated 0-5-10-15-20, divisions
signal output for recorder 0-(-5V) FSD
power output for recorder 12 VDC - jack on side of instrument

power requirements of operating times

continuous use, battery > 10 hours
continuous use with HNU recorder reduces instrument battery operating time to 1/2 normal time
recharge time, max < 14 hours, 3 hours to 90% of full charge
recharge current, max .4 Amps @ 15 VDC

TABLE 1 (Continued)

construction

Designed to withstand the shock and abuse to which portable instruments are often subjected. The readout is housed in a two piece aluminum case, and finished with a solvent resistant baked acrylic textured paint.

The probe is fabricated from extruded aluminum sections and machined plastic.

serviceability

The probe and readout are of a modular design allowing rapid servicing and/or replacement of mechanical and electrical components. All module interwiring includes quick disconnects.

maintenance

The instrument contains only one moving part, and consumes no gases or reagents. The only routine maintenance procedure is cleaning the light source window every several weeks.

calibration check

Check instrument calibration at least once per week with HNU calibration standard to ensure that the high sensitivity of the instrument is maintained.

* Instrument is temperature compensated so that a 20°C change in temperature corresponds to a change in reading of < ± 2% full scale at maximum sensitivity.

SECTION 2

OPERATION

2.1 Unpacking

Unpack the instrument carefully and remove the housing, the probe and any spare parts from the shipping carton. Place the instrument on a table or bench with the label upright. Remove the top section of the instrument by opening the two fasteners on the cover (see figure 1). The inner panel of the top section can be removed by pulling up on the fasteners. The top section of the instrument contains the battery charger and a waist strap. The waist strap clips on to the strap brackets of the instrument when needed.

Before attaching the probe, check the function switch on the control panel to make sure it is in the off position. The 12 pin interface connector for the probe is located just below the span adjustment on the face of the instrument (see figure 2). Carefully match the Alignment Key in the probe connector to the 12 pin connector on the control panel, and then twist the probe connector until a distinct snap and lock is felt.

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

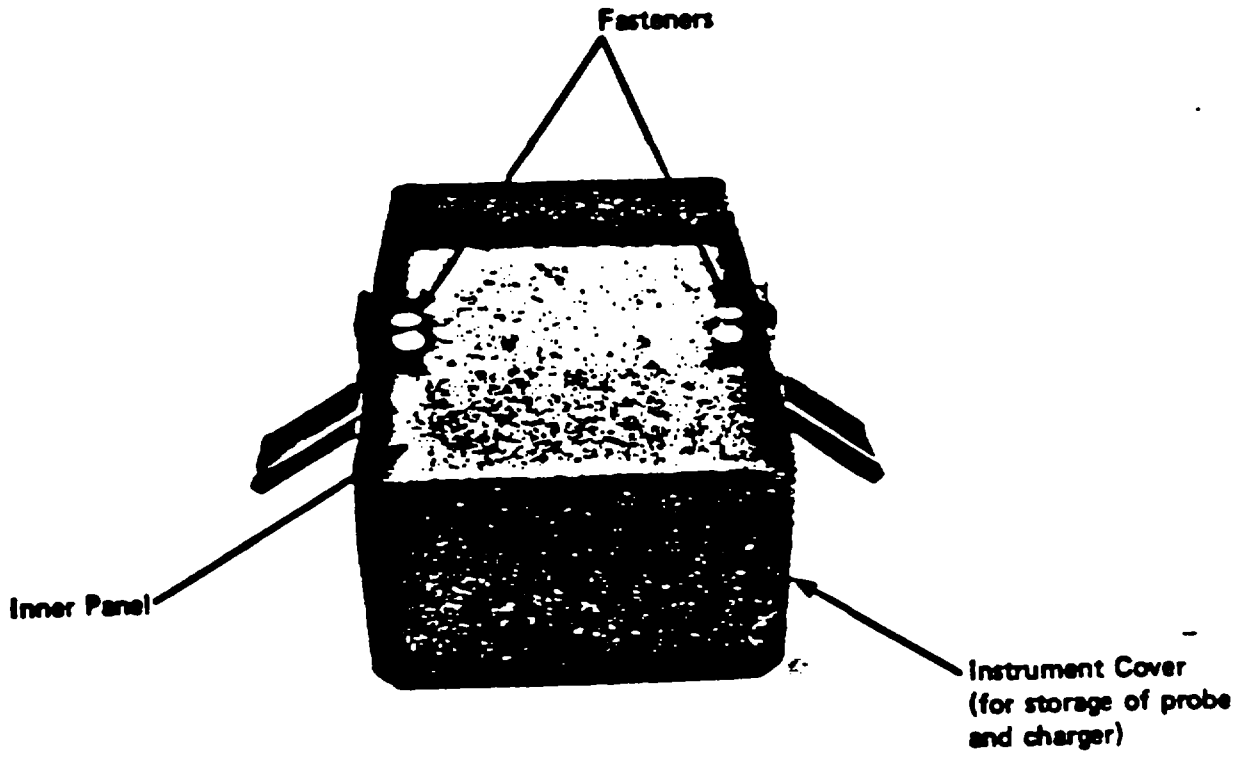
2.2 Operation

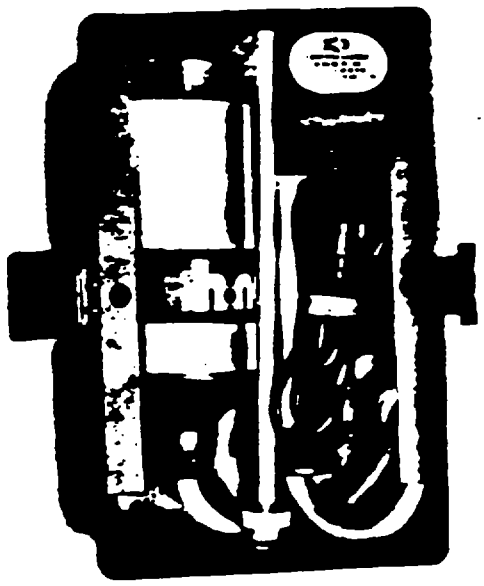
Turn the function switch to the battery check position. The needle on the meter should read within or above the green battery arc on the scaleplate. If the needle is in the lower portion of the battery arc, the instrument should be recharged prior to making any measurements. If red LED comes on, the battery should be recharged.

Next, turn the function switch to the on position. In this position the UV light source should be on. Look into the end of the probe to see the purple glow of the lamp.

A brief description of the instrument controls and functions is shown in Figure 2.

Figure 1 (Continued)





Top View

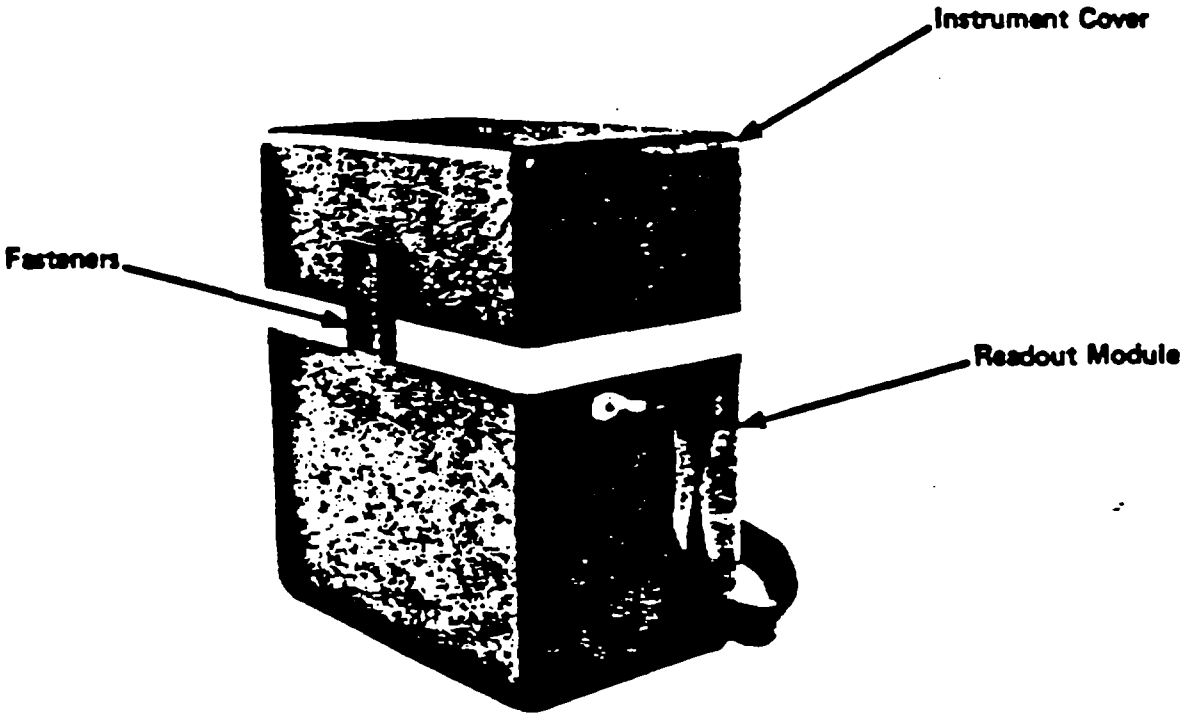


Figure 1. Unpacking the Photoionizer.

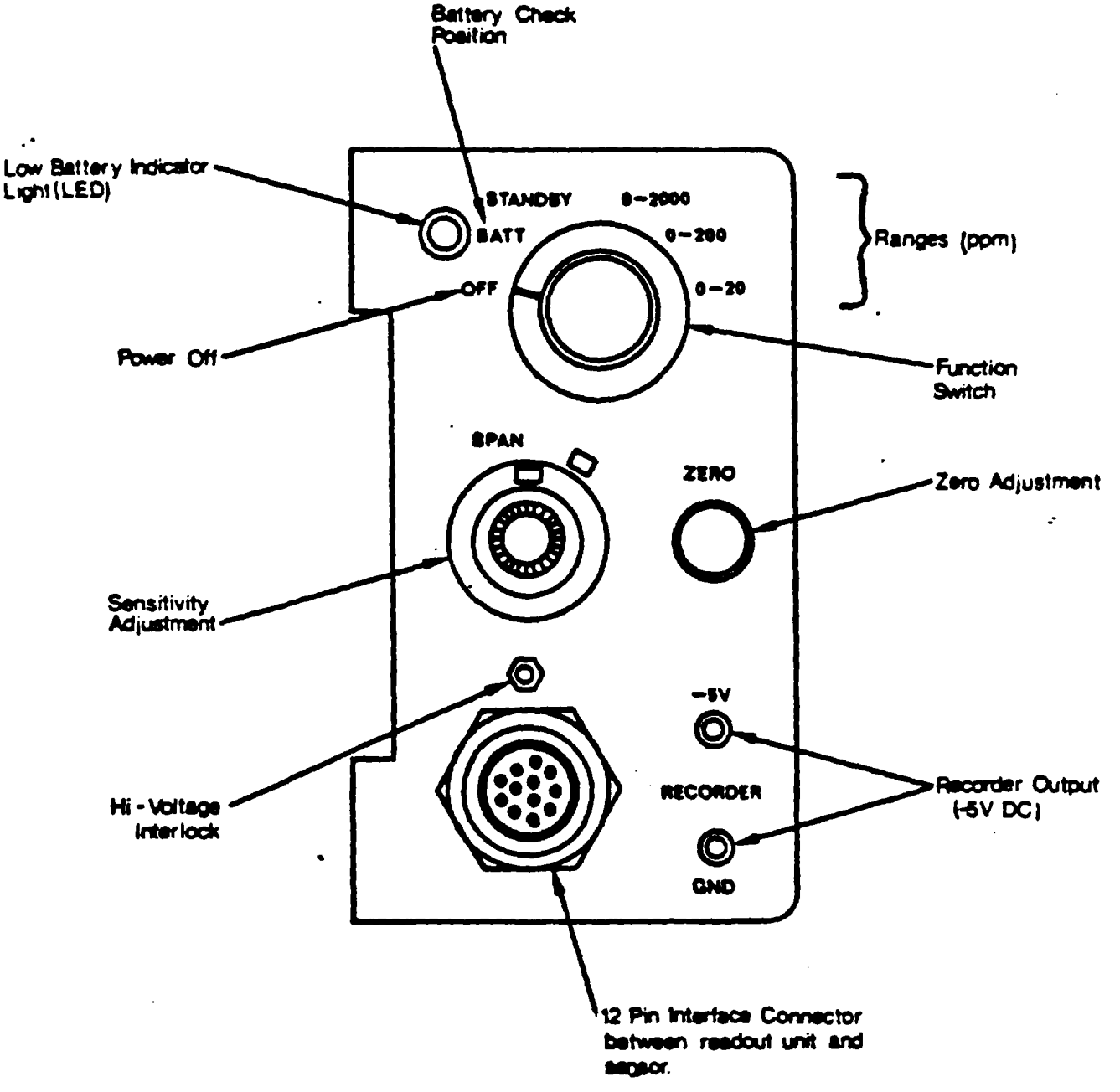
TABLE II

BRIEF DESCRIPTION OF INSTRUMENT CONTROLS AND FUNCTIONS*

Control	Function
Six Position Switch	OFF - Shuts off all power and removes DC voltages. ON - In any other function position or measuring mode, the electronics are on. BATTERY CHECK - Indicates the condition of the battery. If needle position is in lower portion of green battery arc, the instrument should be recharged. STANDBY - UV lamp is off but electronics are on. This position will conserve power and extend the useful operating time between recharges of the battery. This position is also utilized to adjust the electronic zero. RANGES - 0-20, 0-200, 0-2000 direct reading ranges available at minimum gain for benzene. More sensitivity is available by adjusting the span potentiometer.
Zero Potentiometer	A ten turn potentiometer is employed to adjust the zero electronically when the instrument is placed in the standby position with the probe attached. This eliminates the need for a hydrocarbon free gas.
Span Potentiometer	A ten turn counting potentiometer is utilized for upscale setting of the meter on calibration gas. Counter-clockwise rotation increases the sensitivity (~10 times). This pot can increase the sensitivity to make the instrument direct reading for nearly any gas which the instrument responds to.

*For position of layout controls see Figure 2.

Figure 2 Control Panel Functions



To zero the instrument, turn the function switch to the standby position and rotate the zero potentiometer until the meter reads zero. Clockwise rotation of the zero potentiometer produces an upscale deflection while counterclockwise rotation yields a downscale deflection. Note: no zero gas is needed, since this is an electronic zero adjustment (see below). If the span adjustment setting is changed after the zero is set, the zero should be rechecked and adjusted, if necessary. Wait 15 or 20 seconds to ensure that the zero reading is stable. If necessary, readjust the zero.

The instrument is now ready for calibration or measurement by switching the function switch to the proper measurement range. The instrument is supplied calibrated to read directly in ppm (v/v) 0-20, 0-200, 0-2000 of benzene with the span position set at 9.8. For additional sensitivity, the span potentiometer is turned counterclockwise (smaller numbers) to increase the gain. By changing the span setting from 10.0 to 1.0 the sensitivity is increased approximately ten fold. Then, the 0-20, 0-200, and 0-2000 ppm scales become 0-2, 0-20, and 0-200 ppm full scale, respectively. This span control is also utilized to make the instrument scale read directly in ppm of the compound being measured. E.g., it is adjusted to match the value of a calibration gas to that same reading on the instrument scale. The span control can be utilized to calibrate nearly any compound, measured by photoionization, to be direct reading on the 0-20 ppm range. For example, gain settings of 4.5 or 8.9, respectively, will provide direct reading capability (0-20, 0-200 ppm) for vinyl chloride and trichloroethylene, respectively. For a listing of approximate gain setting values see Table IV.

Designation: D 422 – 63 (Reapproved 1972)ε¹

Standard Method for
PARTICLE-SIZE ANALYSIS OF SOILS[1]

This standard is issued under the fixed designation D 422; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

[1] NOTE—Section 2 was added editorially and subsequent sections renumbered in July 1984.

1. Scope

1.1 This method covers the quantitative determination of the distribution of particle sizes in soils. The distribution of particle sizes larger than 75 μm (retained on the No. 200 sieve) is determined by sieving, while the distribution of particle sizes smaller than 75 μm is determined by a sedimentation process, using a hydrometer to secure the necessary data (Notes 1 and 2).

NOTE 1—Separation may be made on the No. 4 (4.75-mm), No. 40 (425-μm), or No. 200 (75-μm) sieve instead of the No. 10. For whatever sieve used, the size shall be indicated in the report.

NOTE 2—Two types of dispersion devices are provided: (1) a high-speed mechanical stirrer, and (2) air dispersion. Extensive investigations indicate that air-dispersion devices produce a more positive dispersion of plastic soils below the 20-μm size and appreciably less degradation on all sizes when used with sandy soils. Because of the definite advantages favoring air dispersion, its use is recommended. The results from the two types of devices differ in magnitude, depending upon soil type, leading to marked differences in particle size distribution, especially for sizes finer than 20 μm.

2. Applicable Documents

2.1 *ASTM Standards:*

D 421 Method for Dry Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants[2]

E 11 Specification for Wire-Cloth Sieves for Testing Purposes[3]

E 100 Specification for ASTM Hydrometers[4]

3. Apparatus

3.1 *Balances*—A balance sensitive to 0.01 g for weighing the material passing a No. 10 (2.00-mm) sieve, and a balance sensitive to 0.1 % of the mass of the sample to be weighed for weighing the material retained on a No. 10 sieve.

3.2 *Stirring Apparatus*—Either apparatus A or B may be used.

3.2.1 Apparatus A shall consist of a mechanically operated stirring device in which a suitably mounted electric motor turns a vertical shaft at a speed of not less than 10 000 rpm without load. The shaft shall be equipped with a replaceable stirring paddle made of metal, plastic, or hard rubber, as shown in Fig. 1. The shaft shall be of such length that the stirring paddle will operate not less than ¾ in. (19.0 mm) nor more than 1½ in. (38.1 mm) above the bottom of the dispersion cup. A special dispersion cup conforming to either of the designs shown in Fig. 2 shall be provided to hold the sample while it is being dispersed.

3.2.2 Apparatus B shall consist of an air-jet dispersion cup[5] (Note 3) conforming to the general details shown in Fig. 3 (Notes 4 and 5).

NOTE 3—The amount of air required by an air-jet dispersion cup is of the order of 2 ft³/min; some small air compressors are not capable of supplying sufficient air to operate a cup.

NOTE 4—Another air-type dispersion device, known as a dispersion tube, developed by Chu and Davidson at Iowa State College, has been shown to give

[1] This method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.03 on Texture, Plasticity, and Density Characteristics of Soils.

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[2] *Annual Book of ASTM Standards*, Vol 04.08.

[3] *Annual Book of ASTM Standards*, Vol 14.02.

[4] *Annual Book of ASTM Standards*, Vol 14.01.

[5] Detailed working drawings for this cup are available at a nominal cost from the American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103. Order Adjunct No. 12-404220-00.

results equivalent to those secured by the air-jet dispersion cups. When it is used, soaking of the sample can be done in the sedimentation cylinder, thus eliminating the need for transferring the slurry. When the air-dispersion tube is used, it shall be so indicated in the report.

NOTE 5—Water may condense in air lines when not in use. This water must be removed, either by using a water trap on the air line, or by blowing the water out of the line before using any of the air for dispersion purposes.

3.3 *Hydrometer*—An ASTM hydrometer, graduated to read in either specific gravity of the suspension or grams per litre of suspension, and conforming to the requirements for hydrometers 151H or 152H in Specifications E 100. Dimensions of both hydrometers are the same, the scale being the only item of difference.

3.4 *Sedimentation Cylinder*—A glass cylinder essentially 18 in. (457 mm) in height and 2½ in. (63.5 mm) in diameter, and marked for a volume of 1000 mL. The inside diameter shall be such that the 1000-mL mark is 36 ± 2 cm from the bottom on the inside.

3.5 *Thermometer*—A thermometer accurate to 1°F (0.5°C).

3.6 *Sieves*—A series of sieves, of square-mesh woven-wire cloth, conforming to the requirements of Specification E 11. A full set of sieves includes the following (Note 6):

3-in. (75-mm)	No. 10 (2.00-mm)
2-in. (50-mm)	No. 20 (850-μm)
1½-in. (37.5-mm)	No. 40 (425-μm)
1-in. (25.0-mm)	No. 60 (250-μm)
¾-in. (19.0-mm)	No. 140 (106-μm)
⅜-in. (9.5-mm)	No. 200 (75-μm)
No. 4 (4.75-mm)	

NOTE 6—A set of sieves giving uniform spacing of points for the graph, as required in Section 17, may be used if desired. This set consists of the following sieves:

3-in. (75-mm)	No. 16 (1.18-mm)
1½-in. (37.5-mm)	No. 30 (600-μm)
¾-in. (19.0-mm)	No. 50 (300-μm)
⅜-in. (9.5-mm)	No. 100 (150-μm)
No. 4 (4.75-mm)	No. 200 (75-μm)
No. 8 (2.36-mm)	

3.7 *Water Bath or Constant-Temperature Room*—A water bath or constant-temperature room for maintaining the soil suspension at a constant temperature during the hydrometer analysis. A satisfactory water tank is an insulated tank that maintains the temperature of the suspension at a convenient constant temperature at or near 68°F (20°C). Such a device is illustrated in Fig. 4. In cases where the work is performed in a room at an automatically controlled constant temperature, the water bath is not necessary.

3.8 *Beaker*—A beaker of 250-mL capacity.

3.9 *Timing Device*—A watch or clock with a second hand.

4. Dispersing Agent

4.1 A solution of sodium hexametaphosphate (sometimes called sodium metaphosphate) shall be used in distilled or demineralized water, at the rate of 40 g of sodium hexametaphosphate/litre of solution (Note 7).

NOTE 7—Solutions of this salt, if acidic, slowly revert or hydrolyze back to the orthophosphate form with a resultant decrease in dispersive action. Solutions should be prepared frequently (at least once a month) or adjusted to pH of 8 or 9 by means of sodium carbonate. Bottles containing solutions should have the date of preparation marked on them.

4.2 All water used shall be either distilled or demineralized water. The water for a hydrometer test shall be brought to the temperature that is expected to prevail during the hydrometer test. For example, if the sedimentation cylinder is to be placed in the water bath, the distilled or demineralized water to be used shall be brought to the temperature of the controlled water bath; or, if the sedimentation cylinder is used in a room with controlled temperature, the water for the test shall be at the temperature of the room. The basic temperature for the hydrometer test is 68°F (20°C). Small variations of temperature do not introduce differences that are of practical significance and do not prevent the use of corrections derived as prescribed.

5. Test Sample

5.1 Prepare the test sample for mechanical analysis as outlined in Method D 421. During the preparation procedure the sample is divided into two portions. One portion contains only particles retained on the No. 10 (2.00-mm) sieve while the other portion contains only particles passing the No. 10 sieve. The mass of air-dried soil selected for purpose of tests, as prescribed in Method D 421, shall be sufficient to yield quantities for mechanical analysis as follows:

5.1.1 The size of the portion retained on the No. 10 sieve shall depend on the maximum size of particle, according to the following schedule:

Nominal Diameter of Largest Particles, in. (mm)	Approximate Minimum Mass of Portion, g
⅜ (9.5)	500
¾ (19.0)	1000

Nominal Diameter of Largest Particles, in. (mm)	Approximate Minimum Mass of Portion, g
1 (25.4)	2000
1½ (38.1)	3000
2 (50.8)	4000
3 (76.2)	5000

5.1.2 The size of the portion passing the No. 10 sieve shall be approximately 115 g for sandy soils and approximately 65 g for silt and clay soils.

5.2 Provision is made in Section 5 of Method D 421 for weighing of the air-dry soil selected for purpose of tests, the separation of the soil on the No. 10 sieve by dry-sieving and washing, and the weighing of the washed and dried fraction retained on the No. 10 sieve. From these two masses the percentages retained and passing the No. 10 sieve can be calculated in accordance with 12.1.

NOTE 8—A check on the mass values and the thoroughness of pulverization of the clods may be secured by weighing the portion passing the No. 10 sieve and adding this value to the mass of the washed and oven-dried portion retained on the No. 10 sieve.

SIEVE ANALYSIS OF PORTION RETAINED ON NO. 10 (2.00-mm) SIEVE

6. Procedure

6.1 Separate the portion retained on the No. 10 (2.00-mm) sieve into a series of fractions using the 3-in. (75-mm), 2-in. (50-mm), 1½-in. (37.5-mm), 1-in. (25.0-mm), ¾-in. (19.0-mm), ⅜-in. (9.5-mm), No. 4 (4.75-mm), and No. 10 sieves, or as many as may be needed depending on the sample, or upon the specifications for the material under test.

6.2 Conduct the sieving operation by means of a lateral and vertical motion of the sieve, accompanied by a jarring action in order to keep the sample moving continuously over the surface of the sieve. In no case turn or manipulate fragments in the sample through the sieve by hand. Continue sieving until not more than 1 mass % of the residue on a sieve passes that sieve during 1 min of sieving. When mechanical sieving is used, test the thoroughness of sieving by using the hand method of sieving as described above.

6.3 Determine the mass of each fraction on a balance conforming to the requirements of 3.1. At the end of weighing, the sum of the masses retained on all the sieves used should equal closely the original mass of the quantity sieved.

HYDROMETER AND SIEVE ANALYSIS OF PORTION PASSING THE NO. 10 (2.00-mm) SIEVE

7. Determination of Composite Correction for Hydrometer Reading

7.1 Equations for percentages of soil remaining in suspension, as given in 14.3, are based on the use of distilled or demineralized water. A dispersing agent is used in the water, however, and the specific gravity of the resulting liquid is appreciably greater than that of distilled or demineralized water.

7.1.1 Both soil hydrometers are calibrated at 68°F (20°C), and variations in temperature from this standard temperature produce inaccuracies in the actual hydrometer readings. The amount of the inaccuracy increases as the variation from the standard temperature increases.

7.1.2 Hydrometers are graduated by the manufacturer to be read at the bottom of the meniscus formed by the liquid on the stem. Since it is not possible to secure readings of soil suspensions at the bottom of the meniscus, readings must be taken at the top and a correction applied.

7.1.3 The net amount of the corrections for the three items enumerated is designated as the composite correction, and may be determined experimentally.

7.2 For convenience, a graph or table of composite corrections for a series of 1° temperature differences for the range of expected test temperatures may be prepared and used as needed. Measurement of the composite corrections may be made at two temperatures spanning the range of expected test temperatures, and corrections for the intermediate temperatures calculated assuming a straight-line relationship between the two observed values.

7.3 Prepare 1000 mL of liquid composed of distilled or demineralized water and dispersing agent in the same proportion as will prevail in the sedimentation (hydrometer) test. Place the liquid in a sedimentation cylinder and the cylinder in the constant-temperature water bath, set for one of the two temperatures to be used. When the temperature of the liquid becomes constant, insert the hydrometer, and, after a short interval to permit the hydrometer to come to the temperature of the liquid, read the hydrometer at the top of the meniscus formed on the stem. For hydrometer 151H the composite correction is the difference between this reading and one; for hy-

drometer 152H it is the difference between the reading and zero. Bring the liquid and the hydrometer to the other temperature to be used, and secure the composite correction as before.

8. Hygroscopic Moisture

8.1 When the sample is weighed for the hydrometer test, weigh out an auxiliary portion of from 10 to 15 g in a small metal or glass container, dry the sample to a constant mass in an oven at 230 ± 9°F (110 ± 5°C), and weigh again. Record the masses.

9. Dispersion of Soil Sample

9.1 When the soil is mostly of the clay and silt sizes, weigh out a sample of air-dry soil of approximately 50 g. When the soil is mostly sand the sample should be approximately 100 g.

9.2 Place the sample in the 250-mL beaker and cover with 125 mL of sodium hexametaphosphate solution (40 g/l). Stir until the soil is thoroughly wetted. Allow to soak for at least 16 h.

9.3 At the end of the soaking period, disperse the sample further, using either stirring apparatus A or B. *If stirring apparatus A is used, transfer* the soil - water slurry from the beaker into the special dispersion cup shown in Fig. 2, washing any residue from the beaker into the cup with distilled or demineralized water (Note 9). Add distilled or demineralized water, if necessary, so that the cup is more than half full. Stir for a period of 1 min.

NOTE 9—A large size syringe is a convenient device for handling the water in the washing operation. Other devices include the wash-water bottle and a hose with nozzle connected to a pressurized distilled water tank.

9.4 If stirring apparatus B (Fig. 3) is used, remove the cover cap and connect the cup to a compressed air supply by means of a rubber hose. A air gage must be on the line between the cup and the control valve. Open the control valve so that the gage indicates 1 psi (7 kPa) pressure (Note 10). Transfer the soil - water slurry from the beaker to the air-jet dispersion cup by washing with distilled or demineralized water. Add distilled or demineralized water, *if necessary, so* that the total volume in the cup is 250 mL, but no more.

NOTE 10—The initial air pressure of 1 psi is required to prevent the soil - water mixture from entering the air-jet chamber when the mixture is transferred to the dispersion cup.

9.5 Place the cover cap on the cup and open the air control valve until the gage pressure is 20 psi (140 kPa). Disperse the soil according to the following schedule:

Plasticity Index	Dispersion Period, min
Under 5	5
6 to 20	10
Over 20	15

Soils containing large percentages of mica need be dispersed for only 1 min. After the dispersion period, reduce the gage pressure to 1 psi preparatory to transfer of soil - water slurry to the sedimentation cylinder.

10. Hydrometer Test

10.1 Immediately after dispersion, transfer the soil - water slurry to the glass sedimentation cylinder, and add distilled or demineralized water until the total volume is 1000 mL.

10.2 Using the palm of the hand over the open end of the cylinder (or a rubber stopper in the open end), turn the cylinder upside down and back for a period of 1 min to complete the agitation of the slurry (Note 11). At the end of 1 *min set the cylinder in a convenient location and* take hydrometer readings at the following intervals of time (measured from the beginning of sedimentation), or as many as may be needed, depending on the sample or the specification for the material under test: 2, 5, 15, 30, 60, 250, and 1440 min. If the controlled water bath is used, the sedimentation cylinder should be placed in the bath between the 2- and 5-min readings.

NOTE 11—The number of turns during this minute should be approximately 60, counting the turn upside down and back as two turns. Any soil remaining in the bottom of the cylinder during the first few turns should be loosened by vigorous shaking of the cylinder while it is in the inverted position.

10.3 When it is desired to take a hydrometer reading, carefully insert the hydrometer about 20 to 25 s before the reading is due to approximately the depth it will have when the reading is taken. As soon as the reading is taken, carefully remove the hydrometer and place it with a spinning *motion in a graduate of clean distilled or demin*eralized water.

NOTE 12—*It is important to remove the hydrometer* immediately after each reading. Readings shall be taken at the top of the meniscus formed by the suspension around the stem, since it is not possible to secure readings at the bottom of the meniscus.

10.4 After each reading, take the temperature of the suspension by inserting the thermometer into the suspension.

11. Sieve Analysis

11.1 After taking the final hydrometer reading, transfer the suspension to a No. 200 (75-μm) sieve and wash with tap water until the wash water is clear. Transfer the material on the No. 200 sieve to a suitable container, dry in an oven at 230 ± 9°F (110 ± 5°C) and make a sieve analysis of the portion retained, using as many sieves as desired, or required for the material, or upon the specification of the material under test.

CALCULATIONS AND REPORT

12. Sieve Analysis Values for the Portion Coarser than the No. 10 (2.00-mm) Sieve

12.1 Calculate the percentage passing the No. 10 sieve by dividing the mass passing the No. 10 sieve by the mass of soil originally split on the No. 10 sieve, and multiplying the result by 100. To obtain the mass passing the No. 10 sieve, subtract the mass retained on the No. 10 sieve from the original mass.

12.2 To secure the total mass of soil passing the No. 4 (4.75-mm) sieve, add to the mass of the material passing the No. 10 sieve the mass of the fraction passing the No. 4 sieve and retained on the No. 10 sieve. To secure the total mass of soil passing the ⅜-in. (9.5-mm) sieve, add to the total mass of soil passing the No. 4 sieve, the mass of the fraction passing the ⅜-in. sieve and retained on the No. 4 sieve. For the remaining sieves, continue the calculations in the same manner.

12.3 To determine the total percentage passing for each sieve, divide the total mass passing (see 12.2) by the total mass of sample and multiply the result by 100.

13. Hygroscopic Moisture Correction Factor

13.1 The hydroscopic moisture correction factor is the ratio between the mass of the oven-dried sample and the air-dry mass before drying. It is a number less than one, except when there is no hygroscopic moisture.

14. Percentages of Soil in Suspension

14.1 Calculate the oven-dry mass of soil used in the hydrometer analysis by multiplying the air-dry mass by the hygroscopic moisture correction factor.

14.2 Calculate the mass of a total sample represented by the mass of soil used in the hydrometer test, by dividing the oven-dry mass used by the percentage passing the No. 10 (2.00-mm) sieve, and multiplying the result by 100. This value is the weight W in the equation for percentage remaining in suspension.

14.3 The percentage of soil remaining in suspension at the level at which the hydrometer is measuring the density of the suspension may be calculated as follows (Note 13): For hydrometer 151H:

$$P = [(100\,000/W) \times G/(G - G_1)](R - G_1)$$

NOTE 13—The bracketed portion of the equation for hydrometer 151H is constant for a series of readings and may be calculated first and then multiplied by the portion in the parentheses.

For hydrometer 152H:

$$P = (Ra/W) \times 100$$

where:

a = correction faction to be applied to the reading of hydrometer 152H. (Values shown on the scale are computed using a specific gravity of 2.65. Correction factors are given in Table 1),

P = percentage of soil remaining in suspension at the level at which the hydrometer measures the density of the suspension,

R = hydrometer reading with composite correction applied (Section 7),

W' = oven-dry mass of soil in a total test sample represented by mass of soil dispersed (see 14.2), g,

G = specific gravity of the soil particles, and

G_1 = specific gravity of the liquid in which soil particles are suspended. Use numerical value of one in both instances in the equation. In the first instance any possible variation produces no significant effect, and in the second instance, the composite correction for R is based on a value of one for G_1.

15. Diameter of Soil Particles

15.1 The diameter of a particle corresponding to the percentage indicated by a given hydrometer reading shall be calculated according to Stokes' law (Note 14), on the basis that a particle of this diameter was at the surface of the suspension at the beginning of sedimentation and had settled to the level at which the hydrometer is measuring the density of the suspension. Accord-

ing to Stokes' law:

$$D = \sqrt{[30n/980(G - G_1)]} \times \sqrt{L/T}$$

where:

D = diameter of particle, mm,

n = coefficient of viscosity of the suspending medium (in this case water) in poises (varies with changes in temperature of the suspending medium),

L = distance from the surface of the suspension to the level at which the density of the suspension is being measured, cm. (For a given hydrometer and sedimentation cylinder, values vary according to the hydrometer readings. This distance is known as effective depth (Table 2)),

T = interval of time from beginning of sedimentation to the taking of the reading, min,

G = specific gravity of soil particles, and

G_1 = specific gravity (relative density) of suspending medium (value may be used as 1.000 for all practical purposes).

NOTE 14—Since Stokes' law considers the terminal velocity of a single sphere falling in an infinity of liquid, the sizes calculated represent the diameter of spheres that would fall at the same rate as the soil particles.

15.2 For convenience in calculations the above equation may be written as follows:

$$D = K\sqrt{L/T}$$

where:

K = constant depending on the temperature of the suspension and the specific gravity of the soil particles. Values of K for a range of temperatures and specific gravities are given in Table 3. The value of K does not change for a series of readings constituting a test, while values of L and T do vary.

15.3 Values of D may be computed with sufficient accuracy, using an ordinary 10-in. slide rule.

NOTE 15—The value of L is divided by T using the A- and B-scales, the square root being indicated on the D-scale. Without ascertaining the value of the square root it may be multiplied by K, using either the C- or CI-scale.

16. Sieve Analysis Values for Portion Finer than No. 10 (2.00-mm) Sieve

16.1 Calculation of percentages passing the various sieves used in sieving the portion of the sample from the hydrometer test involves several steps. The first step is to calculate the mass of the fraction that would have been retained on the No. 10 sieve had it not been removed. This mass is equal to the total percentage retained on the No. 10 sieve (100 minus total percentage passing) times the mass of the total sample represented by the mass of soil used (as calculated in 14.2), and the result divided by 100.

16.2 Calculate next the total mass passing the No. 200 sieve. Add together the fractional masses retained on all the sieves, including the No. 10 sieve, and subtract this sum from the mass of the total sample (as calculated in 14.2).

16.3 Calculate next the total masses passing each of the other sieves, in a manner similar to that given in 12.2.

16.4 Calculate last the total percentages passing by dividing the total mass passing (as calculated in 16.3) by the total mass of sample (as calculated in 14.2), and multiply the result by 100.

17. Graph

17.1 When the hydrometer analysis is performed, a graph of the test results shall be made, plotting the diameters of the particles on a logarithmic scale as the abscissa and the percentages smaller than the corresponding diameters to an arithmetic scale as the ordinate. When the hydrometer analysis is not made on a portion of the soil, the preparation of the graph is optional, since values may be secured directly from tabulated data.

18. Report

18.1 The report shall include the following:

18.1.1 Maximum size of particles,

18.1.2 Percentage passing (or retained on) each sieve, which may be tabulated or presented by plotting on a graph (Note 16),

18.1.3 Description of sand and gravel particles:

18.1.3.1 Shape—rounded or angular,

18.1.3.2 Hardness—hard and durable, soft, or weathered and friable,

18.1.4 Specific gravity, if unusually high or low,

18.1.5 Any difficulty in dispersing the fraction passing the No. 10 (2.00-mm) sieve, indicating any change in type and amount of dispersing agent, and

18.1.6 The dispersion device used and the length of the dispersion period.

NOTE 16—This tabulation of graph represents the gradation of the sample tested. If particles larger than those contained in the sample were removed before testing, the report shall so state giving the amount and maximum size.

18.2 For materials tested for compliance with definite specifications, the fractions called for in such specifications shall be reported. The fractions smaller than the No. 10 sieve shall be read from the graph.

18.3 For materials for which compliance with definite specifications is not indicated and when the soil is composed almost entirely of particles passing the No. 4 (4.75-mm) sieve, the results read from the graph may be reported as follows:

(1) Gravel, passing 3-in. and retained on No. 4 sieve ..... %
(2) Sand, passing No. 4 sieve and retained on No. 200 sieve ..... %
  (a) Coarse sand, passing No. 4 sieve and retained on No. 10 sieve ..... %
  (b) Medium sand, passing No. 10 sieve and retained on No. 40 sieve ..... %
  (c) Fine sand, passing No. 40 sieve and retained on No. 200 sieve ..... %
(3) Silt size, 0.074 to 0.005 mm ..... %
(4) Clay size, smaller than 0.005 mm ..... %
  Colloids, smaller than 0.001 mm ..... %

18.4 For materials for which compliance with definite specifications is not indicated and when the soil contains material retained on the No. 4 sieve sufficient to require a sieve analysis on that portion, the results may be reported as follows (Note 17):

SIEVE ANALYSIS

Sieve Size	Percentage Passing
3-in.	.....
2-in.	.....
1½-in.	.....
1-in.	.....
¾-in.	.....
⅜-in.	.....
No. 4 (4.75-mm)	.....
No. 10 (2.00-mm)	.....
No. 40 (425-μm)	.....
No. 200 (75-μm)	.....

HYDROMETER ANALYSIS

0.074 mm	.....
0.005 mm	.....
0.001 mm	.....

NOTE 17—No. 8 (2.36-mm) and No. 50 (300-μm) sieves may be substituted for No. 10 and No. 40 sieves.

TABLE 1 Values of Correction Factor, a, for Different Specific Gravities of Soil Particles[a]

Specific Gravity	Correction Factor[a]
2.95	0.94
2.90	0.95
2.85	0.96
2.80	0.97
2.75	0.98
2.70	0.99
2.65	1.00
2.60	1.01
2.55	1.02
2.50	1.03
2.45	1.05

[a] For use in equation for percentage of soil remaining in suspension when using Hydrometer 152H.

TABLE 2 Values of Effective Depth Based on Hydrometer and Sedimentation Cylinder of Specified Sizes[a]

Hydrometer 151H		Hydrometer 152H			
Actual Hydrometer Reading	Effective Depth, L, cm	Actual Hydrometer Reading	Effective Depth, L, cm	Actual Hydrometer Reading	Effective Depth, L, cm
1.000	16.3	0	16.3	31	11.2
1.001	16.0	1	16.1	32	11.1
1.002	15.8	2	16.0	33	10.9
1.003	15.5	3	15.8	34	10.7
1.004	15.2	4	15.6	35	10.6
1.005	15.0	5	15.5		
1.006	14.7	6	15.3	36	10.4
1.007	14.4	7	15.2	37	10.2
1.008	14.2	8	15.0	38	10.1
1.009	13.9	9	14.8	39	9.9
1.010	13.7	10	14.7	40	9.7
1.011	13.4	11	14.5	41	9.6
1.012	13.1	12	14.3	42	9.4
1.013	12.9	13	14.2	43	9.2
1.014	12.6	14	14.0	44	9.1
1.015	12.3	15	13.8	45	8.9
1.016	12.1	16	13.7	46	8.8
1.017	11.8	17	13.5	47	8.6
1.018	11.5	18	13.3	48	8.4
1.019	11.3	19	13.2	49	8.3
1.020	11.0	20	13.0	50	8.1
1.021	10.7	21	12.9	51	7.9
1.022	10.5	22	12.7	52	7.8
1.023	10.2	23	12.5	53	7.6
1.024	10.0	24	12.4	54	7.4
1.025	9.7	25	12.2	55	7.3
1.026	9.4	26	12.0	56	7.1
1.027	9.2	27	11.9	57	7.0
1.028	8.9	28	11.7	58	6.8
1.029	8.6	29	11.5	59	6.6
1.030	8.4	30	11.4	60	6.5

TABLE 2 Continued

Hydrometer 151H		Hydrometer 152 H			
Actual Hydrometer Reading	Effective Depth, L, cm	Actual Hydrometer Reading	Effective Depth, L, cm	Actual Hydrometer Reading	Effective Depth, L, cm
1.031	8.1				
1.032	7.8				
1.033	7.6				
1.034	7.3				
1.035	7.0				
1.036	6.8				
1.037	6.5				
1.038	6.2				

[a] Values of effective depth are calculated from the equation:

$$L = L_1 + \tfrac{1}{2}\,[L_2 - (V_b/A)]$$

where:

L = effective depth, cm,
L_1 = distance along the stem of the hydrometer from the top of the bulb to the mark for a hydrometer reading, cm,
L_2 = overall length of the hydrometer bulb, cm,
V_b = volume of hydrometer bulb, cm³, and
A = cross-sectional area of sedimentation cylinder, cm².

Values used in calculating the values in Table 2 are as follows:

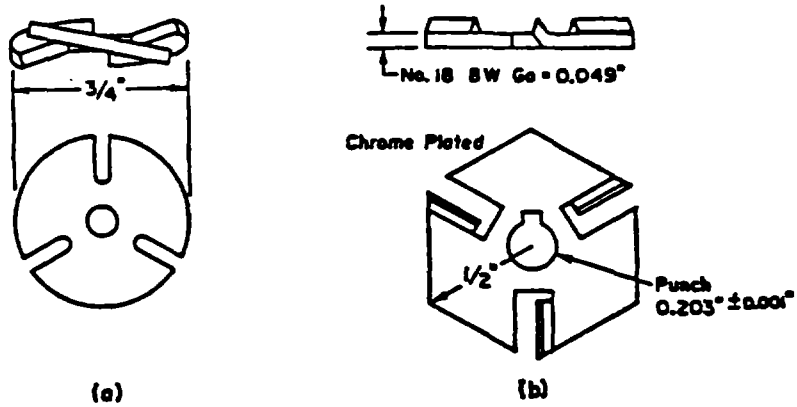
For both hydrometers, 151H and 152H:
L_2 = 14.0 cm
V_b = 67.0 cm³
A = 27.8 cm²

For hydrometer 151H:
L_1 = 10.5 cm for a reading of 1.000
= 2.3 cm for a reading of 1.031

For hydrometer 152H:
L_1 = 10.5 cm for a reading of 0 g/litre
= 2.3 cm for a reading of 50 g/litre

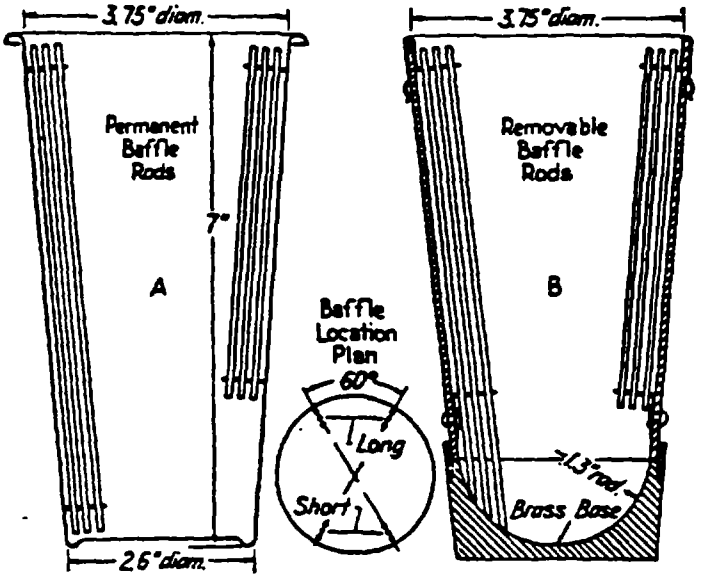
TABLE 3 Values of K for Use in Equation for Computing Diameter of Particle in Hydrometer Analysis

Temperature, °C	Specific Gravity of Soil Particles								
	2.45	2.50	2.55	2.60	2.65	2.70	2.75	2.80	2.85
16	0.01510	0.01505	0.01481	0.01457	0.01435	0.01414	0.01394	0.01374	0.01356
17	0.01511	0.01486	0.01462	0.01439	0.01417	0.01396	0.01376	0.01356	0.01338
18	0.01492	0.01467	0.01443	0.01421	0.01399	0.01378	0.01359	0.01339	0.01321
19	0.01474	0.01449	0.01425	0.01403	0.01382	0.01361	0.01342	0.1323	0.01305
20	0.01456	0.01431	0.01408	0.01386	0.01365	0.01344	0.01325	0.01307	0.01289
21	0.01438	0.01414	0.01391	0.01369	0.01348	0.01328	0.01309	0.01291	0.01273
22	0.01421	0.01397	0.01374	0.01353	0.01332	0.01312	0.01294	0.01276	0.01258
23	0.01404	0.01381	0.01358	0.01337	0.01317	0.01297	0.01279	0.01261	0.01243
24	0.01388	0.01365	0.01342	0.01321	0.01301	0.01282	0.01264	0.01246	0.01229
25	0.01372	0.01349	0.01327	0.01306	0.01286	0.01267	0.01249	0.01232	0.01215
26	0.01357	0.01334	0.01312	0.01291	0.01272	0.01253	0.01235	0.01218	0.01201
27	0.01342	0.01319	0.01297	0.01277	0.01258	0.01239	0.01221	0.01204	0.01188
28	0.01327	0.01304	0.01283	0.01264	0.01244	0.01255	0.01208	0.01191	0.01175
29	0.01312	0.01290	0.01269	0.01249	0.01230	0.01212	0.01195	0.01178	0.01162
30	0.01298	0.01276	0.01256	0.01236	0.01217	0.01199	0.01182	0.01165	0.01149



Metric Equivalents					
in.	0.001	0.049	0.203	½	¾
mm	0.03	1.24	5.16	12.7	19.0

FIG. 1 Detail of Stirring Paddles



Metric Equivalents			
in.	1.3	2.6	3.75
mm	33	66	95.2

FIG. 2 Dispersion Cups of Apparatus

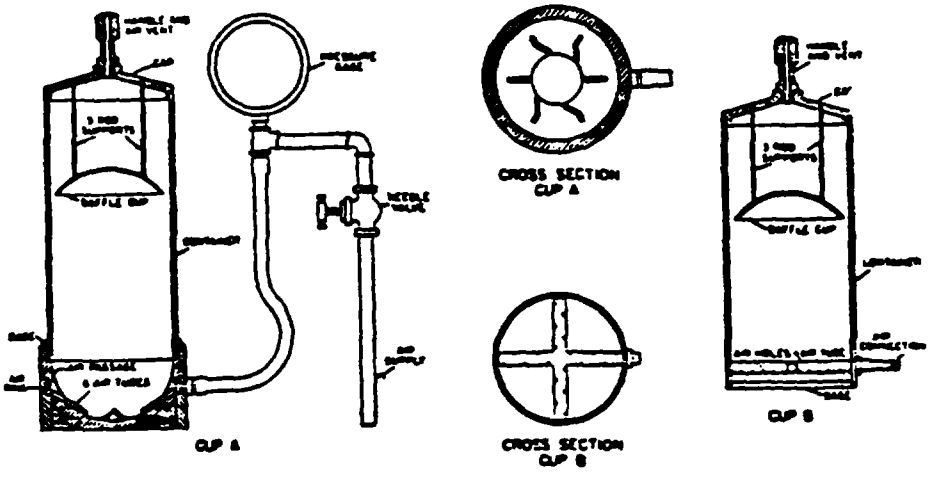
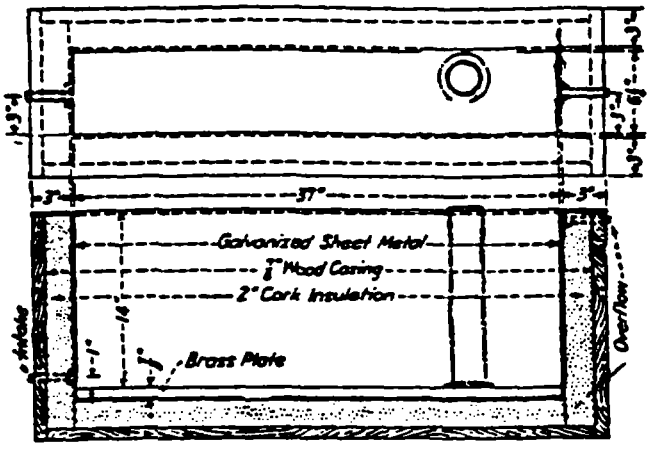


FIG. 3 Air-Jet Dispersion Cups of Apparatus B



Metric Equivalents

in.	½	1	3	6¼	14	37
mm	22.2	25.4	76.2	158.2	356	940

FIG. 4 Insulated Water Bath

SAMPLING AND ANALYSIS PLAN CONTINUED FROM LAST FOLDER

4. Estimated date(s) of collections: 1st August - 2nd September 1988

5. Estimated date(s) and method of shipment: 1st August - 2nd September 1988

   Federal Express Next Day Delivery

6. Number of days analysis and data required after laboratory receipt of samples:

   Laboratory should report results within 30 days of receipt of samples.

7. Analytical protocol required (attach copy if other than a protocol currently used in this program:

   Method for Total Porosity in Soils: "Field and Laboratory Methods Applicable to Overburdens and Mine Soils," Section 3.4.9 - EPA-600/2-78-054 (See attached Method). Measurements are to be made on *undisturbed Shelby tubes sealed in wax.*

8. Special technical instruction (if outside protocol requirements, specify compound names, CAS numbers, detection limits, etc.):

   a.) Use Section 3.4.9.1, 3.4.9.3 - 3.4.9.6 for porosity calculations.

   b.) Determine bulk density using Method 3.4.4.

   c.) Because samples will be shipped in sealed Shelby tubes, only use Section 3.4.4.5 procedural Items 10 thru 17.

   d.) Determine particle density using Method 3.4.8.

   e.) Use only methods specified above. Obtain approval of CPMS, CRL prior to use of any other method. Analysis shall be performed on the portion of each sample that is not used for permeability or sieve and hydrometer analysis.

9. Analytical results required (if known, specify format for data sheets, QA/QC reports, Chain-of-Custody documentation, etc.). If not completed, format of results will be left to program discretion.

   Report all raw data and parameter values used in making computations of total porosity.

10. Other (use additional sheets or attach supplementary information, as needed):

11. Name of sampling/shipping contact: Mona Sutherland

Phone: (312) 621-3944

I. DATA REQUIREMENTS

Parameter	Detection Limit	Precision Desired (±% or Conc.)
Total Porosity		

II. QC REQUIREMENTS

Audits Required	Frequency of Audits	Limits* (±% or Conc.)
Lab Duplicate	2 for sets ≤10	±10%
	1 per 10 for sets >10	

III. ACTION REQUIRED IF LIMITS ARE EXCEEDED:

1.) Reanalyze

2.) Call Region V CRL if problems exist

Jay Thakkar or Chuck Elly

(312) 886-1972 (312) 353-9087

Please return this request to the Sample Management Office as soon as possible to expedite processing of your request for special analytical services. Should you have any questions or need any assistance, please call the Sample Management Office.

EPA-600/2-78-054
March 1978

Environmental Protection Technology Series

FIELD AND LABORATORY METHODS APPLICABLE TO OVERBURDENS AND MINESOILS

3.4.3.6 Calculations—

1. Dispersing agent correction factor = Sum total of temperature corrected hydrometer readings of blanks/3.

2. Weight corrected 2 hour reading = (Temperature corrected 2 hour hydrometer reading) - (Dispersing agent correction factor).

3. Weight corrected 40 second reading = (Temp. corrected 40 second hydrometer reading) - (Dispersing agent correction factor).

4. % Clay = (Weight corrected 2 hour reading/oven-dry weight of total sample) X 100.

5. % Silt = [(Weight corrected 40 second reading - Weight corrected 2 hour reading)/oven-dry weight of total sample] X 100.

6. % Sand = 100 - (% clay + % silt).

3.4.4 Bulk Density (Core Method)

3.4.4.1 Principles—

The soil bulk density determination is based on two measurements, a mass measurement and a volume measurement. The mass is measured by oven drying the sample at 105°C until a constant weight is obtained. The bulk volume measurement includes the space between the soil particles as well as the space occupied by the soil particles. Bulk density, the ratio of sample mass to sample volume, is expressed as grams per cubic centimeter (Blake, 1965).

3.4.4.2 Comments—

This method may be difficult or impractical in soil containing many rock fragments.

A flat soil surface is prepared at the desired depth and the core sampler is driven into the soil. If driven with a heavy hammer, the head of the tool must be protected with a tough wooden plank or block. Care must be taken to see that no compaction takes place so that a known volume of soil is obtained. The sample is transferred to the laboratory and weighed while still moist. The sample is then dried in an oven and weighed again. This sample must be immediately placed in a desiccator after removing from the oven as the dry sample will absorb moisture from the atmosphere (Baver, 1956, p. 180-182).

3.4.4.3 Chemicals—

None required.

3.4.4.4 Materials—

1. Double-cylinder core sampler with steel cutting edge, driving head,

and removable brass or aluminum sleeves.

2. Core cylinder, 7.6 cm (3 in) in diameter and 7.6 cm (3 in) in height with 3.2 mm (0.125 in) thick walls.

3. Balance, can be read to 0.1 g.

4. Drying oven.

5. One-pint containers.

6. Air tight plastic bags.

7. Aluminum weighing pans.

8. Cloth diapers

9. Desiccator containing drierite.

3.4.4.5 Procedure--

1. Assemble double-cylinder core sampler according to the instruction manual.

2. Prepare a flat soil surface at depth in profile to be sampled.

3. Drive core sampler into the soil with the driving head until the soil fills the brass or aluminum sleeve and extends slightly above it.

4. Remove driving head and twist double-cylinder core sampler.

5. Excavate soil on one side of the core sampler until the bottom of the cutting edge can be clearly seen.

6. To insure that the contact of the core with the main soil body is broken, run a knife across the bottom of the cutting edge. NOTE: Do this step taking care not to disrupt the soil core.

7. Pack a cloth diaper into the top of the double-cylinder core sampler until it rests on the top of the soil core and hold in place with one hand.

8. Gently tilt the top of the sampler towards the excavated side until the cutting edge of the sampler is exposed. Put the other hand across the bottom of the cutting edge to hold soil core in place. Remove core sampler from excavation.

9. Remove the core and sleeve from sampler by raising the cutting edge and applying gentle pressure to bottom of soil core while using the cloth diaper to insure that the soil core does not slide or fall from the sleeve.

10. Trim any excess soil off both ends of the soil core so a flat surface exists flush with the edges of the sleeve.

11. Remove the soil from the sleeve ring and place in a pint container lined with a plastic bag. Take care that no soil is lost in transfer.

12. Label the sample as to location, depth sampled and any other pertinent information.

13. Transfer the samples to the laboratory.

14. Weigh a labeled aluminum pan and record the weight (A).

15. Transfer the moist soil sample to the pan and record the weight (B).

16. Place the pan with sample in an oven and allow to dry for 24 hours at 105°C.

17. Remove the pan with sample from the oven and cool in a desiccator. Weigh pan and contents. Record weight (C).

3.4.4.6 Calculations—

1. Bulk Density = (C - A)/347.5 cc, where 347.5 cc is the volume of the cylinder.

2. Percent Field Moisture = ((B - C)/(C - A)) X 100.

3.4.5 Bulk Density (Saran Method)

3.4.5.1 Principle—

See 3.4.4.1

3.4.5.2 Comments—

Care should be exercised when handling methyl ethyl ketone. This chemical is toxic and flammable. An exhaust hood should be used during the mixing of the plastic solution. Containers used for storing the solvent and the plastic solution must have lids which provide a tight seal.

One sampling pit can be used to collect samples from several different depths. Start at the surface and work downwards. Take a sample at the surface and then remove all material until the horizontal layer at the desired depth is exposed. Then take sample and repeat process until all samples needed are collected.

When trimming a clod to the desired size, be careful not to compact or otherwise destroy it. Careful handling of the clod is necessary until final coatings of plastic have been applied.

3.4.5.3 Chemicals—

1. Water.

2. Methyl ethyl ketone ($CH_3COC_2H_5$).

3. Dow Saran F310 solution in methyl ethyl ketone. NOTE: This solution consists of 1 part Saran and 7 parts of methyl ethyl ketone. It is prepared as follows: Under an exhaust hood, add 2310 ml of methyl ethyl ketone to a 3.785 liter (1 gallon) paint can. Add 330 g of Dow Saran Resin F310 to the solvent. The plastic is mixed with an air-powered or nonsparking electric stirrer until the resin dissolves. If a high-speed stirrer is used, the resin should dissolve in about one hour. Seal the container tightly with lid to prevent evaporation of solvent. Care should be exercised when using methyl ethyl ketone since the solvent is flammable and its vapors mix with air to form explosive mixtures. Always work with this solvent under an exhaust hood.

3.4.5.4 Materials—

1. Tile spade and shovel.

2. Sharp knife.

3. Scissors.

4. Thread or fine wire.

5. Plastic bags (large enough to contain sample) with ties.

6. Boxes, heavy, cardboard (large enough to contain samples).

7. Cloth diapers or other suitable packing material.

8. Exhaust hood.

9. Beaker, 600 ml.

10. Balance, can be read to 0.1 g.

11. Weighing pan, aluminum or other metal.

12. Support stand with ring clamp.

13. Drying oven.

14. Wooden rolling pin.

15. Paper (to crush clods on).

16. Sieve with 2 mm openings (10 mesh).

3.4.5.5 Procedure—

1. Dig a pit from the surface of the soil downward until a vertical cross-section of the soil is exposed.

2. Starting at the surface, work downward and remove a section of soil larger than the clod to be studied from the face of the pit with a tile spade.

3. Take a soil clod, about 5 cm in diameter, weighing form 30 to 150 g from a larger piece of soil using a sharp knife to carefully cut away excess material.

4. Carefully break or cut off all protruding points, cut off all roots with scissors, and brush all loose materials from clod.

5. Loop thread or fine wire around clod and tie securely. Be sure to leave a loose end of at least 50 cm (20 in) of thread or fine wire.

6. Open can containing the plastic solution. Holding the clod by the loose thread or fine wire, immerse it in the plastic solution for 5-10 seconds.

7. Remove clod from plastic solution and suspend from a previously prepared line (like a clothes line) for 30 minutes to allow coating to dry. NOTE: Seal container containing plastic solution tightly to prevent evaporation of solvent.

8. When dry, place coated sample in airtight plastic bag. Label the sample. Record location, depth sampled, and other pertinent information in data book.

9. Put the bag in a rigid cardboard container to prevent breaking or crushing of clod. NOTE: To insure that sample bag will be immobilized, use cloth diapers for packing material around the plastic bag.

10. Transport sample to the laboratory.

11. Under an exhaust hood, open can containing plastic solution. Remove sample from plastic bag holding it by the loose thread or fine wire and immerse it in the plastic solution for 30 seconds.

12. Remove clod from plastic solution, reseal container of plastic solution, and hang clod on a line under the exhaust hood for 30 minutes.

13. Repeat steps 11 and 12 four more times.

14. Fill a 600 ml beaker with approximately 350 ml of water.

15. Place beaker, with water, on a balance and weigh it to the nearest 0.1 g. Record weight (A).

16. Attach a ring clamp to the top of a support stand and position stand so that the ring clamp extends over the beaker of water on the balance.

17. After the final coating has dried, take loose end of thread or fine wire and lower clod into beaker of water until clod is resting on the

bottom of the beaker. Record weight (B). NOTE: Do not allow loose end of thread to fall into the beaker.

18. Loop loose end of thread or fine wire over ring clamp and slowly raise clod off the bottom of beaker.

19. When clod is completely surrounded by water, record weight (C). NOTE: It is extremely important that the clod is not touching any part of the beaker and is entirely surrounded by water.

20. Remove clod from beaker and place on tray in an oven at 105°C for 48 hours.

21. Remove clod from oven, cool in a desiccator and weigh to the nearest 0.1 g. Record weight (D).

22. Take a knife and carefully cut plastic coating and thread or fine wire from clod.

23. Put all clod material on a sheet of paper and crush with a wooden rolling pin. NOTE: Be careful not to crush soft coarse fragments, but be sure to remove all fines from coarse fragments.

24. Pass crushed material through a 2 mm sieve.

25. Transfer all material caught on 2 mm sieve to a weighing pan and dry in an oven at 105°C for 4 hours.

26. Cool weighing pan and sample in a desiccator. Weigh to nearest 0.1 g and record weight (E).

27. Discard material and weigh weighing pan. Record weight (F).

3.4.5.6 Calculations—

1. Legend:

A = Weight of beaker and water.

B = Weight of beaker, water, and moist clod.

C = Weight of beaker, water, and moist clod suspended in water.

D = Weight of oven-dry clod.

E = Weight of weighing pan and clod material greater than 2 mm in effective diameter.

F = Weight of weighing pan empty.

V = Volume of moist clod.

X = Volume of coarse fragments in clod.

2. Bulk density of clod = D/V,

Where V = (C-A)/(1.00 g/ml), the density of water is assumed to be 1.00 g/ml.

3. Bulk density of the less than 2 mm material of the clod = [D - (E - F)]/(V - X), where: X = (E - F)/(2.65 g/ml) NOTE: This calculation assumes that all material greater than 2 mm in effective diameter has no porosity and has a particle density fo 2.65 g/ml.

4. Percent moisture of field sample on an oven-dry weight basis = [((B - A) - D)/D] X 100.

3.4.6 Bulk Density (Varsol Method)

3.4.6.1 Principle--

(See 3.4.4.1)

3.4.6.2 Comments--

The nonpolar liquid, Varsol, is used because of its availability, cheapness and absence of an offensive odor. Because of its nonpolar nature, it can replace air trapped in pores without causing the clod to slake like a polar liquid (water).

Clods used must hold together without breaking during routine field and laboratory work. When samples are packed for transportation to the laboratory, cushioning agents (i.e. diapers, styrofoam chips, crumpled paper) should be used to reduce the chances of clod breakage. Corrections can be made for soils containing coarse fragments using steps 28 through 31 in the procedure.

The density of each new container of Varsol should be determined by using a clean and dry 50 ml volumetric pipet and pipetting the Varsol into a clean and dry preweighed beaker. The weight of the Varsol is recorded to 0.01 g. The pipetting and weighing is repeated a total of three times. An average weight of the three readings is divided by 50 (ml of Varsol used to determine the density).

3.4.6.3 Chemicals--

Varsol - Trade name of EXXON cleaning fluid (but can usually be purchased from other suppliers). We have found Varsol to have a rather consistent density of 0.77 g/cc.

3.4.6.4 Materials--

1. Digging implements (spade and shovel).

2. Knife.

3. Plastic bags (large enough to contain sample) with ties.

4. Containers, rigid cardboard (large enough to contain samples).

5. Drying oven.

6. Thread (or similar light weight, thin cord).

7. Balance, can be read to 0.1 g.

8. Weighing pan (preferably aluminum, but glass or other metal can be substituted).

9. Blotting paper.

10. Desiccator apparatus, vacuum type, with hole in center of lid for a rubber stopper (Corning 3100 or equivalent). Supported above the bottom of the desiccator is a perforated porcelain desiccator plate having a large center hole. A two-hole rubber stopper is placed in the desiccator lid. In one hole is placed a 8 mm o.d., T-shaped tubing connector. From one end of the T-connector, a short piece of tubing with a hosecock clamp is applied to allow air back into the desiccator after evacuation. From the other end of the T-connector, attach a length of vacuum hose with a hosecock clamp to the vacuum source equiped with vacuum gauge. A short piece of 8 mm o.d. glass tubing (bent at 90°) is inserted into the second hole of the rubber stopper with the 90° bend being outside the desiccator. A length of tygon tubing is attached to the inside end of the glass tubingo so that when the desiccator is closed, the tubing extends below and through the center hole of the porcelain plate. Another piece of tygon tubing with hosecock is applied to the other end of the glass tubing and cut to extend to near the bottom of the Varsol container.

11. Support stand with ring clamp (aluminum rod can be substituted for the ring clamp).

12. Beaker, 600 ml.

13. Wooden rolling pin (optional).

14. Brown paper (optional).

3.4.6.5 Procedure--

1. Dig a pit from the surface of the soil downward until a vertical cross section of the soil is exposed through the depths to be sampled.

2. Remove a large layer of soil with a spade from the face of the sampling pit. Take a soil clod about 5 cm in diameter and weighing from 30 to 150 g from the layer of soil. NOTE: Use a knife to cut the clod from the soil. More than one clod can be taken for testing.

20. After soaking, open clamp on air inlet to allow the inside of the desiccator to return to atmospheric pressure.

21. Remove lid of desiccator carefully. Remove clod on its base of blotting paper from the fluid.

22. Separate blotting paper and clod. Carefully place clod into beaker of fluid on the balance pan and allow clod to rest on beaker bottom. Do not let the loose end of thread fall into the beaker. Record weight (D). NOTE: Separation of blotting paper and clod after removal of both from Varsol will eliminate a few drops of surplus fluid from the sample, but the drainage tension will be slight.

23. Take loose end of thread attached to clod and loop thread over the ring clamp (or straight rod) and slowly raise the clod off the bottom of beaker.

24. When clod is completely surrounded by fluid, record weight (E). NOTE: It is essential that clod is not touching the sides or bottom of the beaker and is entirely surrounded by the fluid.

25. Remove clod from beaker and place in weighing pan (pre-weighed in step 6). Allow samples to air dry overnight under a hood.

26. Dry clods in an oven at 105°C for 24 hours.

27. Remove samples from oven. Cool in desiccator and weigh to nearest 0.1 g. Record weight (F). NOTE: Steps 28 thru 31 are necessary if bulk density and porosity of the textural particles without coarse fragments are required.

28. Put clod on sheet of brown paper and crush with a wooden rolling pin. NOTE: Be careful not to crush small, soft coarse fragments, but be sure to remove all fines from coarse fragments.

29. Pass sample through a 2 mm sieve.

30. All material caught on 2 mm sieve is transferred to a weighing pan (pre-weighed in step 6) and dried in an oven at 105°C for 4 hours.

31. Cool weighing pan and sample in deiccator. Then weigh sample plus weighing pan and record weight (G).

3.4.6.6 Calculations—

1. Legend:

A = Oven-dry weight of weighing pan.

B = Weight of moist clod and weighing pan.

C = Weight of beaker and Varsol.

3. Put the sample in an airtight plastic bag. Label the sample. Record location, depth sampled, and other pertinent information in data book.

4. Put the bag in a rigid cardboard container to prevent breaking or crushing the clod. NOTE: To insure that sample bag will be immobilized, use cloth diapers for packing material around the plastic bag.

5. Transport the sample to the laboratory.

6. Weigh an oven-dry weighing pan and record the weight (A).

7. Carefully break off all protruding points and brush all loose material from the clod.

8. Loop thread around clod and tie leaving about 50 cm (20 in) of thread loose.

9. Place moist clod in weighing pan and weigh it to the nearest 0.1 g. Record weight (B).

10. Place moist clod on a small square of heavy blotting paper in the vacuum desiccator.

11. Apply grease to the ground glass surfaces of the lid and the bowl of the desiccator.

12. Place the lid on the bowl and make a tight seal. NOTE: Make sure the tubing extends below and through the center hole of the porcelain base plate in the bottom of the desiccator.

13. Clamp off the hoses that lead to the supply of Varsol and air inlet.

14. Evacuate to a pressure of less than 0.1 bar.

15. Clamp off hose leading to vacuum source.

16. Open clamp to hose leading to Varsol and admit fluid slowly until it completely covers sample.

17. After sample is completely covered with Varsol, allow sample to soak for one hour.

18. Fill a 600 ml beaker with enough Varsol to cover sample completely (approximately 350 ml) and weigh on balance to nearest 0.1 g. Record weight (C).

19. Take a support stand and attach a ring clamp at the top of stand. Position stand in such a manner that the ring clamp extends over the beaker of Varsol on the balance.

D = Weight of beaker, Varsol, and clod.

E = Weight of beaker, Varsol, and clod suspended in Varsol.

F = Oven-dry weight of clod and weighing pan.

G = Oven-dry weight of coarse fragments contained in clod and weighing pan.

X = Volume of water in clod (equals the volume of pore space filled with water).

Y = Volume of Varsol in clod (equals the volume of pore space filled with Varsol).

Z = Volume of clod.

T = Volume of coarse fragments.

Density of water = 1.00 g/cc.

Density of Varsol = 0.77 g/cc (see 3.4.6.2).

2. Bulk density of clod = (F - A)/Z, where:

Z = (E - C)/Density of Varsol.

3. Total pore space = X + Y, where:

X = (B - F)/Density of water; and

Y = [(D - C) - (B - A) - (F - A)]/Density of Varsol.

4. Total porosity = [(X + Y)/Z] X 100.

5. Bulk density of the less than 2 mm material in the clod.
Bulk density = (F - G)/(Z - T), where: T = (G - A)/2.65
NOTE: The coarse fragments are assumed to have no porosity; therefore, a particle density of 2.65 g/cc is used to find the volume of the coarse fragments. When coarse fragments have porosity the calculated bulk density and porosity of the fines (less than 2 mm material) will be incorrect, but bulk density and porosity of the whole clod, including coarse fragments, will be correct.

3.4.7 Bulk Density (Sand Method)

3.4.7.1 Principle—

See 3.4.4.1

3.4.7.2 Comments—

The calculated volume of the jar and attachment remain constant as long as

both maintain the same relative position to each other. If the two are to be separated, match marks should be made to permit reassembly to this position. The individual measured volumes of water (Q_1, Q_2, and Q_3) require filling the jar and attachment repeatedly (see 3.4.7.6, no. 1). Replicates should not differ more than 3 ml between the highest and lowest volume determined. Vibration of the sand during any of the weighings or density determinations may cause an increase in the sand bulk density and a decrease in accuracy. Sand bulk density (T) may change over time due to changes in moisture content or effective graduation. Field measurements should be run as soon as possible after the sand density (T) has been determined. Each new bag of sand must have its sand density determined (ASTM, 1974).

Care should be taken in excavating to minimize compaction of the soil surrounding the hole. Any material falling from the sides of the hole must be removed and placed with the material to be weighed. In this method, discrimination of very thin horizons is lost; however, due to the relatively large sample size, small errors in measuring the sand weight results in insignificant errors (Blake, 1965).

This method is especially suited to minesoils where coarse fragments prevent using a core sampler. The procedure also works well in coarse textured or unconsolidated materials that cannot be tested with either the Varsol or Saran techniques.

3.4.7.3 Chemicals—

Acetone (CH_3COCH_3) (optional).

3.4.7.4 Materials—

1. Template consisting of a thin, flat, metal plate 30.5 cm (12 in) square, with a 16.5 cm (6.5 in) diameter hole in its center.

2. Sand-funnel apparatus consisting of a lower cone flanged to 16.5 cm (6.5 in) to fit the above template and a top cone section that is threaded to receive the sand jug. A valve is located between the two cones to control the sand flow into the density hole (specifications in ASTM, 1974 p. 211).

3. A standard sand that is clean, dry, and free-flowing. Particle size should be uniform passing a sieve with 0.841 mm openings (20 mesh) and retained on a sieve with a 0.250 mm openings (60 mesh). (Ottawa sand or equivalent).

4. Balance, 20 kg (44.10 lb) capacity which can be read to 1.0 g (Model L-500 available from Soiltest, Inc., Evanston, IL or equivalent).

5. Large spoon.

6. Sand scoop.

7. Brown paper (optional).

8. Wooden rolling pin (optional).

9. Sieve, 2 mm openings (10 mesh).

3.4.7.5 Procedure (modified from ASTM, 1974)—

NOTE: Steps 1-16 and 3.4.7.6 no. 1-3 should be completed in the laboratory prior to going to the field. Steps 1-8 and 3.4.7.6 no. 1 must be completed when either the jar or funnel apparatus is replaced. Steps 9-12 and 3.4.7.6 no. 2 must be repeated for each new bag of sand. Steps 13-16 and 3.4.7.6 no. 3 must be repeated if the funnel apparatus is replaced.

1. Assemble apparatus and place match marks on both the jar and funnel apparatus to permit accurate realignment in case of separation.

2. Weigh assembled apparatus empty and record weight (A).

3. Place apparatus upright. Open valve and fill with water until the water appears over the valve.

4. Close valve and pour off excess water. Remove any water remaining in the funnel by sponging and then wiping dry.

5. Weigh apparatus filled with water. Record weight (B). Determine temperature of the water and record temperature (C).

6. Discard water in apparatus.

7. Repeat steps 3-6 two more times and determine the volume of the apparatus from an average of the three weighings.

8. Thoroughly dry apparatus by the addition of acetone to absorb water, followed by drying with a jet of moisture-free air or drying on a drying rack.

9. Place dry density apparatus upright on a firm, level surface. Close valve and fill funnel with sand.

10. Open valve and fill apparatus. NOTE: Keep funnel at least half full of sand during the filling procedures.

11. Close valve sharply and remove sand remaining in funnel.

12. Weigh apparatus filled with sand and record weight (D).

13. Invert apparatus and seat in template on a clean, level, planar surface.

14. Open valve and keep open until sand stops running.

15. Close valve sharply. Weigh apparatus and remaining sand. Record weight (E).

16. Replace sand following steps 9-11.

17. In the field, prepare the surface of the location to be tested so that it is a level plane.

18. Place template on surface.

19. Using a large spoon, dig the test hole inside the template hole, being careful to avoid disturbing the soil bounding the hole. NOTE: The excavated hole should have a diameter equal to the diamter of the template hole. The excavated walls of the finished hole should be as close to vertical as possible. The hole depth should be at least 7.6 cm (3 in) but not exceeding 16.5 cm (6.5 in) deep.

20. Place all loosened soil in a container, being careful not to lose any material.

21. Seat the density apparatus on the template and open the valve. After the sand has stopped flowing, close the valve sharply.

22. Weigh apparatus and remaining sand. Record weight (F).

23. Replace as much sand as possible from the hole back into the jar, being careful not to get contaminants in the sand from the hole.

24. Refill apparatus with sand using steps 9-11.

25. Preweigh a weighing pan and record weight (G).

26. Place moist material removed from the test hole on the preweighed pan. Record weight (H).

27. Place material in an oven at 105°C for 16 hours.

28. Cool in desiccator and reweigh. Record weight (I).
NOTE: Steps 29-32 are optional and are used when bulk density without coarse fragments is required.

29. Put excavated material on a sheet of brown paper and crush with a wooden rolling pin. NOTE: Be careful not to crush small soft course fragments, but be sure to remove all fines from coarse fragments.

30. Pass sample through a 2 mm sieve.

31. All material caught on a 2 mm sieve is transferred to weighing pan and dried in an oven at 105°C for 4 hours.

32. Cool weighing pan and sample in desiccator. Weigh sample plus weighing pan and record weight (J).

3.4.7.6 Calculations--

1. Legend:

A = Weight of empty apparatus.

B_1 = Weight of apparatus filled with water from first weighing (see 3.4.7.5, steps 2 through 7).

B_2 = Weight of apparatus filled with water from second weighing (see 3.4.7.5, steps 2 through 7).

B_3 = Weight of apparatus filled with water from third weighing (see 3.4.7.5, steps 2 through 7).

C = Temperature of water.

D = Weight of apparatus filled with sand.

E = Weight of apparatus and sand excluding sand in funnel.

F = Weight of apparatus and sand excluding sand in excavated hole and sand in funnel.

G = Weight of weighing pan.

H = Weight of moist sample and weighing pan.

I = Weight of oven-dry sample and weighing pan.

J = Weight of coarse fragments and weighing pan.

K = Volume of coarse fragments.

N_1 = Weight of water required to fill apparatus on first weighing (see 3.4.7.5, steps 2 through 7).

N_2 = Weight of water required to fill apparatus on second weighing (see 3.4.7.5, steps 2 through 7).

N_3 = Weight of water required to fill apparatus on third weighing (see 3.4.7.5, steps 2 through 7).

P_1 = Volume-temperature correction factor from Table 12 for first weighing (see 3.4.7.5, steps 2 through 7).

P_2 = Volume-temperature correction factor from Table 12 for second weighing (see 3.4.7.5, steps 2 through 7).

P_3 = Volume-temperature correction factor from Table 12 for third weighing (see 3.4.7.5, steps 2 through 7).

TABLE 12. VOLUME OF WATER PER GRAM BASED ON TEMPERATURE

Temperature (C) °C	Volume of Water (P) ml/g	Temperature (C) °C	Volume of Water (P) ml/g
12	1.00048	22	1.00221
14	1.00073	24	1.00268
16	1.00103	26	1.00320
18	1.00138	28	1.00375
20	1.00177	30	1.00435
		32	1.00497

Q_1 = Volume of water required to fill apparatus from first weighing (see 3.4.7.5, steps 2 through 7).

Q_2 = Volume of water required to fill apparatus from second weighing (see 3.4.7.5, steps 2 through 7).

Q_3 = Volume of water required to fill apparatus from third weighing (see 3.4.7.5, steps 2 through 7).

R = Average volume of density apparatus.

S = Weight of sand required to fill apparatus.

T = Bulk density of sand.

U = Weight of sand required to fill funnel.

V = Weight of sand required to fill excavated hole and funnel.

W = Volume of excavated hole.

Y = Weight of oven-dry sample

Z = Weight of moist sample.

2. $R = (Q_1 + Q_2 + Q_3)/3$, where:

$Q_1 = M_1 \times P_1$.

$Q_2 = N_2 \times P_2$.

$Q_3 = N_3 \times P_3$, and

$N_1 = B_1 - A$.

$N_2 = B_2 - A$.

$N_3 = B_3 - A$.

3. $T = S/R$, where:

$S = D - A$.

4. $U = D - E$.

5. $V = D - F$.

6. $W = (V - U)/T$.

7. Bulk density of soil = Y/W, where $Y = I - G$.

8. Percent moisture = $[(Z - Y)/Y] \times (100)$, where $Z = H - G$.

9. Bulk density of the less than 2 mm material in sample.
Bulk density = $[Y - (J - G)]/(W - K)$, where $K = (J - G)/2.65$.
NOTE: The coarse fragments are assumed to have no porosity; therefore, a particle density of 2.65 g/cc (density of quartz) is used to find the volume of the coarse fragments. See note under 3.4.6.6.

3.4.8 Particle Density

3.4.8.1 Principle—

The relationship of the solid soil particles to their total volume excluding the pore spaces between particles is called the particle density. It is normally expressed as grams per cubic centimeter. The mass of the solid particles is found by weighing and their total volume is determined by the displacement of a liquid whose mass and density are known (Blake, 1965).

3.4.8.2 Comments—

If measurements of volumes and weights are done carefully, this method is precise. A lack of precision in either measurement may result in serious error.

A non-polar liquid, Varsol, is used in the procedure instead of water because of the higher density values water gives for finely divided, active powders. Other polar liquids (e.g. toluene, xylene, or carbon tetrachloride) can be used, but they need special care in handling.

This measurement is used to mathematically determine porosity, airspace, and sedimentation rates for particle-size analysis. Minesoil samples are screened through a 2 mm sieve after rolling with a rolling pin. Sample is not ground with mortar and pestle.

3.4.8.3 Chemicals —

Varsol - Trade name of EXXON cleaning fluid (but can usually be purchased from other suppliers). We have found Varsol to have a rather consistent density of 0.77 g/cc.

3.4.8.4 Materials—

1. Pycnometer flask with ground glass lid (modified Hubbard-Carmick, Pyrex brand 1620 or equivalent).

2. Balance, can be read to 0.0001 g.

3. Vacuum desiccator.

3.4.8.5 Procedure (modified from Blake, 1965 and Gradwell, 1955)—

NOTE: All weights are recorded to $\pm$ 0.0001.

1. Oven dry the less than 2 mm sample at 60°C overnight.

2. Weigh a clean, dry pycnometer flask and lid. Record weight (W_a).

3. Add about 10 g of oven-dry sample to pycnometer. Clean outside and neck of pycnometer of any soil that may have spilled during transfer.

4. Weigh the pycnometer, including lid, and its contents. Record weight (W_s).

5. Fill pycnometer about one-half full with Varsol, washing any soil adhering to the neck into the pycnometer.

6. Place pycnometer into the vacuum desiccator, apply vacuum, and remove any entrapped air. Entrapped air will be removed when all bubbling ceases.

7. Remove the pycnometer and shake gently. NOTE: Repeat steps 6 and 7 until all bubbling ceases.

8. Fill the pycnometer with enough Varsol so that when the lid is put in place, the hole in the lid will be completely filled with Varsol.

9. Insert the lid and seat it carefully.

10. Thoroughly dry and clean the outside of the pycnometer with a dry cloth.

11. Weigh the pycnometer and its contents. Record weight (W_{sv}).

12. Remove sample and Varsol from the pycnometer. NOTE: Thoroughly wash pycnometer and lid with Varsol to insure removal of sample.

13. Fill pycnometer with enough Varsol so that the hole in the lid will be filled with Varsol when the lid is seated.

14. Insert and seat lid. Thoroughly dry the outside with a dry cloth.

15. Weigh pycnometer filled with Varsol. Record weight (W_v).

3.4.8.6 Calculations—

Particle density (Dp) = dv $(W_s - W_a)/[(W_s - W_a) - (W_{sv} - W_v)]$, where:

dv = Density of Varsol in g/cc (see note below).

W_s = Weight pycnometer plus sample.

W_a = Weight of pycnometer filled with air.

W_{sv} = Weight of pycnometer filled with sample and Varsol.

W_v = Weight of pycnometer filled with Varsol.

NOTE: The density of Varsol must be determined for each new supply of Varsol. Using a pipette, add exactly 50 cc to a previously tared beaker. Record weight of the Varsol.

dv = weight (g) of Varsol/50 cc.

3.4.9 Total Porosity

3.4.9.1 Principle—

The bulk volume of a field moist soil sample contains soil particles, moisture, and air. The portion of the bulk volume filled with moisture and air is called pore space. Bulk density measurements (3.4.4-3.4.7) are calculated by dividing the oven-dry weight of the mass (in grams) by the bulk volume. This value is considerably lower than the average particle density (3.4.8). This means that part of the bulk volume is pores filled with air. Calculation of total porosity is done by converting data from densities into volumes. The volume (VB) of the bulk sample is derived from a bulk density measurement. The volume (VP) is the collective volume occupied by solid particles and is derived from the particle density measurement. Therefore, VP/VB is the fraction of the volume occupied by solid particles. In this manner, total porosity can be calculated using the equation in 3.4.9.6 (Vomocil, 1965).

3.4.9.2 Comments—

Total porosity can be measured directly if the "Varsol" method is used to find the bulk density. The procedure and calculations are given in 3.4.6.

Do not use an assumed particle density of 2.65 g/cm^3 if carbolithic materials are present in the sample in appreciable amounts. Measure the particle density of this material using 3.4.8.

3.4.9.3 Chemicals—

None required.

3.4.9.4 Materials—

None required.

3.4.9.5 Procedure—

1. Determine the bulk density using one of the following methods: (a) 3.4.4; (b) 3.4.5; (c) 3.4.6; or (d) 3.4.7.

2. Determine particle density using method 3.4.8. NOTE: In cases where great accuracy is not required, use the assumed value of 2.65 g/cm^3 for the particle density of mineral soils.

3.4.9.6 Calculations—

1. TP = Total porosity: percentage of the bulk volume not occupied by solids.

2. BD = Bulk density of soil.

3. PD = Particle density of soil.

4. TP = [(PD - BD)/PD] X 100.

3.4.10 Free Swelling (Settling Volume)

3.4.10.1 Principle—

Swelling is an innate property of the clays. Swelling may arise in two different ways: (1) water molecules becoming positioned between the particles of clay; (2) water molecules becoming positioned within the molecular structure of the clay mineral. Kaolinite and mica-like clays will only exhibit swelling due to the former process; therefore, these clays will have limited volume change, especially kaolinite. Clays of the montmorillonite type exhibit extensive swelling mainly because of the latter process. Free swelling is an important property of this type of clay mineral (Marshall, 1949).

3.4.10.2 Comments—

Step number 4 of 3.4.10.5 (procedure) should be performed very carefully and slowly so that no sample is lost. Also, step number 10 should be performed exactly as described.

This simple method can be used effectively to evaluate the stability of materials. Materials exhibiting extensive swelling would be unstable on steep slope, haul-road, etc. Also, future land use would be affected by such materials.

3.4.10.3 Chemicals—

Distilled water (H_2O).

3.4.10.4 Materials—

1. Graduated cylinders, 100 ml capacity with 1 ml graduations.

2. Powder funnels.

3. Sieve, 0.25 mm openings (60 mesh).

4. Polypropylene wash bottle.

5. Balance, can be read to 0.001 g.

6. Pencil, yellow or any color that can be seen easily through turbid water.

7. Standard liquid limit device (Sowers, 1965, Fig. 1-1, p. 395) adjusted to drop a distance of 1 cm.

3.4.10.5 Procedure—

1. Weigh a 10.00 g air-dry sample of earthy material ground to pass a 60 mesh sieve.

2. Fill a 100 ml graduated cylinder to the 85 ml mark with distilled water.

3. Put a powder funnel in the neck of the graduated cylinder.

4. Slowly add the 10.00 g of earthy material to the graduated cylinder in several small increments. NOTE: This step must be done slowly so that all earthy material is transferred into the cylinder without unnecessary entrapment of air.

5. Add distilled water to the cylinder until the liquid level reaches the 100 ml mark, washing off any particles adhering to the sides of the cylinder.

6. Set cylinder aside and let stand undisturbed for 6 hours.

7. At the end of 6 hours, place cylinder on cup of liquid limit device and turn crank 30 times at a rate of one revolution per second. NOTE: After every five revolutions straighten cylinder without changing the rate if necessary to keep cylinder upright.

8. Set cylinder aside and let stand undisturbed for an additional 18 hours.

A small DC operated fan is used to pull air through the photoionization sensor at a flow rate of three to seven hundred centimeters per minute (ca. 0.5 lpm). The fan provides nearly instantaneous response times (Figure 3) while consuming little power. The characteristics of a fan are such that it cannot tolerate a significant pressure drop without affecting the flow rate and therefore either the instrument reading or response time. Since photoionization is essentially a nondestructive technique, changes in flow rate do not affect the signal but if a large pressure drop is imposed at the inlet of the probe, the sample may not reach the sensor.

TABLE III

VERIFICATION OF ELECTRONIC ZERO FOR PHOTOIONIZATION ANALYZER*

Sample	Instrument Reading (ppm)	% of F.S.
Room Air	0.7	35
Room Air Passed Through 6" x 3/4" OD Charcoal Scrubber	0.1	5
Zero Air	0.25	12.5
Zero Air Passed Through 6" x 3/4" OD Charcoal Scrubber	0.04	2

*Maximum Gain = 2 ppm full scale.

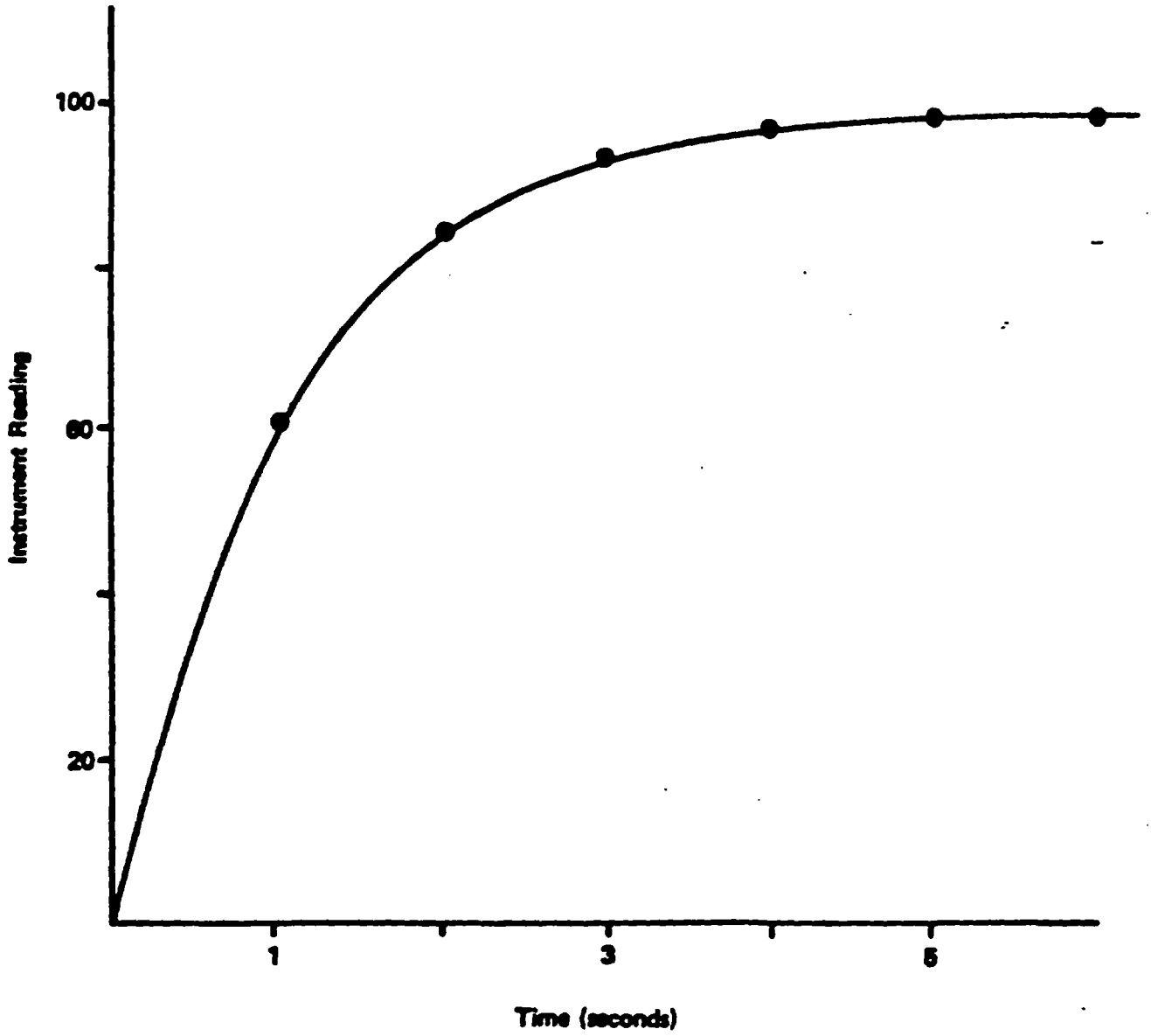
TABLE IV

RELATIVE PHOTOIONIZATION SENSITIVITIES* FOR VARIOUS GASES

Chemical Grouping	Relative Sensitivity	Examples
Aromatic	10.0	Benzene, Toluene, Styrene
Aliphatic Amine	10.0	Diethylamine
Chlorinated Unsaturated	5-9	Vinyl Chloride, Vinylidene Chloride, Trichloroethylene
Carbonyl	5-7	MEK, MIBK, Acetone, Cyclohexene
Unsaturated	3-5	Acrolein, Propylene, Cyclohexene, Allyl Alcohol
Sulfide	3-5	Hydrogen Sulfide, Methyl Mercaptan
Paraffin (C_5-C_7)	1-3	Pentane, Hexane, Heptane
Ammonia	0.3	—
Paraffin (C_1-C_4)	0	Methane, Ethane . . .

*Sensitivities in ppm (v/v).

Figure 3. Time Response for the Photoionization Analyzer.



The instrument was designed to measure trace gases over a concentration range from less than 1 ppm to 2000 ppm. Higher levels of various gases (to percentage range) can be measured but the recommended procedure is to dilute the sample with clean air to a concentration of less than 500 ppm. This is generally within the linear range of the instrument and if the measured concentration is multiplied by the dilution ratio the correct concentration in the stream can be determined. A typical calibration curve is shown in Figure 4. Note that the calibration curve for benzene (the photoionization standard) is linear (over more than three decades) up to about 600 ppm (v/v).

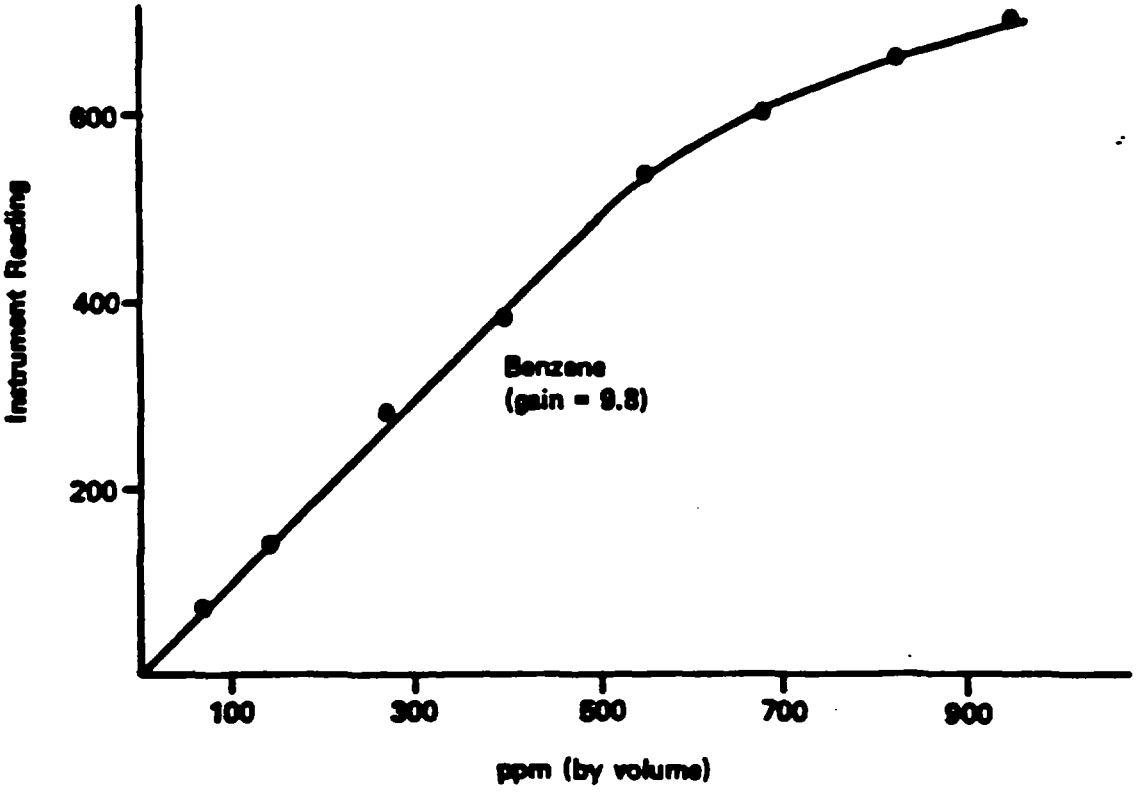
If the probe is held close to AC power lines or power transformers, an error may be observed. For measurements made in close proximity to such items, their effect on measurements can be determined by the following procedure. Zero the instrument in an electrically quiet area, in the standby position, then move the instrument to the questionable area involved. If AC pickup is going to be a problem, the meter (in the standby position) will indicate the magnitude of the error.

The instrument is equipped with an automatic solid state battery protection circuit. When the battery voltage drops below ~ 11 volts, this circuit will automatically turn off the power to the instrument. This prevents deep discharging of the battery and considerably extends the battery life. If the instrument is unintentionally left on overnight, the battery will be unharmed because of the battery protection circuit. If the instrument battery check reads low and the lamp doesn't fire, plug the charger into the instrument. The power to the analyzer should then be returned.

To charge the battery, place the mini phone plug into the jack on left side of the bezel prior to plugging charger into 120 VAC. When disconnecting charger, remove from 120 VAC before removing mini phone plug. The battery is completely recharged overnight (ca. 14 hours). To ensure that the charger is functioning, turn the function switch to the battery check position, place phone plug into jack and plug charger into AC outlet. The meter should go upscale if charger is working and is correctly inserted into the jack.

The instrument can be operated during the recharge cycle. This will lengthen the time required to completely recharge the instrument battery.

Figure 4. Typical Calibration Curve for Photoionization Analyzer.



SECTION 3

CALIBRATION

Static or dynamic gas generation systems can be utilized for calibration of the instrument. A number of such systems for generating test atmospheres for various gases have been described by G. O. Nelson in "Controlled Test Atmospheres," Ann Arbor Science Publishers, Ann Arbor, Michigan (1971).

The most convenient packages for calibration are the non-toxic analyzed gas mixtures available from HNU Systems in pressurized containers (Catalogue #101-350).

A rapid procedure for calibration involves bringing the probe and readout in close proximity to the calibration gas, cracking the valve on the tank and checking the instrument reading. This provides a useful spot check for the instrument.

The recommended and most accurate procedure for calibration of the instrument from a pressurized container is to connect one side of a "T" to the pressurized container of calibration gas, another side of the "T" to a rotameter and the third side of the "T" directly to the 8" extension to the photoionization probe (see Figure 5). Crack the valve of the pressurized container until a slight flow is indicated on the rotameter. The instrument draws in the volume of sample required for detection, and the flow in the rotameter indicates an excess of sample. Now adjust the span pot so that the instrument is reading the exact value of the calibration gas. (If the instrument span setting is changed, the instrument should be turned back to the standby position and the electronic zero should be readjusted, if necessary.)

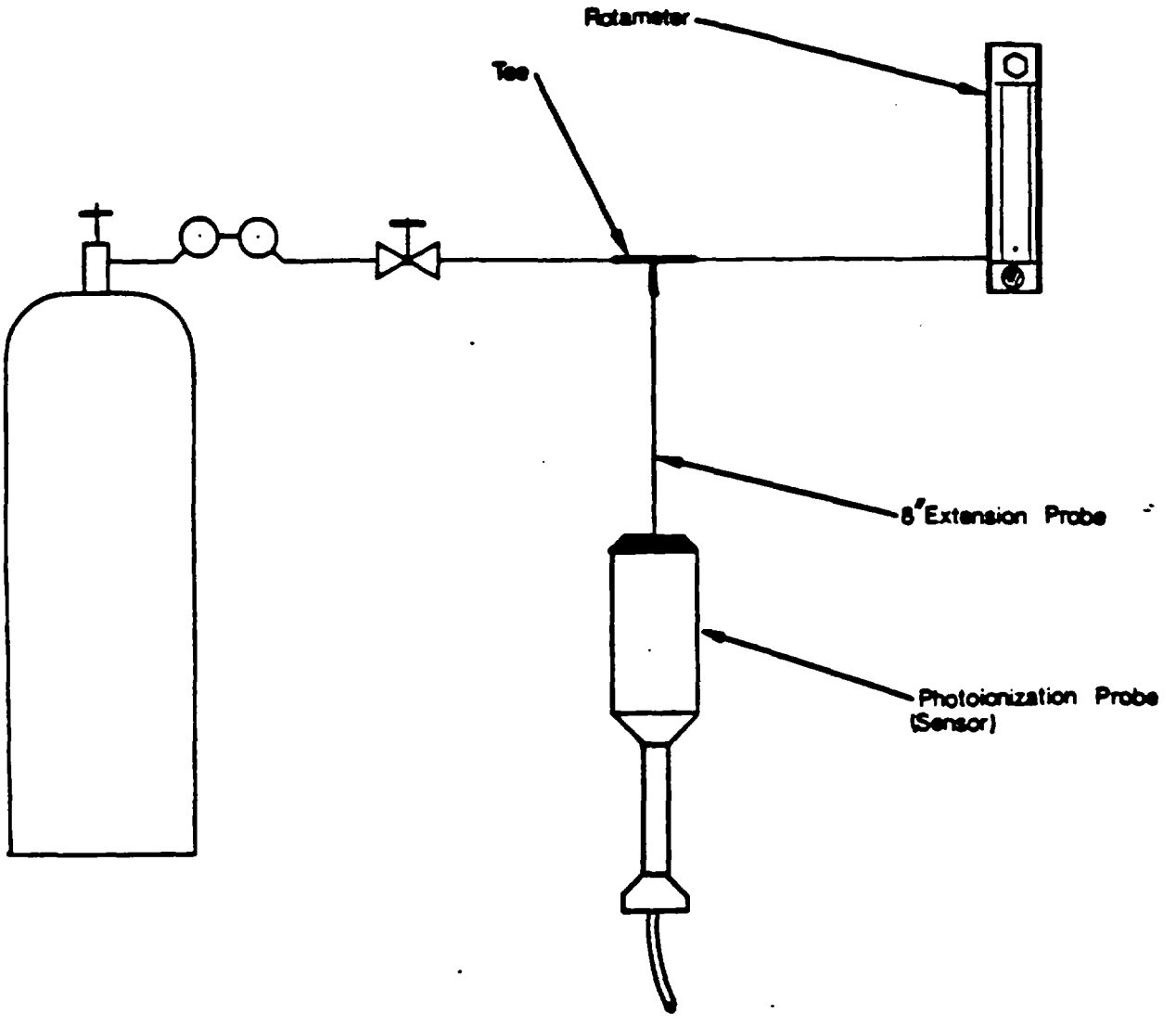


Figure 5. Recommended Calibration Procedure for Photoionization Analyzer

The calibration gas* should be prepared in the same matrix (air, nitrogen, hydrogen, etc.) in which it is to be measured, otherwise an inaccurate reading may be obtained. The increased response which is seen in oxygen free gases can be attributed to a reduction in the quenching of ions by oxygen (actually O_2^-) and is typical of any ionization detector. The quenching effect of oxygen is constant from about ten percent O_2 to very high levels.

If a gas standard prepared in nitrogen is to be used for measurements in air, fill a 0.5 or 1 liter bag with the standard then add 50 or 100 cc of pure oxygen to bring the level to 10-12%.

Any error between this value and 20% oxygen is quite small.

If the sample to be measured is in nitrogen, standards should be prepared in nitrogen. This will result in an increase in sensitivity of approximately 4.

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* Calibration with toxic gases should be performed in a hood since the 101 is a non-destructive analyzer.

SECTION 4

DETECTION PRINCIPLE AND THEORY

The detection principle of this portable instrument is photoionization. A wide variety of organic compounds and some inorganic compounds can be measured with this technique. Photoionization (with ~ 10 eV photons) applied to the analysis of trace gases in air can eliminate fragment ion formation (signals) from the major components of air yet still allow the ionization of many impurities of interest in industrial atmospheres. This is demonstrated by the listing of ionization potentials* in Tables V-XVII. Note the high (12 eV) ionization potentials for the major components of air. In addition, the choice of a sufficiently low ionization energy often permits the selective ionization of one or two components in a complex gas mixture.

While the ionization potential serves as a rough guide to whether or not a response is obtained, it does not predict what the quantitive response actually is. In some cases, a species with an ionization potential 10.3 or 10.4 eV will give a response. In these cases, however, the response is usually low because of its low ionization efficiency at 10 eV. A partial list of actual relative sensitivities obtained with a photoionization analyzer is given in Table XVIII. The use of the tables should allow a determination of the specificity of the instrument in a given application on many industrial processes; this instrument may not respond to the starting materials or by-products but will respond to a product. An example of this is seen in the vinyl chloride monomer plants where neither ethylene or dichloroethane is detected but vinyl chloride is detected.

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* Ionization potential is defined as the energy required to move an electron an infinite distance from the nucleus or more simply, the energy required to produce a positive ion and an electron.

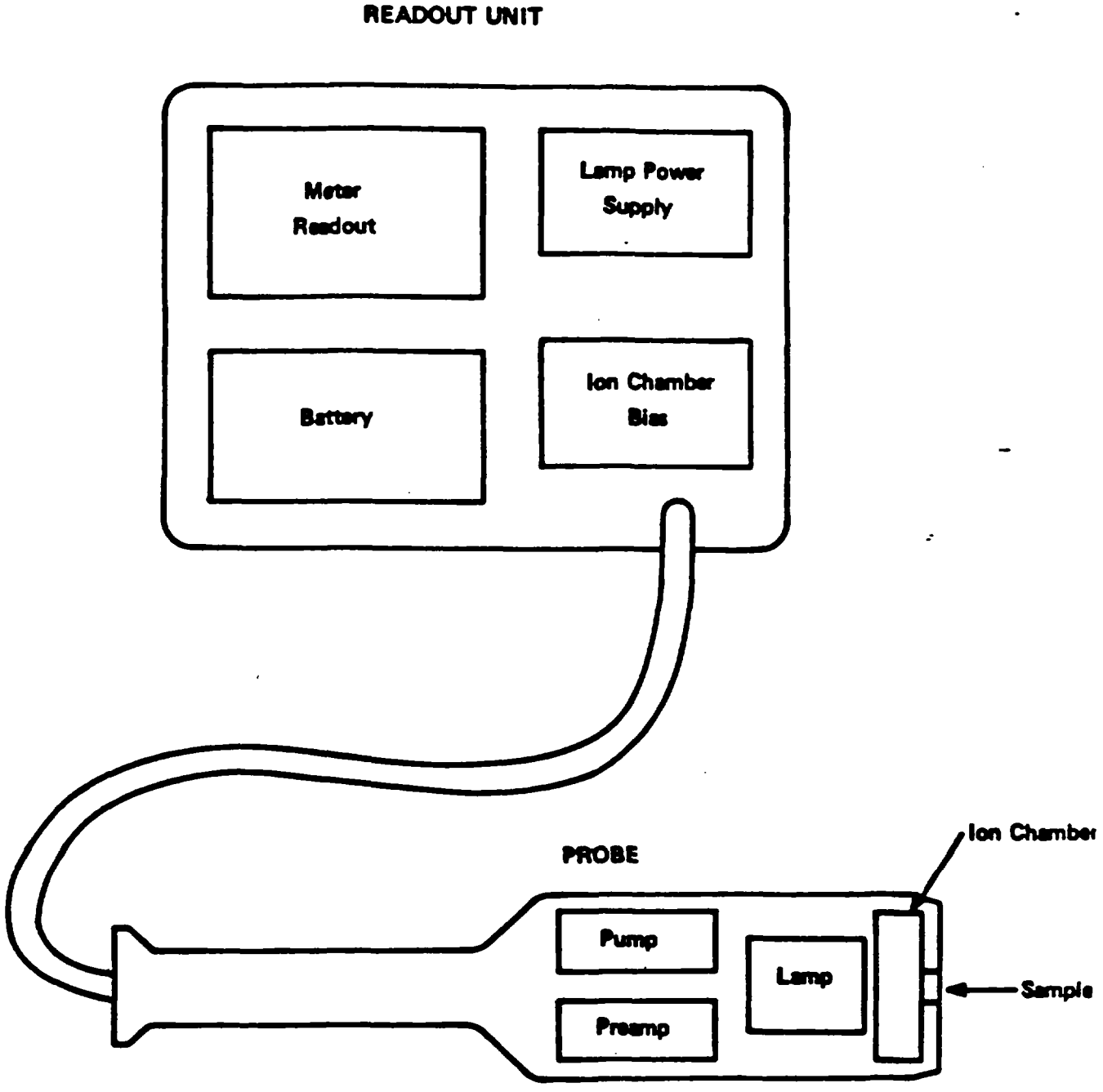


Figure 8. Block Diagram of Portable Photoionization Analyzer.

A block diagram of the major components of the photoionization analyzer is shown in Figure 6. The instrument is separated into two units interconnected by multiconductor electrical cable. The probe contains a fan for moving the air into the sensor, the ultraviolet lamp which is ignited by applying a DC voltage between the anode and cathode, the ionization chamber which contains a pair of electrodes and is adjacent to the lamp, and a signal amplifier. The photons (~ 10 eV) which are emitted from the lamp pass through a UV transmitting window and into the ionization chamber where absorption of the UV radiation by a molecule which has an ionization potential of 10 eV or less will lead to ion formation via:

$$RH + h\nu \rightarrow RH^{+} + e^{-}$$

A positively biased high voltage electrode is used to push any ions formed by absorption of UV to the collector electrode where the current (proportional to concentration) is measured. This current is then converted to a proportional voltage by the amplifier in the probe. An electrical diagram of the instrument is depicted in Figure 7. The amplifier is gain stabilized by negative feedback and provides a voltage source output to drive the analog meter readout as well as the gain control network. The sensitivity of the instrument is controlled by changing the loop gain of the amplifier. A 12 volt battery provides the primary power for a high efficiency DC-DC converter which supplies the various potentials required for instrument operation.

Figure 7. Electrical Block Diagram of Photoionization Analyzer

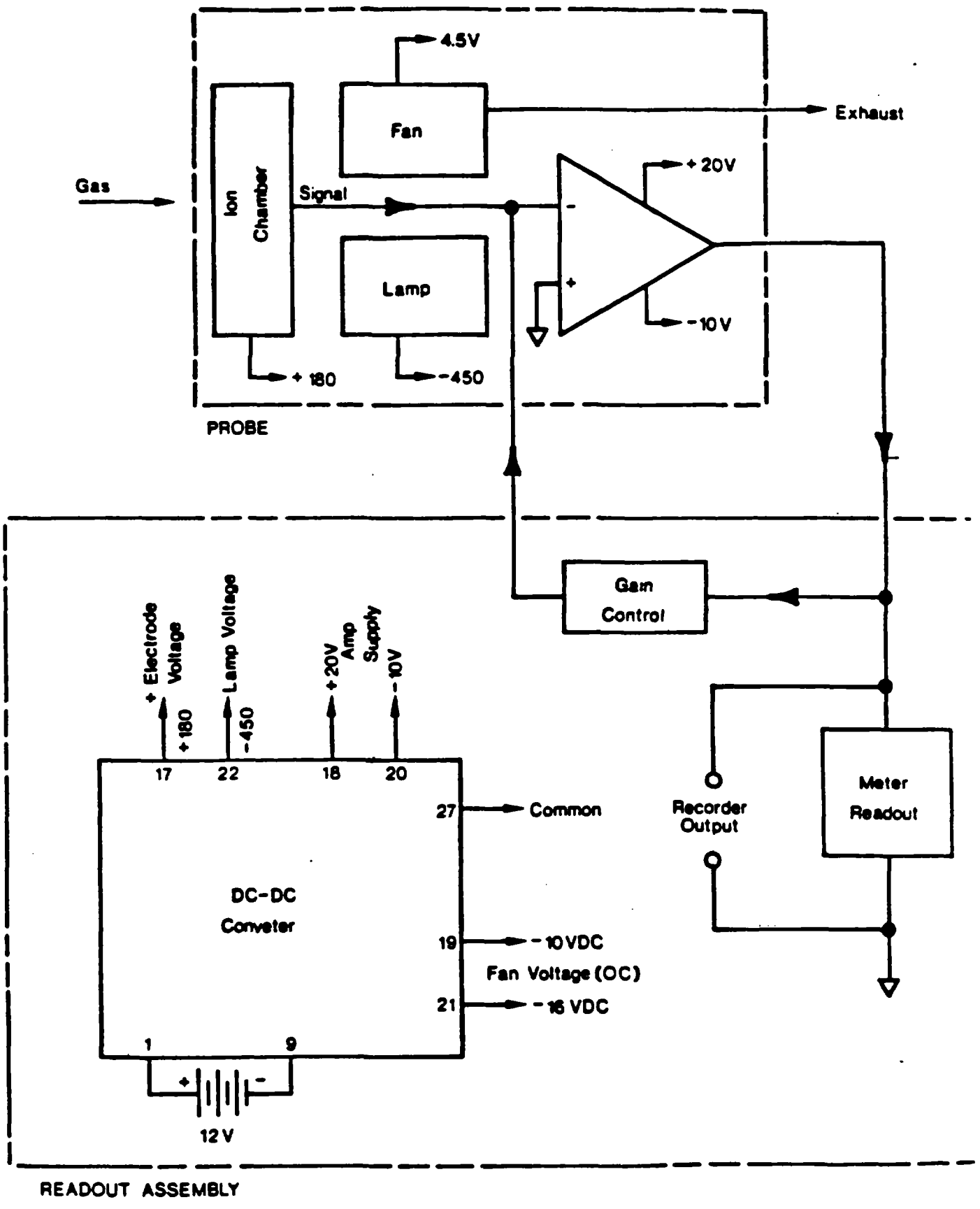


TABLE V

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 VI

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 VII

ALKYL HALIDES

Molecule	IP (eV)
HCl	12.74
Cl_2	11.48
CH_4	12.98
methyl chloride	11.28
dichloromethane	11.35
trichloromethane	11.42
tetrachloromethane	11.47
ethyl chloride	10.98
1,2-dichloroethane	11.12
1-chloropropane	10.82
2-chloropropane	10.78
1,2-dichloropropane	10.87
1,3-dichloropropane	10.85
1-chlorobutane	10.67
2-chlorobutane	10.65
1-chloro-2-methylpropane	10.66
2-chloro-2-methylpropane	10.61
HBr	11.62
Br_2	10.55
methyl bromide	10.53
dibromomethane	10.49
tribromomethane	10.51
CH_2BrCl	10.77
$CHBr_2Cl$	10.59
ethyl bromide	10.29
1,1-dibromoethane	10.19
1-bromo-2-chloroethane	10.63

TABLE VII (Continued)

Molecule	IP (eV)
1-bromopropane	10.18
2-bromopropane	10.075
1,3-dibromopropane	10.07
1-bromobutane	10.13
2-bromobutane	9.98
1-bromo-2-methylpropane	10.09
2-bromo-2-methylpropane	9.89
1-bromopentane	10.10
HI	10.38
I_2	9.28
methyl iodide	9.54
diiodomethane	9.34
ethyl iodide	9.33
1-iodopropane	9.26
2-iodopropane	9.17
1-iodobutane	9.21
2-iodobutane	9.09
1-iodo-2-methylpropane	9.18
2-iodo-2-methylpropane	9.02
1-iodopentane	9.19
F_2	15.7
HF	15.77
$CFCl_3$ (Freon 11)	11.77
CF_2Cl_2 (Freon 12)	12.31
CF_3Cl (Freon 13)	12.91
$CHClF_2$ (Freon 22)	12.45
$CFBr_3$	10.67

TABLE VII (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
$n\text{-}C_3F_7I$	10.36
$n\text{-}C_3F_7CH_2Cl$	11.84
$n\text{-}C_3F_7CH_2I$	9.96

TABLE VIII

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 IX

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 X

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 XI

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 XII

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 XIII

OLEFINS, CYCLO-OLEFINS, POLENES, 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-cinylcyclohexene	8.93
cyclo-octatetraene	7.99
acetylene	11.41
propyne	10.36
1-butyne	10.18

TABLE XIV

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 XV

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 XVI

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	7.96
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 XVI (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	8.86

TABLE XVII

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
$(n\text{-}C_3F_7)(CH_3)C{=}O$	10.58
trichlorovinylsilane	10.79
$(C_2F_5)_3N$	11.7
isoprene	9.08
phosgene	11.77

TABLE XVIII

RELATIVE SENSITIVITIES FOR VARIOUS GASES
(10.2 eV Lamp)

Species	Photoionization Sensitivity*
p-xylene	11.4
m-xylene	11.2
benzene	10.0 (reference standard)
toluene	10.0
diethyl sulfide	10.0
diethyl amine	9.9
styrene	9.7
trichloroethylene	8.9
carbon disulfide	7.1
isobutylene	7.0
acetone	6.3
tetrahydrofuran	6.0
methyl ethyl ketone	5.7
methyl isobutyl ketone	5.7
cyclohexanone	5.1
naptha (86% aromatics)	5.0
vinyl chloride	5.0
methyl isocyanate	4.5
iodine	4.5
methyl mercaptan	4.3
dimethyl sulfide	4.3
allyl alcohol	4.2

TABLE XVIII (continued)

Species	Photoionization Sensitivity*
propylene	4.0
mineral spirits	4.0
2,3-dichloropropene	4.0
cyclohexene	3.4
crotonaldehyde	3.1
acrolein	3.1
pyridine	3.0
hydrogen sulfide	2.8
ethylene dibromide	2.7
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
ethylene oxide	1.0
acetic anhydride	1.0
α pinene	0.7
dibromochloropropane	0.7
epichlorohydrin	0.7
nitric oxide	0.6
β pinene	0.5
citral	0.5
ammonia	0.3
Nitrobenzene	~ 40

TABLE XVIII (continued)

Species	Photoionization Sensitivity*
acetic acid	0.1
nitrogen dioxide	0.02
methane	0.0
acetylene	0.0
ethylene	0.0

*Expressed in ppm (v/v).

SECTION 5

TROUBLESHOOTING

If problems occur while using the photoionization analyzer, it is recommended that the following troubleshooting guide be followed before consulting the factory.

5.1 General Aid to Fault Determination

Check battery condition. Recharge if necessary (Section 2). Turn the instrument on. Look into the Sample Inlet of the probe unit. A violet colored glow from the UV light source should be observed in all positions of the mode switch except the standby position. If unstable readings are obtained a faulty probe cable or electrical connection could be the problem. To check, hold the probe normally and flex the cable firmly. Watch the meter for fluctuations as the cable is stressed. Individual wires in the readout can be checked in a similar way. Check the coaxial connector on the amplifier board in the probe.

In the more sensitive ranges, a fluctuation in the reading may be noted if a hand or other large object is placed in very close proximity to the probe. This is normal for the instrument and will not result in an error in the measurement as long as the probe is held stationary while the measurement is being taken.

If the probe is held close to AC power lines or power transformers an error may be observed. If measurements are to be made in close proximity to such items, their effect on measurements can be determined by the following procedure. Zero the instrument in an electrically quiet area in the standby position, then move the instrument to the questionable area involved. If AC pickup is going to be a problem, the meter (in the standby position) will indicate the magnitude of the error.

5.2 Disassembly of Instrument

PROBE - Turn the function switch to the OFF position and disconnect the probe connector from the readout unit. Remove the exhaust screw found near the base of the probe (see Figure 8.) Grasp the end cap in one hand and the probe shell in the other, and gently pull to separate the end cap and lamp housing from the shell. Loosen the screws on the top of the end cap and separate the end cap and ion chamber from the lamp and lamp housing. Care must be taken so that the ion chamber doesn't fall out of the end cap and the lamp doesn't slide out of the lamp housing. Turn the end cap over in your hand and tap on the top of it; the ion chamber should fall out in your 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 housing assembly by unsnapping the coaxial connection and then removing the retaining screw.

To reassemble this unit, first slide the lamp back into the lamp housing. Place the ion chamber on top of the lamp housing, checking to make sure that the contacts are properly aligned. Place the end cap on top of the ion chamber and replace the two screws. The screws should be tightened only enough to seal the "O" ring. DO NOT OVERTIGHTEN. Line up the pins on the base of the lamp housing with the pins inside the probe shell. Gently slide the housing assembly into the probe shell. DO NOT FORCE the assembly into the shell as it only fits one way.

READOUT UNIT - Turn the function switch to the OFF position and disconnect the probe from the readout unit before disassembly is conducted (see Figure 10). Remove the accessory power jack plug. Loosen the screw on the bottom of the case and, holding the instrument by the bezel, remove the case. The power supply board and control panel can be removed by unscrewing two screws and two nuts. The entire panel, including the function switch, zero and span pots is removed in this operation. Electrically disconnecting this module is simple, since all connections are made with Molex connectors.

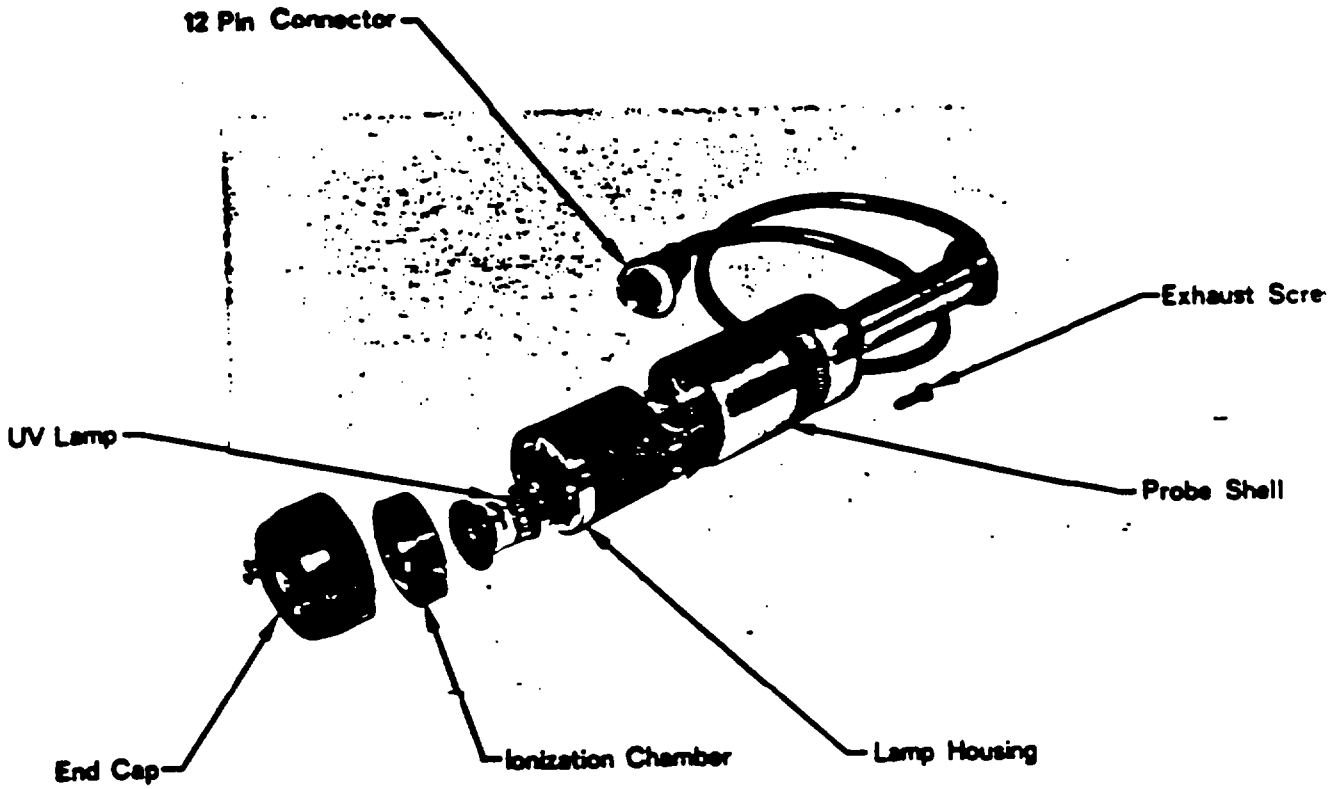
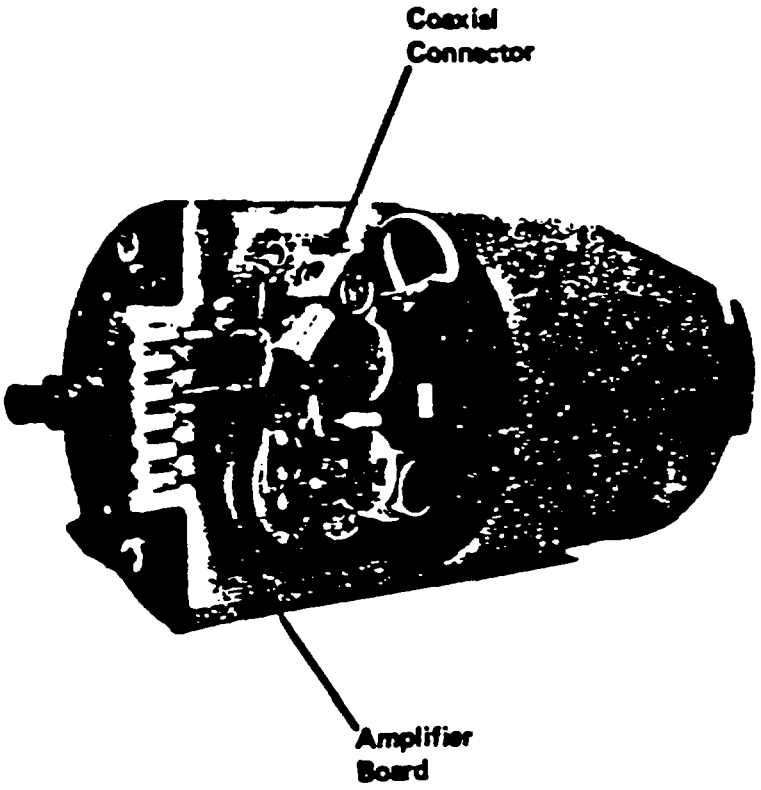


Figure 8. Component Parts of Probe



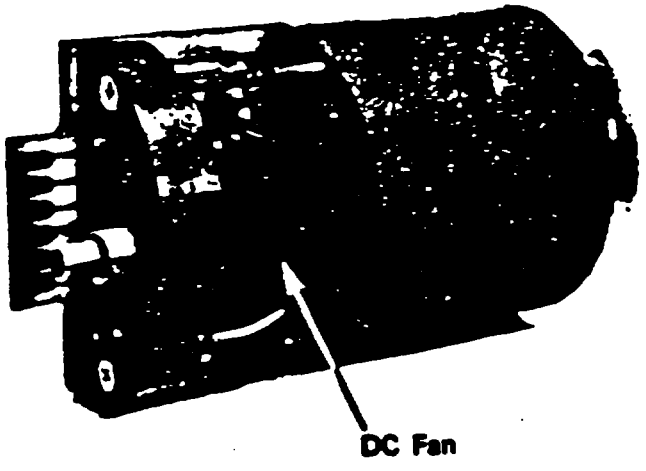


Figure 9. Component Parts of Lamp Housing.

5.3 Specific Faults

1. No meter response in any switch position (including BATT CHK)

   A. Broken meter movement

      (1) Tip instrument rapidly from side to side. Meter needle should move freely, and return to zero.

   B. Electrical connection to meter is broken

      (1) Check all wires leading to meter and clean the contacts of quick-disconnects.

   C. Battery is completely dead

      (1) Disconnect battery and check voltage with a volt-ohm meter.

   D. Check 2 amp fuse

   E. If none of the above solves the problem, consult the factory.

2. Meter responds in BATT CHK position, but reads zero or near zero for all others

   A. Power supply defective

      (1) Check power supply voltages per Figure 11. If any voltage is out of specification, consult the factory.

   B. Input transistor or amplifier has failed

      (1) Rotate zero control; meter should deflect up/down as control is turned.

      (2) Open probe. Both transistors should be fully seated in sockets

   C. Input signal connection broken in probe or readout

      (1) Check input connector on printed circuit board. Should be firmly pressed down.

      (2) Check components on back side of printed circuit board. All connections should be solid, and no wires should touch any other object.

      (3) Check all wires in readout for solid connections.

3. Instrument responds correctly in BATT CHK, AND STBY, but not in measuring mode.

   A. Check to see that light source is on (See General Faults section.)

      (1) Check high voltage power supply (see Figure 11).

      (2) Open end of probe, remove lamp and check high voltage on lamp contact ring.

      (3) If high voltage is present at all above points, light source has most likely failed. Consult the factory.

4. Instrument responds correctly in all positions, but signal is lower than expected.

   A. Check span setting for correct value.

   B. Clean window of light source

   C. Double check preparation of standards. See Section 3.

   D. Check power supply 180 V output. See Figure 11.

   E. Check for proper fan operation. Check fan voltage. See Figure 11.

   F. Rotate span setting. Response should change if span pot is working properly.

5. Instrument responds in all switch positions, but is noisy (erratic meter movement).

   A. Open circuit in feedback circuit. Consult the factory.

   B. Open circuit in cable shield or probe shield. Consult the factory.

6. Instrument response is slow and/or irreproducible.

   A. Fan operating improperly. Check fan voltage. See Figure 11.

   B. Check calibration and operation. See Sections 2 and 3.

7. Low battery indicator.

   A. Indicator comes on if battery charge is low.

   B. Indicator also comes on if ionization voltage is too high.

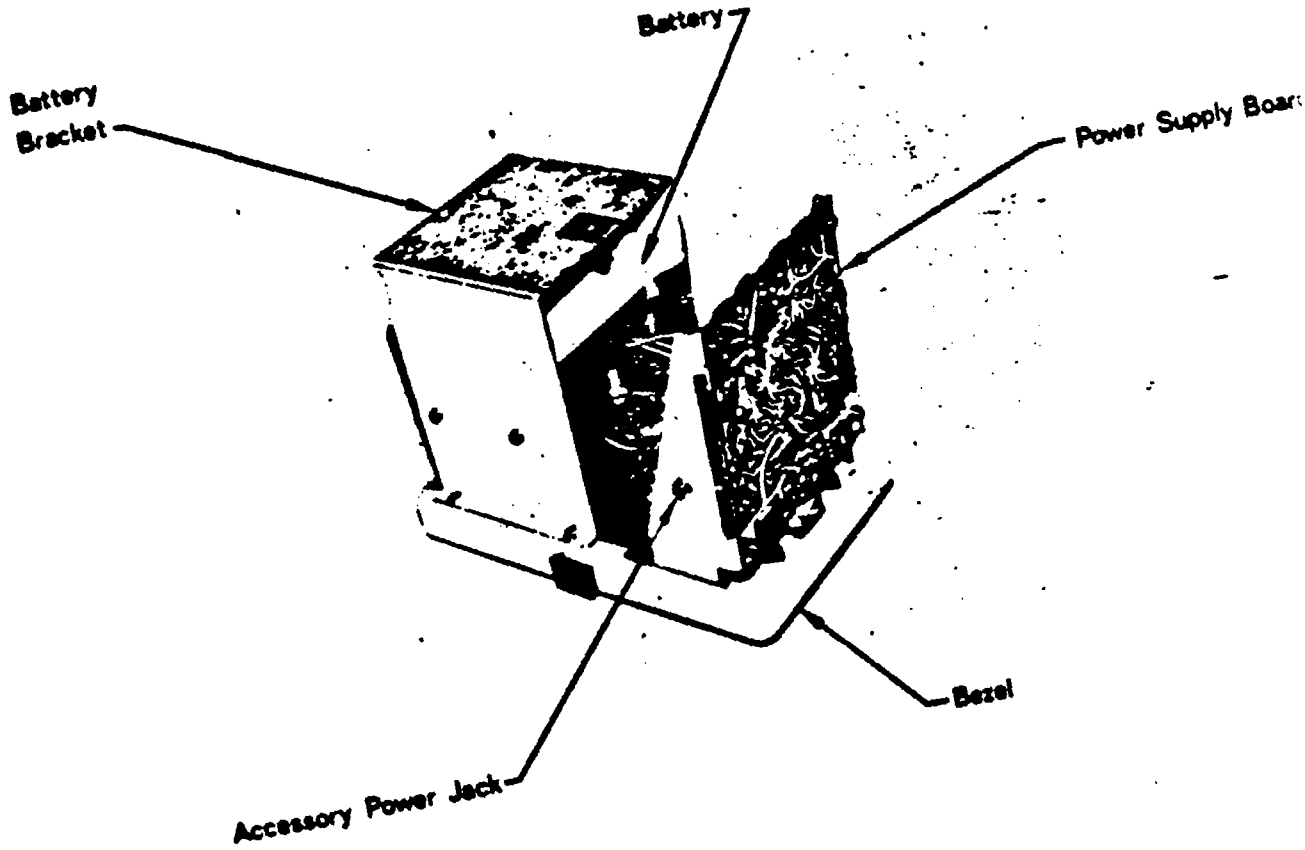
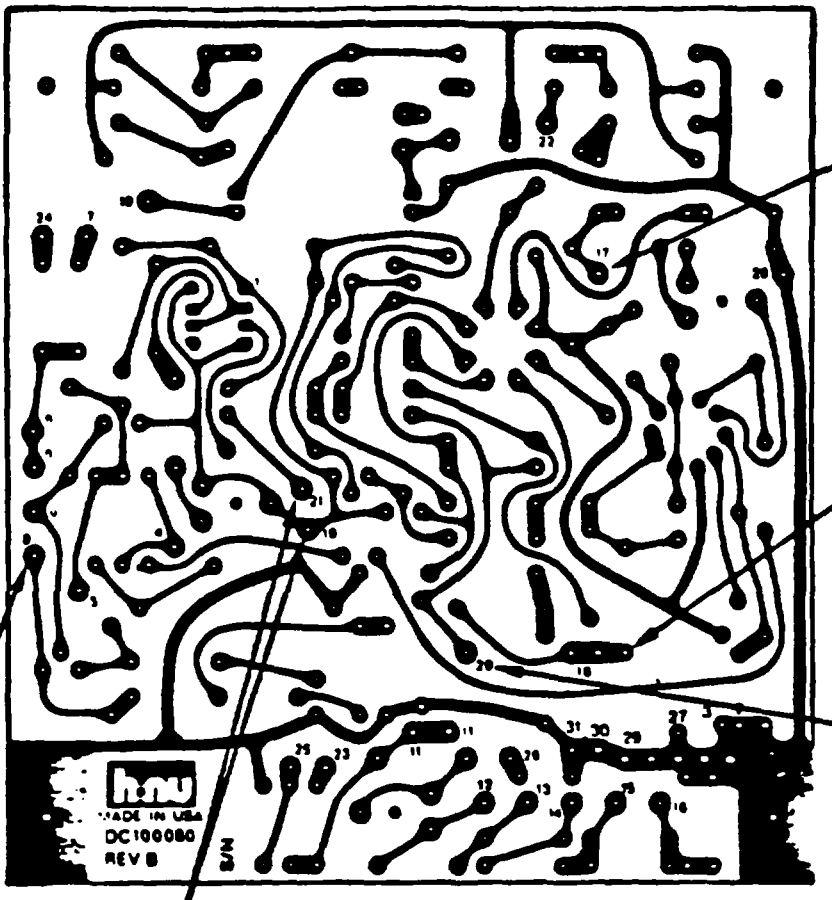


Figure 10. Component Parts Of Readout Unit.

1. All voltages measured with probe connected and instrument mode switch in BATT CHK position.

2. All measurements referred to ground (pads 2,3 and 27) except pad 21 measured to pad 19 and pad 8 to pad 11.



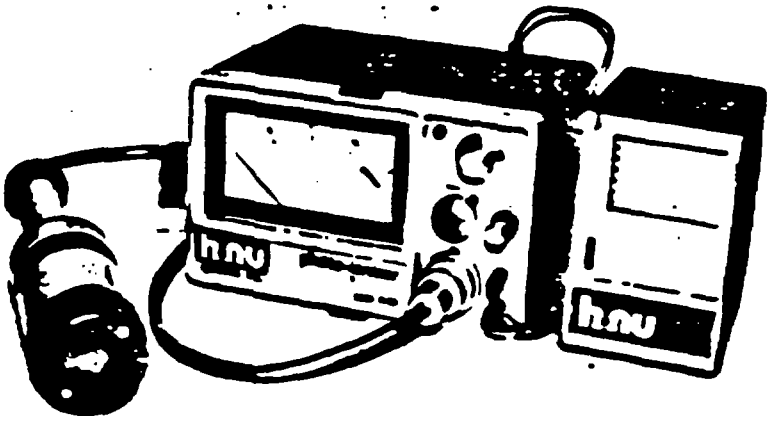
All Voltages Respect to Ground							
pads	voltage	pads	voltage	pads	voltage	pads	voltage
1	−5.7V	9	−12.2V	17	180V	25	0
2	GRD	10	−12.1V	18	−19.4V	26	0
3	GRD	11	0	19	−10.6V	27	GRD
4	−10.7V	12	0	20	−9.7V	28	0
5	−11.3V	13	0	21	−14.5V	29	GRD
6	−12.1V	14	0	22	−400V	30	GRD
7	0	15	0	23	0	31	GRD
8	−12.2V	16	0	24	0		

Figure 11 Power Supply PC Board

SECTION 6

REPLACEMENT PARTS LIST

Part No.		Assembly
100004A		Probe Shell Assembly
100005A	*	Ion Chamber
100006A		Fan/Light Source Housing
100007A		Amplifier Board
100008A		Fan
100009A	*	Light Source (10.2 eV)
100010A	*	"O" Ring Kit
100011A		Battery
100012A		Meter
100013A		Charger
100014A		Power Supply Unit
100015A & 100016A		Case (both halves)
100017A & 100018A		Straps
100019A		Switch
100020A		Pot (span)
4750-0001A		Pot (zero)
100074		Probe Extension

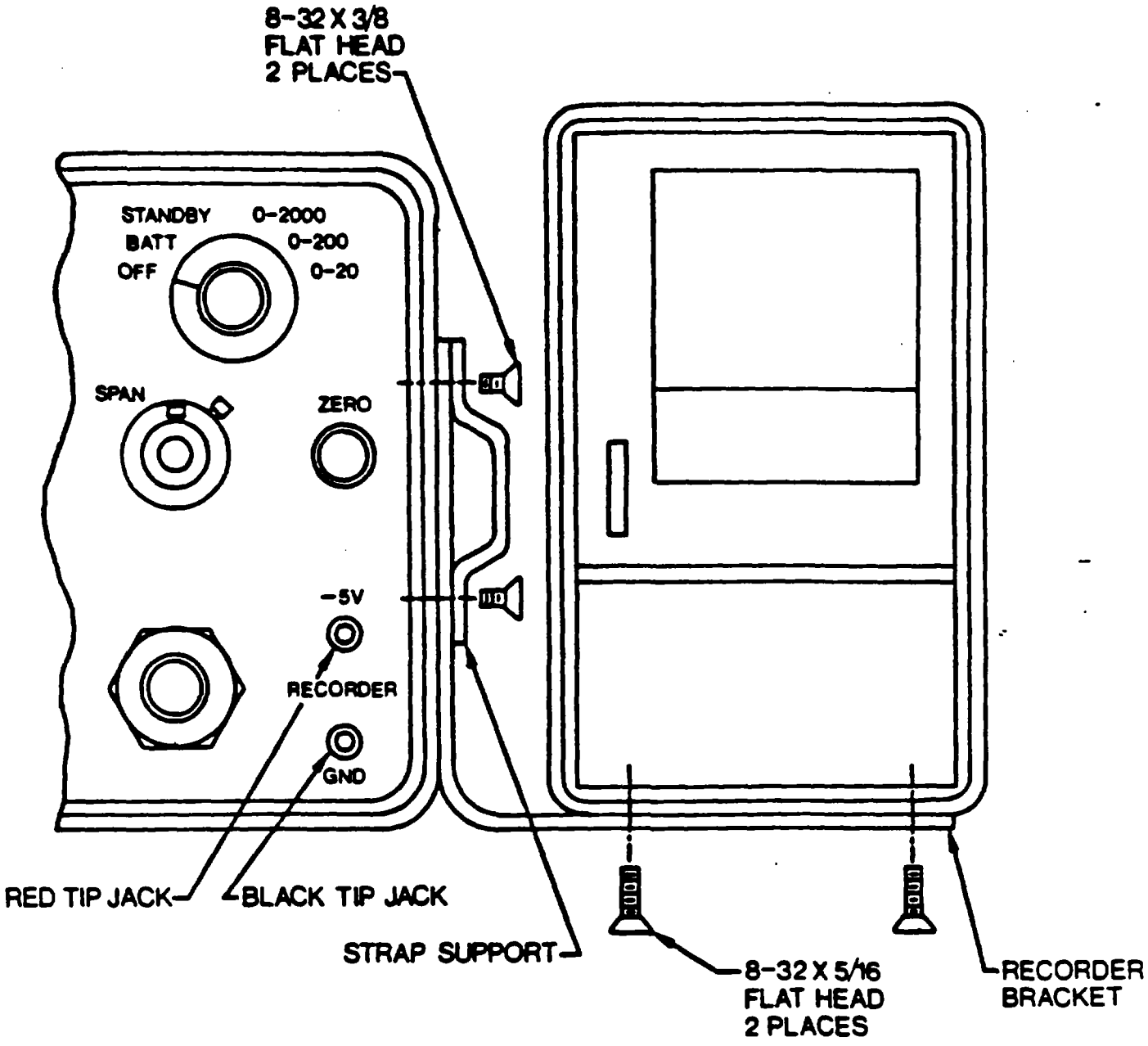


SECTION 7

MODEL PI101 PHOTOIONIZATION ACCESSORIES

101-300	Portable Recorder, having a 2" chart width with 2"/hour chart speed. Operates on 12 VDC power from Model PI101. Complete with multiconductor interface cable for battery power & signal and mounting bracket for attaching recorder to side of PI101.
101-301	Chart Paper, for portable recorder, 6 rolls.
101-320	Audible Alarm, 85 decibels, adjustable 0 to 100% of full scale on any range.
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 gas cylinder, Model 101-350, complete with gauges for reading both cylinder pressure and flow.
101-500	Cleaning Compound, for removing deposits from window of UV lamp.

SECTION 8
PI-101 RECORDER ASS'Y
INSTRUCTIONS



NOTES:

1. Remove strap support on right side of PI-101 case.
2. Mount recorder bracket between case & strap support using 8-32 X 3/8 long screws supplied.
3. Mount recorder to bracket using 8-32 X 5/16 screws supplied.
4. Connect harness to plug on rear of recorder. Insert power plug into receptacle on side of case. Insert red pin plug into red tip jack and black pin plug into black tip jack on PI-101 front panel.

SECTION 9

WARRANTY

HNU Systems Incorporated warrants that all items delivered under this order will 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.

Publications on Photoionization Available from HNU Systems

(1) Driscoll, J. N. and P. Warneck, "The Analysis of ppm Levels of Gases in Air by Photoionization Mass Spectrometry," J. Air Poll. Cont. Assoc. *23*, 858 (1973).

(2) Driscoll, J. N. and F. F. Spaziani, "A New Instrument for Continuous Monitoring of Odorous Sulfur Compounds," presented at the ISA National Meeting, N.Y. (Oct. 1974).

(3) Driscoll, J. N. and F. F. Spaziani, "Trace Gas Analysis by Photoionization" presented at the ISA Analysis Instrumentation Div. Meeting, King of Prussia, Pa. (May 1975).

(4) Photoionization Detector for Gas Chromatography," presented at the Pittsburgh Conf. on Anal. Chem. and Spectroscopy, Cleveland (March 1976).

Requests for these papers should be sent to:

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ADDENDUM

The following changes to the Instruction Manual should be noted for all Model 101 Photoionization Analyzers equipped with 11.7, 9.5 eV light sources, or calibrated on species other than benzene.

Page

3 Table I

Performance: Consult specifications sheet accompanying instrument.

11 Paragraph 2: Consult specifications sheet for span setting specific for gas on which instrument was calibrated.

NOTE: Gain settings listed apply to 10.2 eV lamp. Different gain settings are used with other lamps. Consult factory.

13 Table III

NOTE: Data obtained using 10.2 eV lamp.

14 Table IV

NOTE: Data obtained using 10.2 eV lamp.

18 Figure 4

NOTE: Data obtained using 10.2 eV lamp.

24 Paragraph 1, Line 6: "The photons which are emitted from the lamp, pass through a UV transmitting window and into the ionization chamber where absorption of the UV radiation by a molecule which has an ionization potential equal to or less than the energy of the light source will lead to ion formation via;" (continued)

25 Figure 7: For the 9.5 eV light source, the lamp voltage changes to +450 volts.

ADDENDUM A

to

Instruction Manual

for

Model PI 101

PHOTOIONIZATION ANALYZER

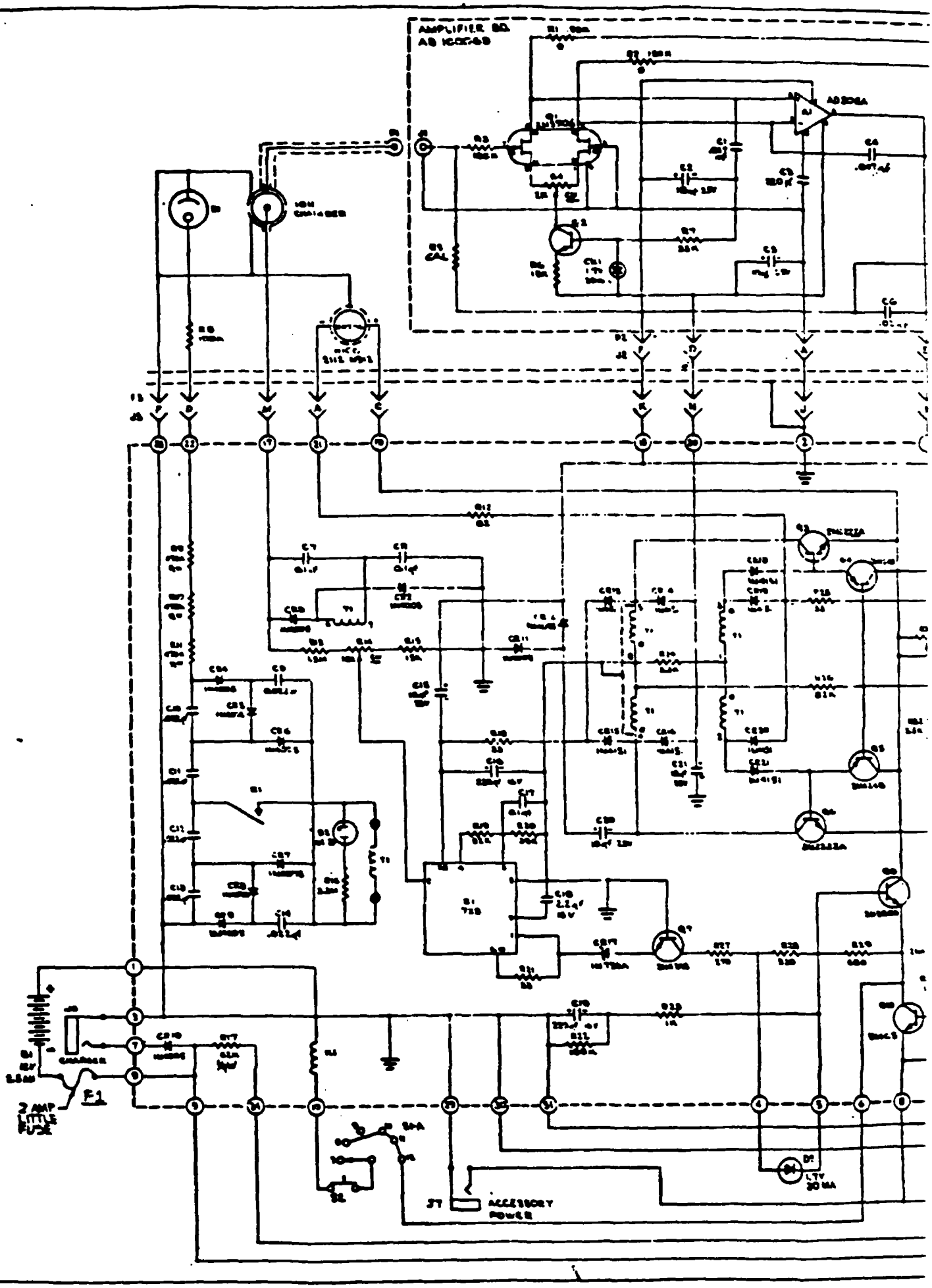
ION CHAMBER CLEANING PROCEDURE

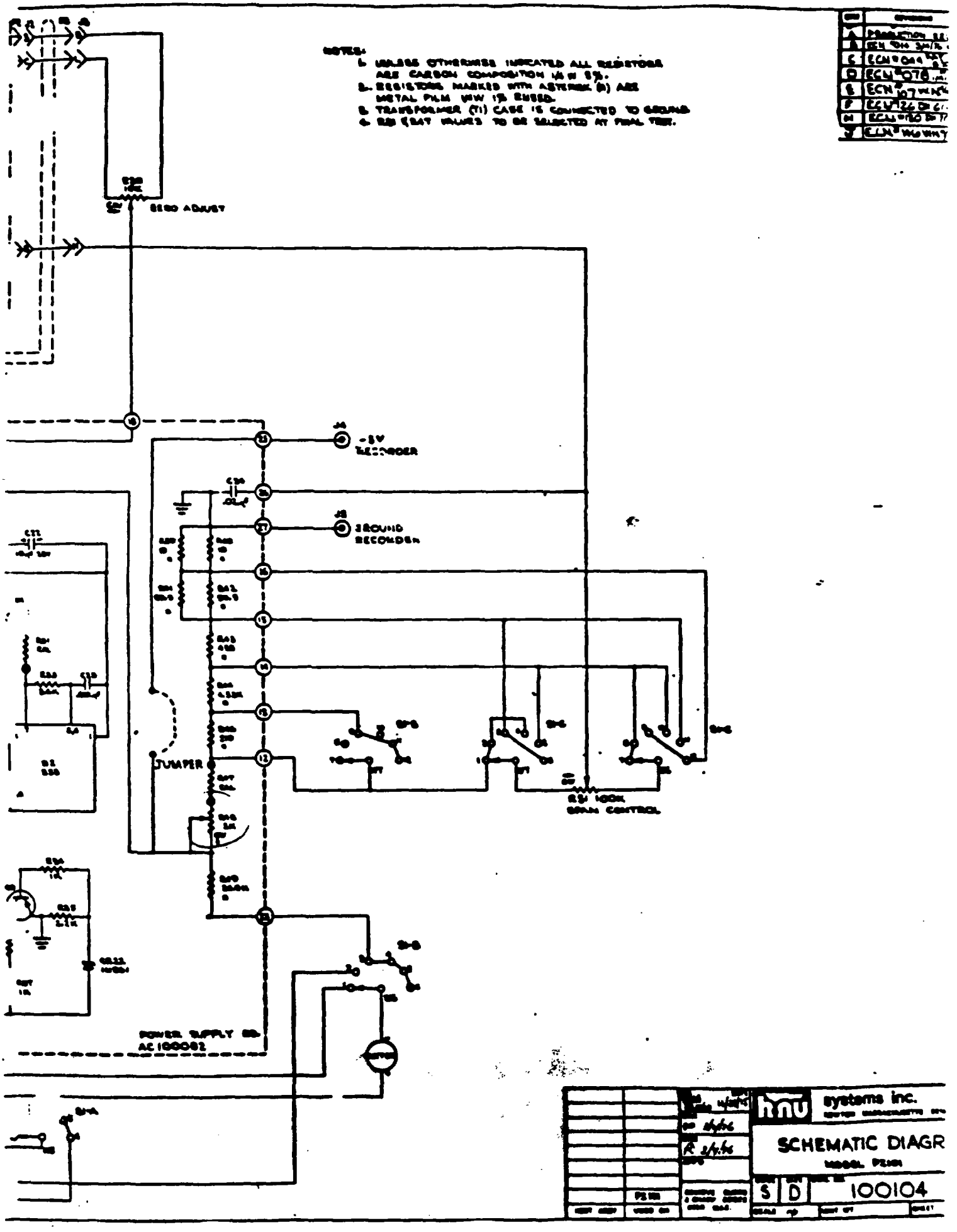
Although the technique of photoionization is not sensitive to moisture, some electronic instability can be seen in the 101 portable analyzer as the result of excessive moisture. The following chart lists the symptoms expected, the possible causes, and solutions:

Symptom	Possible Cause	Solution
Loss in sensitivity	Condensation on instrument window	Avoid extreme temperature changes
		Acclimatize instrument to environment
Zero drift	Condensation on polarizing electrode	"
	Ion chamber is dirty	Clean ion chamber

To clean the ion chamber: (See Section 5.2)

Remove the ion chamber. Remove all four screws, swing screen aside, and pull out the mesh. Using a Q-tip, gently clean the chamber with methanol to remove deposit . Dry in a vacuum oven at 90°C for 2 hours. Reassemble.


AMPLIFIER BD.
AB 1C0C4B
F1
2 AMP
ACCESSORY
POWER
LTV
20 MA


NOTES:
1. UNLESS OTHERWISE INDICATED ALL RESISTORS ARE CARBON COMPOSITION 1/4 W 5%.
2. RESISTORS MARKED WITH ASTERISK (*) ARE METAL FILM 1/4W 1% RATED.
3. TRANSFORMER (T1) CASE IS CONNECTED TO GROUND.
4. R20 (SET VALUES TO BE SELECTED AT FINAL TEST.
ZERO ADJUST
-5V RECORDER
GROUND RECORDER
JUMPER
GAIN CONTROL
POWER SUPPLY
AC 100082
hnu systems inc.
SCHEMATIC DIAGR
S
D
100104

APPENDIX B: hNu TROUBLE SHOOTING GUIDE

APPENDIX B

hNu TROUBLE SHOOTING GUIDE

1. No meter response in any switch position (including BATT CHK)

   A. Broken meter movement

      (1) Tip instrument rapidly from side to side. Meter needle should move freely, and return to zero.

   B. Electrical connection to meter is broken

      (1) Check all wires leading to meter and clean the contacts of quick-disconnects.

   C. Battery is completely dead

      (1) Disconnect battery and check voltage with a volt-ohm meter.

   D. Check 2 amp fuse

   E. If none of the above solves the problem, consult the factory.

2. Meter responds in BATT CHK position, but reads zero or near zero for all others

   A. Input transistor or amplifier has failed

      (1) Rotate zero control; meter should deflect up/down as control is turned.

      (2) Open probe. Both transistors should be fully seated in sockets.

   B. Input signal connection broken in probe or readout

      (1) Check input connector on printed circuit board. Should be firmly pressed down.

      (2) Check components on back side of printed circuit board. All connections should be solid, and no wires should touch any other object.

      (3) Check all wires in readout for solid connections.

3. Instrument responds correctly in BATT CHK, and STBY, but not in measuring mode.

   A. Check to see that light source is on

hNu TROUBLE SHOOTING GUIDE

4. Instrument responds correctly in all positions, but signal is lower than expected.

   A. Check span setting for correct value.

   B. Clean window of light source.

   C. Double check preparation of standards.

   D. Check for proper fan operation.

   E. Rotate span setting. Response should change if span pot is working properly.

5. Instrument responds in all switch positions, but is noisy (erratic meter movement).

   A. Open circuit in feedback circuit. Consult the factory.

   B. Open circuit in cable shield or probe shield. Consult the factory.

6. Instrument response is slow and/or irreproducible.

   A. Fan operating improperly.

   B. Check calibration and operation.

7. Low battery indicator.

   A. Indicator comes on if battery charge is low.

   B. Indicator also comes on if ionization voltage is too high.

APPENDIX C: IONIZATION POTENTIALS OF SELECTED MOLECULES

TABLE C-1

IONIZATION POTENTIALS (IP) OF
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 C-2

IONIZATION POTENTIALS (IP) OF
SOME 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 C-3

IONIZATION POTENTIALS (IP) OF
SOME ALKYL HALIDES

Molecule	IP (eV)
HCl	12.74
Cl_2	11.48
CH_4	12.98
methyl chloride	11.28
dichloromethane	11.35
trichloromethane	11.42
tetrachloromethane	11.47
ethyl chloride	10.98
1,2-dichloroethane	11.12
1-chloropropane	10.82
2-chloropropane	10.78
1,2-dichloropropane	10.87
1,3-dichloropropane	10.85
1-chlorobutane	10.67
2-chlorobutane	10.65
1-chloro-2-methylpropane	10.66
2-chloro-2-methylpropane	10.61
HBr	11.62
Br_2	10.55
methyl bromide	10.53
dibromomethane	10.49
tribromomethane	10.51
CH_2BrCl	10.77
$CHBr_2Cl$	10.59
ethyl bromide	10.29
1,1-dibromoethane	10.19
1-bromo-2-chloroethane	10.63

TABLE C-3 (Cont.)

IONIZATION POTENTIALS (IP) OF
SOME ALKYL HALIDES

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
$n\text{-}C_3F_7I$	10.36
$n\text{-}C_3F_7CH_2Cl$	11.84
$n\text{-}C_3F_7CH_2I$	9.96
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

TABLE C-3 (Cont.)

IONIZATION POTENTIALS (IP) OF
SOME ALKYL HALIDES

Molecule	IP (eV)
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

TABLE C-4

IONIZATION POTENTIALS (IP) OF
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 C-5

IONIZATION POTENTIALS (IP) OF
SOME 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 C-6

IONIZATION POTENTIALS (IP) OF
SOME 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 C-7

IONIZATION POTENTIALS (IP) OF
SOME 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 C-8

IONIZATION POTENTIALS (IP) OF
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 C-9

IONIZATION POTENTIALS (IP) OF
SOME OLEFINS, CYCLO-OLEFINS, POLENES, 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-cinylcyclohexene	8.93
cyclo-octatetraene	7.99
acetylene	11.41
propyne	10.36
1-butyne	10.18

TABLE C-10

IONIZATION POTENTIALS (IP) OF
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 C-11

IONIZATION POTENTIALS (IP) OF
SOME 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 C-12

IONIZATION POTENTIALS (IP) OF SOME 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	7.96
2-methylnapthalene	7.955
biphenyl	8.27
phenol	8.50
anisole	8.22
phenetole	8.13

TABLE C-12 (Cont.)

IONIZATION POTENTIALS (IP) OF
SOME AROMATIC COMPOUNDS

Molecule	IP (eV)
benzaldehyde	9.53
acetophenone	9.27
benzenethiol	8.33
phenyl isocyanate	8.77
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

TABLE C-12 (Cont.)

IONIZATION POTENTIALS (IP) OF
SOME AROMATIC COMPOUNDS

Molecule	IP (eV)
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 C-13

IONIZATION POTENTIALS (IP) OF
SOME 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
$(n\text{-}C_3F_7)(CH_3)C{=}O$	10.58
trichlorovinylsilane	10.79
$(C_2F_5)_3N$	11.7
isoprene	9.08
phosgene	11.77

APPENDIX D: RELATIVE SENSITIVITIES FOR VARIOUS GASES (10.2 eV Lamp)

RELATIVE SENSITIVITIES FOR VARIOUS GASES

(10.2 eV Lamp)

Species	Photoionization Sensitivity*	
p-xylene	11.4	
m-xylene	11.2	
benzene	10.0	(reference standard)
toluene	10.0	
diethyl sulfide	10.0	
diethyl amine	9.9	
styrene	9.7	
trichloroethylene	8.9	
carbon disulfide	7.1	
isobutylene	7.0	
acetone	6.3	
tetrahydrofuran	6.0	
methyl ethyl ketone	5.7	
methyl isobutyl ketone	5.7	
cyclohexanone	5.1	
naptha (86% aromatics)	5.0	
vinyl chloride	5.0	
methyl isocyanate	4.5	
iodine	4.5	
methyl mercaptan	4.3	
dimethyl sulfide	4.3	
allyl alcohol	4.2	

*Expressed in ppm (V/V)

RELATIVE SENSITIVITIES FOR VARIOUS GASES

(10.2 eV Lamp)

Species	Photoionization Sensitivity*
propylene	4.0
mineral spirits	4.0
2,3-dichloropropene	4.0
cyclohexene	3.4
crotonaldehyde	3.1
acrolein	3.1
pyridine	3.0
hydrogen sulfide	2.8
ethylene dibromide	2.7
n-octane	2.5
acetaldehyde oxime	2.3
hexane	2.2
phosphine	2.0
heptane	1.7
allyl chloride (3-chloropropene)	1.5
ethylene oxide	1.0
acetic anhydride	1.0
α-pinene	0.7
dibromochloropropane	0.7
epichlorohydrin	0.7
nitric oxide	0.6
β-pinene	0.5

*Expressed in ppm (V/V)

RELATIVE SENSITIVITIES FOR VARIOUS GASES

(10.2 eV Lamp)

Species	Photoionization Sensitivity*
citral	0.5
acetic acid	0.1
nitrogen dioxide	0.02
methane	0.0
acetylene	0.0
ethylene	0.0

*Expressed in ppm (V/V)

APPENDIX G: GLOSSARY OF TERMS

GLOSSARY

AC battery charger - a black rectangular box with two cords attached to it. One cord plugs into an AC outlet, while the other cord attaches to the instrument being recharged. The OVA charger has a charge on/off switch.

Backflush valve - on the OVA; used to reverse the hydrogen flow through the column; injected samples then flow directly to the detector.

B-column - One of the three types of columns made for the OVA. This column contains 3% Diisodecyl Phthalate on chromosorb WAW 60/80 mesh. This is a low polarity column.

Battery check - instrument switch on both the OVA and the hNu that indicates the charge in the battery.

Battery pack - located on the front of the OVA and on the back of the hNu; serves as the power source of the instrument.

Carrier gas - used in the OVA to carry ambient air through the column and to the detector, or directly to the detector. H_2 is the gas.

Charcoal filter - there are two that can be used on the OVA. One is permanently attached and is used whenever a chromatogram is run. The other may be screwed into the probe/readout assembly.

Chromatogram - a finger print of a sample. Different peaks on a strip chart represent different volatile organic chemicals. A chromatogram is obtained after a syringe injection of headspace gas is made into the column through the T-adapter.

Column - a variable length nickel tube (usually 8", 12" or 24") that contains a certain parking (Type T, B, or G).

Concentration range selector - This is on the OVA and hNu. The desired range can be set when monitoring the ambient air. The OVA and hNu both have three settings: 1 to 10, 1 to 100, and 1 to 1000 on the OVA; while the hNu has 0 to 20, 0 to 200, and 0 to 2000.

DOT exemption - a letter of exemption of the OVA from the aircraft rules which do not allow flammable gas to be shipped. This exemption may allow the OVA to be shipped or carried full on passenger aircraft.

Electronic zero - found on the hNu; it is used to adjust the zero electronically when the instrument is placed in the standby position with the probe attached.

Fan - in the hNu, it maintains a flow of sample gas through the ion chamber.

Flame arrestor - a gold colored metal screen that contains the flame of the flame ionization detector. It is located at the bottom of the OVA.

Flame ionization detector - a detector that uses a flame, fueled by hydrogen, to ionize individual contaminants as they emerge from the column. The ions are then attracted to an oppositely charged electrode, causing a current and finally an electric signal to the Strip Chart Recorder.

Flame-out alarm - audible alarm that is activated when the flame in the flame ionization detector goes out.

Gas select knob - found on the OVA, it provides a choice of setting where a certain gas can be used to calibrate the instrument.

G-column - one of the three types of columns made for the OVA. This column contains a 10% OV-101 on chromosorb W AW-DMCS treated 60/80 mesh.

Glow plug - located in the chamber that supports the flame for the flame ionization detector. It provides the ignition source for the flame.

Headspace sample - a VOA vial filled three quarters of the way with water or soil. The remaining quarter of the vial is airspace.

Hydrogen - a diatomic gas that serves as the carrier gas and fuel supply for the OVA.

Hydrogen fill hose - a hose with a pressure gauge, an adaptor to a type 1A hydrogen cylinder, and an adaptor to the refill valve on the OVA. It serves to refill the OVA with hydrogen from the type 1A cylinder.

H_2 refill valve - This valve is only turned on when there is an open path through the hydrogen fill line to the type 1A hydrogen cylinder.

H_2 supply pressure valve - in the open position this valve allows a measured flow of hydrogen through the column and on to the detector in the OVA.

H_2 tank valve - in the open position this allows the hydrogen from the OVA's cylinder to flow to the H_2 supply pressure valve.

Ignite button - when this is depressed the element in the glow plug glows red hot and causes ignition of the flame of the flame ionization detector.

Injection - this takes place when a syringe containing gas is introduced into the column through the septum contained in the T-adaptor, and depressed so as to enter its contents into the column.

Instrument switch - found on the OVA, this switch turns on the electronics for the OVA except for the pump and glow plug.

Ionization energy - energy needed to ionize gaseous molecules. This is usually expressed as ionization potential.

Isothermal column - a column that is wrapped around a hollow metal tube and then insulated with styrofoam. The purpose of this structure is to keep the column at a fixed temperature throughout the analysis.

Lamp - found in the probe of the hNu, it emits ultraviolet light (photons) into the ionization chamber.

Mercury - used in making standards for the OVA. A small amount is used to cover the septum when the standard is inverted for storage in order to prevent the solvent vapor from escaping.

Mylar bag - used to hold a gas mixture, which can be introduced into the OVA or hNu through an attached hose or syringe injection.

"Off-scale" - term used to describe the full scale deflection of the needle for a particular concentration on the OVA or hNu.

Packing - the inner contents of the chromatographic columns used for the OVA. The different packings are designated by letters: T, B, and G.

Parts per billion - 1 part of a chemical in 1 billion parts of air or water (by volume).

Parts per million - 1 part of a chemical in 1 million parts of air or water (by volume).

Photoionization - the absorption of ultraviolet light (a photon) by a molecule that leads to ionization. $RH + h\nu \rightarrow RH^+ + e^-$, where RH is a trace gas and hv is a photon with an energy greater than or equal to ionization potential of RH.

Photon - a quantity of ultraviolet light

Porous filters - particle filters that are found in the probe fixtures and at the junction of the umbilical cord and the side pack assembly.

Primary calibration gas - for the OVA this gas is a methane/air mixture, and the gas select knob is set at 3.0; while the hNu uses a benzene/air mixture and the span setting is 9.8.

Probe/Probe readout assembly (OVA) - attached to the end of the umbilical cord of the OVA, it contains the inlet of the air sampling line and a dial with a linear scale readout.

Probe (hNu) - attached at the end of the electrical cord that orginates from the instrument panel of the hNu. The probe contains a lamp, ionization chamber and a fan to draw in sample gas to the ionization chamber.

Probe extender - both the OVA and hNu have one. It attaches to the end of the probe to shorten the distance one has to get to the source of interest.

Pump switch - found on the OVA, when in the on position it pumps in ambient air at a rate of 2 units.

Retention time - the total time required for a volatile chemical to emerge from the column into the detector from the moment of introduction into the column of the OVA.

Sample screening - Determining total volatile organic chemical content of ambient air or a headspace sample by injection into the T-adaptor of the OVA while the OVA is in the backflush mode.

Sample flow rate gauge - This gauge is used to monitor the intake of ambient air by the pump.

Sample inject valve - When this valve is in the "up" position ambient air is pumped directly to the detector and the instrument is in the survey mode. If depressed during the survey mode, the ambient air is redirected through a charcoal filter before continuing to the detector.

Septum - This is a replaceable, circular, rubber disc with a ten millimeter diameter that fits into the septum adaptor.

Septum adaptor - This screws onto the T-adaptor and provides a guide for the syringe during injections.

Side Pack Assembly - This is the main unit of the OVA. It contains most of the operating controls and indicators, the electronic circuitry, detector chamber, hydrogen fuel supply and electrical power supply.

Standard - This is a known chemical that is in solution with distilled water and contained in a VOA vial in such a way that a headspace is present. A syringe can then withdraw some of the headspace gas after the vial is agitated, and this gas can then be injected into the column for chromatographic analysis. Comparison to unknown samples then follows.

Standby knob - this is found on the hNu and allows the hNu to warm up in a non-emergency demanding position. The instrument can also be electronically zeroed at this position.

Strip Chart Recorder - a ticking type recorder that forms a permanent record of the electronic signals that come from the detector.

Survey mode - the OVA is in this mode when the sample inject valve is in the up position. In this mode ambient air is pumped directly to the detector.

Syringe - a gas tight hollow glass tube with a hollow needle on one end and a plunger on the other end that is used to collect headspace gas or ambient air for injections into the OVA.

T-Column - one of the three types of columns made for the OVA. This column contains a 1% 1,2,3 Tris (2 cyanoethoxy) propane (also known as TCEP) on chromosorb W HP, 60/80 mesh.

Teflon tape - used to obtain an air tight seal between connectors in the hydrogen line of the OVA.

Total volatile organic reading - measurement of total volatile organic chemical content of ambient air.

Ultraviolet light - This light or radiation has a wavelength (λ) between 4000-2000 $\mathring{A}$.

Umbilical cord - two cords intertwined bridging the side pack assembly of the OVA to the probe assembly. This umbilical cord contains an electronic cable and an ambient air sampling line.

UV transmitting window - window on the UV lamp of the hNu that emits photons of UV light.

VOA Vial - a tubular glass vial with a rubber septum cap that is coated with Teflon on one side (usually 40 to 45 ml).

Volatile organics - organic chemicals that have low boiling points and high vapor pressures.

APPENDIX 4.2

CENTURY ORGANIC VAPOR ANALYZER
MODEL OVA 128

Instruction

MI
611-132
December 1985

Model OVA 128
CENTURY Organic Vapor Analyzer

FIGURE 1
PORTABLE ORGANIC VAPOR ANALYZER

FOXBORO®

WILLIAMS RUSSELL & JOHNSON INC

INTRODUCTION

The Model OVA 128 CENTURY Organic Vapor Analyzer (OVA 128) is manufactured in three configurations. These are:

- Basic Flame Ionization Detector for monitoring total hydrocarbons
- Gas chromatograph supplied with two columns
- Gas chromatograph tri-column for Benzene Analysis.

A battery charger can be ordered for either 120 V ac, 60 Hz or for 220 V ac, 50 Hz. Classifications are:

- FM certified for use in Class I, Groups A, B, C, and D, Division 1 hazardous environments.
- BASEEFA certified intrinsically safe, Ex ib, for IIC, Zone 1, Temperature Class T6. BASEEFA No. 76002/B std. SFA 3007.

Accessories for the OVA 128 are:

- Strip Chart Recorder - either FM or BASEEFA certified.
- Activated Charcoal Filter Assembly - used for zeroing the analyzer in a contaminated environment. Also used with dessicant as a moisture trap.
- Sample Dilutor Assembly for 10:1, 25:1, or 50:1 sample dilution.
- Septum Adapter for direct, on-line injection with the GC.
- Portable Isothermal Pack (PIP) for temperature control of GC columns.

The OVA 128 is a sensitive instrument designed to measure trace quantities of organic materials in air. It is essentially a flame ionization detector such as utilized in laboratory gas chromatographs and has similar analytical capabilities. The flame ionization detector is an almost universal detector for organic compounds with the sensitivity to measure in the parts per million range (V/V) in the presence of atmospheric moisture, nitrogen oxides, carbon monoxide, and carbon dioxide.

The instrument has broad application since it has a chemically resistant air sampling system and can be readily calibrated to measure almost all organic vapors. It has a single linearly scaled readout from 0 ppm to 10 ppm with a X1, X10, and X100 range switch. This range expansion feature provides accurate readings across a wide concentration range with either 10, 100 or 1000 ppm full scale deflection. Designed for use as a portable survey instrument, it can also be readily adapted to fixed remote monitoring or mobile installations. It is ideal for the determination of many organic air pollutants and for monitoring the air in potentially contaminated areas.

The OVA 128 is certified by Factory Mutual Research Corporation (FM) for use in Class I, Groups A, B, C, & D, Division I hazardous locations. Similar foreign certifications have been obtained, including BASEEFA. This requirement is especially significant in industries where volatile flammable petroleum or chemical products are manufactured or used and for instruments which are used in portable surveying or for analyzing concentrations of gases and vapors. Such instruments must be incapable, under normal or abnormal conditions, of causing ignition of hazardous mixtures in the air. In order to maintain the certified safety, it is important that the precautions outlined in this manual be practiced and that no modifications be made to these instruments.

It is highly recommended that the entire manual be read before operating the instrument. It is essential that all portions relating to safety of operation and maintenance be thoroughly understood.

Reference Literature

MI 611-101 Operation of Tri-Column GC Option
MI 611-102 Operation of Dilutor Kit
MI 611-105 Operation of Portable Isothermal Pack

GENERAL DESCRIPTION

The OVA 128 Analyzer is designed to detect and measure hazardous organic vapors and gases found in most industries. It has broad application since it has a chemically resistant sampling system and can be calibrated to almost all organic vapors. It can provide accurate indication of gas concentration in one of three ranges: 0 to 10 ppm; 0 to 100 ppm; or 0 to 1000 ppm. While designed as a lightweight portable instrument, it can be permanently installed to monitor a fixed point.

The instrument utilizes the principle of hydrogen flame ionization for detection and measurement of organic vapors. The instrument measures organic vapor concentration by producing a response to an unknown sample, which can be related to a gas of known composition to which the instrument has previously been calibrated. During normal survey mode operation, a continuous sample is drawn into the probe and transmitted to the detector chamber by an internal pumping system.

The sample stream is metered and passed through particle filters before reaching the detector chamber. Inside the detector chamber, the sample is exposed to a hydrogen flame which ionizes the organic vapors. When most organic vapors burn, they leave positively charged carbon-containing ions. An electric field drives the ions to a collecting electrode. As the positive ions are collected, a current corresponding to the collection rate is generated. This current is measured with a linear electrometer preamplifier which has an output signal proportional to the ionization current. A signal conditioning amplifier is used to amplify the signal from the preamp and to condition it for subsequent meter or external recorder display. The display is an integral part of the Probe/Readout Assembly and has 270° scale deflection.

In general, the hydrogen flame ionization detector is more sensitive for hydrocarbons than any other class of organic compounds. The response of the OVA varies from compound to compound, but gives repeatable results with all types of hydrocarbons; i.e., saturated hydrocarbons (alkanes), unsaturated hydrocarbons (alkenes and alkynes) and aromatic hydrocarbons.

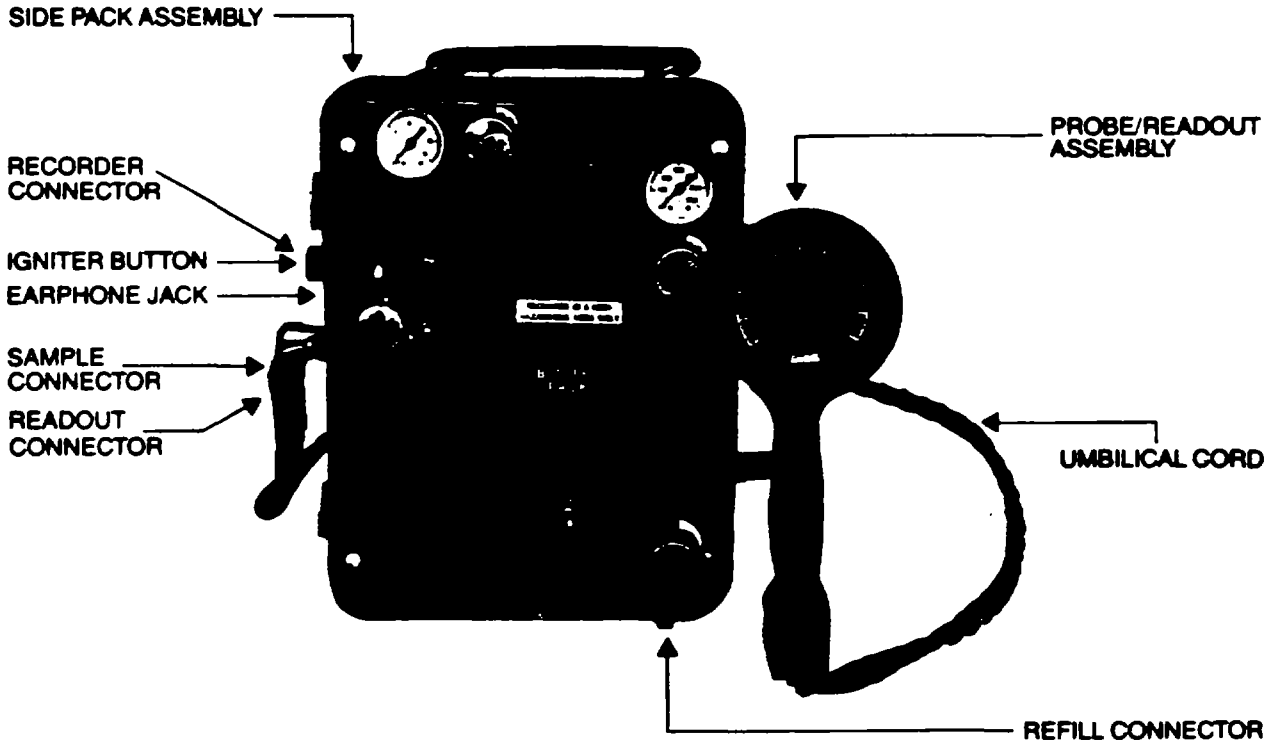


FIGURE 2
PORTABLE ORGANIC VAPOR ANALYZER
Model OVA 128

Typical response of various hydrocarbons, relative to methane is as follows:*

Compound	Relative Response (percent)
Methane	100 (reference)
Hexane	70
Propane	64
N-butane	61
N-pentane	100
Ethylene	85
Acetylene	200
Benzene	150
Toluene	120
Ethane	90

Compounds containing oxygen, such as alcohols, ethers, aldehydes, carbolic acid and esters give a lower response than that observed for hydrocarbons. This is particularly noticeable with compounds having a high ratio of oxygen to carbon such as the lower members of each series which have one, two or three carbons. With compounds containing higher numbers of carbons, the effect is diminished to such an extent that the response is similar to that of the corresponding hydrocarbons.

Nitrogen-containing compounds (i.e., amines, amides, and nitriles) respond in a manner similar to that observed for oxygenated materials. Halogenated compounds also show a lower relative response as compared with hydrocarbons. Materials containing no hydrogen, such as carbon tetrachloride, give the lowest response; the presence of hydrogen in the compounds results in higher relative responses. Thus, $CHCl_3$ gives a much higher response than does CCl_4. As in the other cases, when the carbon to halogen ratio is 5:1 or greater, the response will be similar to that observed for simple hydrocarbons.

*NOTE: Each OVA detector will have slightly different responses for organic vapors relative to methane. The user should determine responses for his individual instrument. The typical response of various compounds relative to methane is as follows:

KETONES	
Acetone	60
Methyl ethyl ketone	80
Methyl isobutyl ketone	100
ALCOHOLS	
Methyl alcohol	15
Ethyl	25
Isopropyl	65
HALOGEN COMPOUNDS	
Carbon tetrachloride	10
Chloroform	65
Trichloroethylene	70
Vinyl chloride	35

The OVA has negligible response to carbon monoxide and carbon dioxide which, due to their structure, do not produce appreciable ions in the detector flame. Thus, other organic materials may be analyzed in the presence of CO and CO_2.

Applications

(1) Measurement of most toxic organic vapors present in industry for compliance with Occupational Safety and Health Administration (OSHA) requirements.

(2) Evaluation and monitoring applications in the air pollution field.

(3) Source identification and measurement for fugitive emissions (leaks) as defined by EPA.

(4) Forensic science applications.

(5) Controlling and monitoring atmospheres in manufacturing and packaging operations.

(6) Leak detection related to volatile fuel handling equipment.

(7) Monitoring the background level of organic vapors at hazardous waste sites.

(8) Quality control procedures geared to leak checking, pressurized system checks, combustion efficiency checks, etc.

Major Features

The basic instrument consists of two major assemblies, the Probe/Readout Assembly and the Side Pack Assembly (See Figure 2). The recorder is optional on all models, but is normally used with all instruments which incorporate the GC Option. The output meter and alarm level adjustments are incorporated in the Probe/Readout Assembly.

The Side Pack Assembly contains the remaining operating controls and indicators, electronic circuitry, detector chamber, hydrogen fuel supply, and electrical power supply.

Other major features are: linear scale readout, approximately two second response time and portable operating time of 8 hours for fuel supply and battery pack. A battery test feature allows charge condition to be read on the meter. Hydrogen flame-out is signified by an audible alarm plus a visual indication on the meter. The instrument contains a frequency modulated detection alarm which can be preset to sound at a desired concentration level. The frequency of the detection alarm varies as a function of detected level giving an audible indication of organic vapor concentration. An earphone is provided to allow the operator to hear the alarm in noisy areas or to avoid disturbing workers.

During use, the Side Pack Assembly can be carried by the operator on either his left or right side or as a back pack. The Probe/Readout Assembly can be detached from the Side Pack Assembly and disassembled for transport and storage.

Standard Accessories

A variety of sampling fixtures can be used. In addition, small diameter tubing can be used for remote sampling or electrically insulated flexible extensions can be used for places that are difficult to reach.

Telescoping Probe

Probe length can be increased or decreased over a 22 to 30 inch range to suit the individual user. A knurled locking nut is used to lock the probe at the desired length. The probe is attached to the Readout Assembly. When appropriate, the probe is replaced with a Close Area Sampler, which is supplied as a standard accessory.

Sampling Accessories

Part Number	Description
510125-1	Close area sampler - Connects directly to the readout assembly.
510035-1	Telescoping wand - Adjustable length -accommodates the probe listed below.
510126-1	Tubular area sampler - Used with the telescoping wand.

Particulate Filters

The primary filter of porous stainless steel is located behind the sample inlet connector (see Side Pack Assembly drawing). In addition, a replaceable porous metal filter is installed in the "close area" sampler.

Carrying Case

An instrument carrying case is provided to transport, ship and store the disassembled Probe/Readout Assembly, the Side Pack Assembly and other equipment.

Specifications

READOUT: 0 to 10, 0 to 100, 0 to 1000 ppm (linear)
SAMPLE FLOW RATE: 1 1/2 to 2 1/2 litre per minute at 22°C, 760 mm, using close area sampler
RESPONSE TIME: Approximately 2 seconds for 90% of final reading.
PRIMARY ELECTRICAL POWER: 12 volt (nominal) battery pack.
FUEL SUPPLY: Approximately 75 mL volume tank of pure hydrogen, maximum pressure 2400 psig, fillable in case.
HYDROGEN FLOW RATE: Factory set 12.5 ±0.5 mL/min (minus GC option) 11.0 ±0.5 mL/min (GC models)
PORTABLE OPERATING TIME: Minimum 8 hours with battery fully charged, hydrogen pressure at 1800 psig.
PHYSICAL DIMENSIONS: 9" x 12" x 5" (229 mm x 305 mm x 127 mm) Sidepack only.
WEIGHT: 12 pounds (5.5 kg) (sidepack and hand-held probe assembly)
DETECTION ALARM: Audible alarm plus meter indication. User preset to desired level.
FLAME-OUT ALARM: Audible alarm plus meter indication (needle drops off scale in negative direction).
BATTERY TEST: Battery charge condition indicated on readout meter. Upon activation of momentary contact switch, a meter reading above the indicator line means that there is 4 hours minimum service life remaining (at 22°C).
FILTERS: In-line sintered metal filters will remove particles larger than 10 microns.
OPERATING TEMPERATURE RANGE: 10°C to 40°C.
MINIMUM AMBIENT TEMPERATURE: 15°C for Flame Ignition (coldstart).
ACCURACY: Based on the use of a calibration gas for each range:

Calibration Temp. °C	Operating Temp. °C	Accuracy in % of Individual Full Scale X1	X10	X100
20 to 25	20 to 25	±20	±10	±10
20 to 25	10 to 40	±20	±20	±20

RELATIVE HUMIDITY: 5% to 95%, Effect on accuracy: ±20% of individual full scale
RECORDER OUTPUT: 0 to 5 volts
MINIMUM DETECTABLE LIMIT (METHANE): 0.2 ppm
STANDARD ACCESSORIES:

1. Instrument carrying and storage case
2. Hydrogen fuel filling hose assembly
3. Battery charger
4. Earphone
5. Various sampling fixtures
6. Maintenance tool kit
7. Operators manual (2 each)
8. Padded leather carrying straps

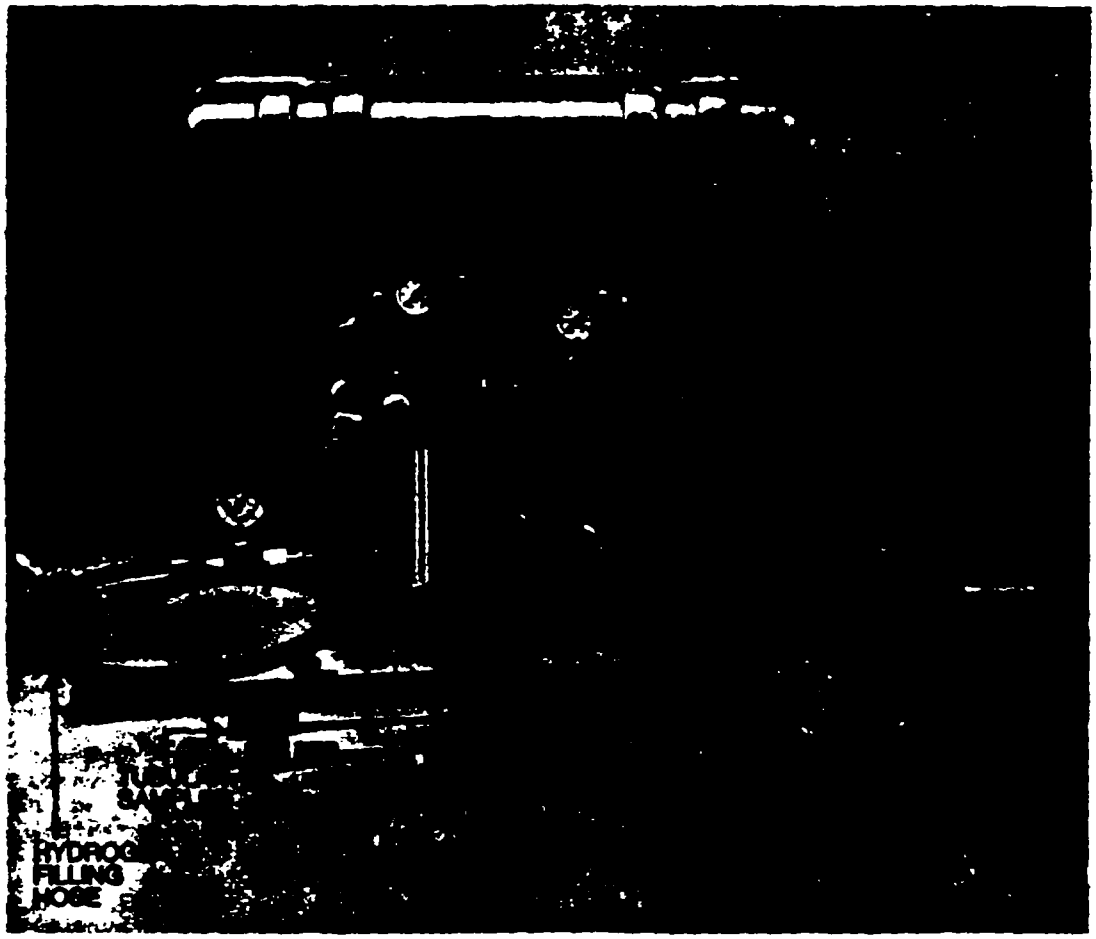


FIGURE 3
OVA-128 ANALYZER COMPONENTS
(Gas Chromatograph Model Shown)

OPERATING PROCEDURES

Controls and Indicators

Sidepack Assembly

1) INSTR/BATT Test Switch* - Three position toggle switch controls all instrument electrical power except the pump and alarm power. It also permits display of the battery charge condition on the readout meter.

2) PUMP (ON/OFF) Switch* - Toggle switch controls power to the internal pump and audio alarms.

3) Igniter Switch - Momentary push button switch connects power to the igniter coil in the detector chamber and simultaneously disconnects power to pump.

4) CALIBRATE Switch (range selector) -Selects the desired range: X1 (0 to 10 ppm); X10 (0 to 100 ppm); X100 (0 to 1000 ppm).

5) CALIBRATE ADJUST (zero) Knob -Potentiometer used to "zero" the instrument.

6) GAS SELECT KNOB (span control) - Ten-turn dial readout potentiometer sets the gain of the instrument (commonly referred to as span control).

7) Recorder Connector - Five-pin connector used to connect the instrument to an external recorder with the following pin connections:

   Pin E - + 12 V dc
   Pin H - Ground
   Pin B - Signal 0 to 5 V dc

8) Charger Connector - BNC connector used to connect the battery pack to the battery charger.

9) HYDROGEN TANK VALVE - Valve used to supply or close off the fuel supply from the hydrogen tank.

10) HYDROGEN TANK PRESSURE Indicator - High pressure gauge measures pressure in the hydrogen fuel tank which is an indication of fuel supply.

11) HYDROGEN SUPPLY VALVE - Valve used to supply or close off hydrogen fuel to the detector chamber.

12) HYDROGEN SUPPLY PRESSURE Indicator - Low pressure gauge used to monitor hydrogen pressure at the capillary restrictor.

13) SAMPLE FLOW RATE Indicator - Indicator to monitor the sample flow rate.

14) REFILL CONNECTION - ¼ in AN fitting to connect the hydrogen refill hose to the instrument.

15) REFILL VALVE - Valve to open one end of the instrument fuel tank for refilling with hydrogen.

16) EARPHONE JACK - Used to connect the earphone; speaker is disabled when earphone is used.

17) VOLUME Knob - Potentiometer adjusts the volume of the internal speaker and earphone.

18) Readout and Sample Connectors - Used to connect the sample hose and umbilical cord from the Probe/Readout to the Side Pack.

<u>Controls and Indicators</u>

Probe/Readout Assembly

1) Meter - Linear scaled 270° meter displays the output signal level in ppm.

2) Alarm Level Adjust Knob - Potentiometer (located on the back of the Readout Assembly) is used to set the concentration level at which the audible alarm is actuated.

*Special Switch - switch handle must be pulled to change position. This prevents accidental movement.

Startup Procedure

a) Connect the Probe/Readout Assembly to the Sidepack Assembly by attaching the sample line and electronic jack to the Sidepack.

b) Select the desired sample probe (close area sampler or telescoping probe) and connect the probe handle. Before tightening the knurled nut, check that the probe accessory is firmly seated against the flat seals in the probe handle and in the tip of the telescoping probe.

c) Move the Instr/Batt Switch to the test position. The meter needle should move to a point beyond the white line, indicating that the integral battery has more than 4 hours of operating life before recharging is necessary.

d) Move the Instr/Batt Switch to the "ON" position and allow a 5 minute warm-up.

e) Turn the Pump Switch on.

f) Use the Calibrate Adjust knob to set the meter needle to the level desired for activating the audible alarm. If this alarm level is other than zero, the Calibrate Switch must be set to the appropriate range.

g) Turn the Volume Knob fully clockwise.

h) Using the Alarm Level Adjust knob, turn the knob until the audible alarm is activated.

i) Move the Calibrate Switch to X1 and adjust the meter reading to zero using the Calibrate Adjust (zero knob).

j) Open the hydrogen Tank Valve 1 or 2 turns and observe the reading on the Hydrogen Tank Pressure Indicator. (Approximately 150 psi of pressure is required for each hour of operation).

k) Open the Hydrogen Supply Valve 1 or 2 turns and observe the reading on the Hydrogen Supply Pressure Indicator. The reading should be between 8 and 12 psi.

Note: With GC instrument, a column or jumper must be installed.

l) After approximately one minute, depress the Igniter Button until the hydrogen flame lights. The meter needle will travel upscale and begin to read "Total Organic Vapors". Caution: Do not depress igniter for more than 6 seconds. If flame does not ignite, wait one minute and try again.

m) The instrument is ready for use. NOTE: If the ambient background organic vapors are "zeroed out" using the Calibrate Adjust knob, the meter needle may move off-scale in the negative direction when the OVA is moved to a location with lower background. If the OVA is to be used in the 0 to 10 ppm range, it should be "zeroed" in an area with very low background. A charcoal filter (Part No. 510095-1) can be used to generate the clean background sample.

Operating Procedures

The following procedure describes operation of the OVA in the "Survey Mode" to detect total organic vapors.

a) Set the CALIBRATE Switch to the desired range. Survey the areas of interest while observing the meter and/or listening for the audible alarm indication. For ease of operation, carry the Side Pack Assembly positioned on the side opposite the hand which holds the Probe/Readout Assembly. For broad surveys outdoors, the pick-up fixture should be positioned several feet above ground level. When making quantitative readings or pinpointing, the pickup fixture should be positioned at the point of interest.

b) When organic vapors are detected, the meter pointer will move upscale and the audible alarm will sound when the setpoint is exceeded. The frequency of the alarm will increase as the detection level increases.

If the flame-out alarm is actuated, check that the pump is running, then press the igniter button. Under normal conditions, flame-out results from sampling a gas mixture that is above the lower explosve level which causes the hydrogen flame to extinguish. If this is the case, reignition is all that is required to resume monitoring. Another possible cause for flame-out is restriction of the sample flow line which would not allow sufficient air into the chamber to support combustion. The normal cause for such restriction is a clogged particle filter.

It should be noted that the chamber exhaust port is on the bottom of the case and blocking this port with the hand will cause fluctuations and/or flame-out.

Shut Down Procedure

The following procedure should be followed for shut down of the equipment:

A. Close HYDROGEN TANK VALVE
B. Close HYDROGEN SUPPLY VALVE
C. Move INSTR Switch to OFF
D. Wait 5 seconds and move PUMP Switch to OFF. INSTRUMENT IS NOW IN A SHUT DOWN CONFIGURATION.

Fuel Refilling

NOTE: Use PREPURIFIED or ZERO grade hydrogen (certified total hydrocarbons as methane <0.5 ppm recommended).

a) The instrument and the charger should be completely shut down during hydrogen tank refilling operations. Refilling should be done in a ventilated area. THERE SHOULD BE NO POTENTIAL IGNITERS OR FLAME IN THE AREA.

b) If you are making the first filling on the instrument or if the filling hose has been allowed to fill with air, the filling hose should be purged with hydrogen prior to filling the instrument tank. This purging is not required for subsequent fillings.

c) The filling hose assembly should be left attached to the hydrogen supply tank when possible. Ensure that the FILL/BLEED Valve on the instrument end of the hose is in the OFF position. Connect the hose to the refill connection on the Side Pack Assembly.

d) Open the hydrogen supply bottle valve slightly. Open the REFILL VALVE and the HYDROGEN TANK VALVE on the instrument panel and place the FILL/BLEED Valve on the filling hose assembly in the FILL position. The pressure in the instrument tank will be indicated on the HYDROGEN TANK PRESSURE Indicator.

e) After the instrument fuel tank is filled, close the REFILL VALVE on the panel, the FILL/BLEED Valve on the filling hose assembly and the hydrogen supply bottle valve.

f) The hydrogen trapped in the hose should now be bled off to atmospheric pressure. CAUTION should be used in this operation as described in Step (g) below, since the hose will contain a significant amount of hydrogen at high pressure.

g) The hose is bled by turning the FILL/BLEED Valve on the filling hose assembly to the BLEED position. After the hose is bled down to atmospheric pressure, the FILL/BLEED Valve should be turned to the FILL position to allow the hydrogen trapped in the connection fittings to go into the hose assembly. Then, again, turn the FILL/BLEED Valve to the BLEED position and exhaust the trapped hydrogen. Then turn the FILL/BLEED Valve to OFF to keep the hydrogen at one atmosphere in the hose so that at the time of the next filling there will be no air trapped in the filling line.

h) Close the HYDROGEN TANK VALVE.

i) With the HYDROGEN TANK VALVE and the HYDROGEN SUPPLY VALVE closed, a small amount of HYDROGEN at high pressure will be present in the regulators and plumbing. As a leak check, observe the HYDROGEN TANK PRESSURE Indicator while the remainder of the system is shut down and ensure that the pressure reading does not decrease rapidly (more than 350 psi/h) which would indicate a significant leak in the supply system.

Battery Charging

WARNING: Never charge in a hazardous environment.

a) Plug charger connector into mating connector on battery cover and insert ac plug into 115 V ac wall outlet.

b) Move the battery charger switch to the ON position. The lamp above the switch button should illuminate.

c) Battery charge condition is indicated by the meter on the front panel of the charger; meter will deflect to the left when charging. When fully charged, the pointer will be in line with "charged" marker above the scale.

d) Approximately one hour of charging time is required for each hour of operation. However, an overnight charge is recommended. The charger can be left on indefinitely without damaging the batteries. When finished, move the battery charger switch to OFF and disconnect from the Side Pack Assembly.

THE FOLLOWING ARE SPECIAL INSTRUCTIONS FOR RECHARGING BATTERIES WHICH HAVE BEEN COMPLETELY DISCHARGED.

It has been established that the above battery charging procedures may not be effective when the operator has allowed the battery to COMPLETELY discharge.

When this happens and the above procedures fail to charge the battery, perform the following additional steps:

e) Remove the battery from the instrument case.

f) Connect to any variable dc power supply.

g) Apply 40 volts at ½ ampere maximum.

h) Observe the power supply meter. As soon as the battery begins to draw current, gradually reduce the power maintaining ½ A maximum until the meter reads approximately 15 volts.

NOTE: The time required to reach the 15 volt reading will depend on degree of discharge.

i) Repeat steps (a), (b), (c), and (d) above to complete the charging cycle.

SUMMARY OF OPERATING PROCEDURES

Start Up

a) Check battery condition by moving the INSTR Switch to the BATT position.

b) Move INSTR Switch to ON and allow five (5) minutes to warm-up.

c) Use the Calibrate Adjust knob to set the meter needle to the level desired for activating the audible alarm. If this alarm level is other than zero, the Calibrate Switch must be set to the appropriate range.

d) Turn the Volume Knob fully clockwise.

e) Using the Alarm Level Adjust knob, turn the knob until the audible alarm is activated.

f) Set CALIBRATE Switch to X1 position, use CALIBRATE Knob and set meter to read 0.

g) Move PUMP Switch to ON position, then place instrument panel in vertical position and check SAMPLE FLOW RATE indication. The normal range is 1.5 to 2.5 units. If less, check filters.

h) Open the HYDROGEN TANK VALVE and the HYDROGEN SUPPLY VALVE. Wait one minute for hydrogen to purge the system.

i) Depress Igniter Button until burner lights. Do not depress Igniter Button for more than six seconds. (If burner does not ignite, let hydgrogen flow for one minute and again attempt ignition.)

j) Use CALIBRATE Knob to "zero" out ambient background. For maximum sensitivity below 10 ppm, set CALIBRATE Switch to X1 and readjust zero on meter. To avoid false flame-out alarm indication, set meter to 1 ppm with CALIBRATE Knob and make differential readings from there.

Shut Down

a) Close the HYDROGEN SUPPLY VALVE

b) Close the HYDROGEN TANK VALVE

c) Move the INSTR Switch and PUMP Switch to OFF

d) Instrument is now in shut down configuration

CALIBRATION

Recalibration to Various Organic Vapors

The OVA 128 is capable of responding to nearly all organic compounds. At the time of manufacture, the analyzer is calibrated to mixtures of methane in air. For precise analysis it is necessary to recalibrate with the specific compound of interest. The GAS SELECT control is used to set the electronic gain for a particular compound.

The instrument is recalibrated using a mixture of a specific vapor in air, with known concentration. After the instrument is in operation and the normal background is zeroed, draw a sample of the calibration gas into the instrument. The GAS SELECT Knob on the panel is then used to set the readout meter indication to correspond to the concentration of the calibation gas mixture.

The instrument has now been calibrated to the vapor mixture being used. After this adjustment, the setting on the "digidial" should be recorded for that particular organic vapor compound. This exercise can be performed for a large variety of compounds, thereby generating a "library" which can be used for future reference without need for additional calibration standards.

To read a particular compound, the GAS SELECT control is turned to the predetermined setting for the compound. Calibration on any one range automatically calibrates the other two ranges.

Using Empirical Data

Relative response data can be used to estimate the concentration of a vapor without need to recalibrate the analyzer. With the instrument calibrated to methane, obtain the concentration reading for a calibration sample of the test vapor. The response factor (R) in percent, for that vapor is:

$$R = \frac{\text{Actual Concentration}}{\text{Measured Concentration}}$$

To determine the concentration of an unknown sample of that vapor, multiply the measured concentration by R.

Calibration Standards

Commercial Standards

Commercially available standard samples offer the most convenience and are recommended for the most precise analyses. Always remember to obtain the desired vapor in an air background. Samples should be drawn from the cylinder into a collapsed sample bag, then drawn from the bag by the instrument to prevent a pressure or vacuum at the sample inlet.

Preparation of Standards

The following procedure is for generating calibration standards as an alternative to using commercial mixtures.

Obtain a five (5) gallon glass bottle and determine its volume by measuring the volume of water needed to fill it (use of a 1000 mL graduated cylinder is convenient). Another approach is to weigh the empty bottle, fill it with water and weigh again. The difference between the two values is the weight of water. By multiplying the weight of water in pounds by 0.455, obtain the volume of the bottle in liters. Empty the water and allow the bottle to dry. Place a one-foot piece of Teflon tubing in the flask to aid in mixing the vapors uniformly with the air. The volume of such a bottle should be about 20 liters, which is 20,000 mL. If the volume were 20,000 mL, then a 2 mL sample of a gas would be equivalent to 200 mL per 2 million mL or 100 ppm (V/V). Use of a gas tight Syringe, readable in 0.01 mL, allows the preparation of mixtures in the 1-2 ppm range, which are sufficient for the quantitative estimation of concentrations. A plastic stopper is loosely fitted to the tip of the bottle. The needle of the syringe is placed inside the jug neck and the stopper squeezed against the needle to decrease leakage during sample introduction. Inject the sample into the bottle and withdraw the needle without removing the stopper. Tighten the stopper and shake the bottle for a few minutes with sufficient vigor that the plastic tubing in the bottle moves around to ensure good mixture of the vapors with the air.

Calculations

$$\text{Injection} = \frac{\text{Volume Concentration X Molecular Weight X System Volume}}{\text{Density X Molar Volume at STP*}}$$

$$= \frac{(C)\ (MW)\ (V)}{(D)\ (V)}$$

Using the Ideal Gas Law, PV=RT, the molar volume of any gas at STP (25°C and 1 atm) is:

$$V = \frac{RT}{P} = \frac{\text{Universal Gas Constant x Temperature}}{\text{Pressure}}$$

$$= \frac{\left[(0.08206\ \frac{\text{litre atm}}{\text{mol K}})\right](298.15\ \text{K})}{1\ \text{atm}}$$

$$= (24.47\ \text{L})\ (\text{mol}^{-1})$$

Therefore, the injection volume necessary to prepare 1 liter of a 100 ppm sample of hexane would be:

$$\text{Injection Volume} = \frac{(100\ \text{ppm})\ [(86.18\ \text{g})\ (\text{mol}^{-1})]\ (1\ \text{liter})}{[(0.659\ \text{g})\ (\text{mL}^{-1})]\ [(24.47\ \text{L})\ (\text{mol}^{-1})]\ [(1000\ \text{mL})\ (1^{-1})]}$$

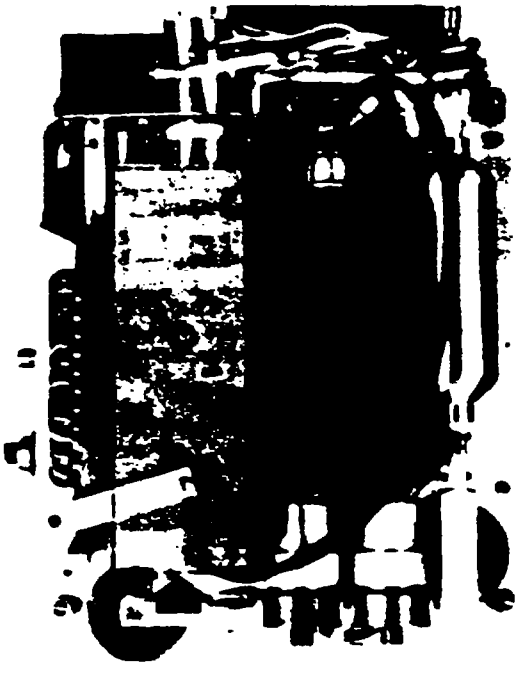
$$= 0.534\ \mu\text{L}$$

* STP - Standard Temperature and Pressure

Primary Calibration for Methane

Internal electronic adjustments are provided to calibrate and align the circuits. After initial factory calibration, it should not be necessary to repeat the calibration unless the analyzer undergoes repairs which affect calibration. If the OVA 128 will be extensively used for analysis of a sample other than methane, recalibration of the electronics (after resetting the GAS SELECT CONTROL) may result in better accuracy. See Recalibration to Various Organic Vapors above.

Primary calibration of this instrument is accomplished at the factory using methane-in-air, sample gases.



R-31 R-32 R-33 R-38

FIGURE 4
LOCATION OF ELECTRONIC ADJUSTMENTS

Calibration Using Known Samples for Each Range *(Refer to Figure 4)*

The accuracy stated under Specifications is obtained when the instrument is calibrated with known concentrations for each range. Prepare separate samples of methane-in-air in these concentration ranges: 7 to 10 ppm, 90 to 100 ppm, and 900 to 1000 ppm. Calibrate the instrument as follows:

a) Place the instrument in normal operation and allow a minimum of 15 minutes for warm-up and stabilization.

b) Set the GAS SELECT control to 300.

c) Set the CALIBRATE Switch to X1.

d) Set the CALIBRATE ADJUST (Zero) Knob so that the meter reads zero.

e) Check that the meter reads zero on the X10 and X100 ranges.

f) Set the CALIBRATE Switch to X1 and introduce the sample with known concentration in the 7 to 10 ppm range.

g) Adjust R31 so that the meter reading corresponds to the sample concentration.

h) Set the CALIBRATE Switch to X10 and introduce the sample with known concentration in the 90 to 100 ppm range.

i) Adjust R32 so that the meter reading corresponds to the sample concentration.

j) Set the CALIBRATE Switch to X100 and introduce the sample with known concentration in the 900 to 1000 ppm range.

k) Adjust R33 so that the meter reading corresponds to the sample concentration.

l) The instrument is now calibrated for methane and ready for service.

Calibration Using a Single Sample Calibration *(Refer to Figure 4)*

Calibration may be accomplished using a single known sample of methane in air in the range of 90 to 100 ppm. This may not provide the accuracy stated under specifications but is adequate for field survey work.

a) Place instrument in normal operation with CALIBRATE Switch set to X10 and GAS SELECT control set to 300.

b) Use the CALIBRATE ADJUST (zero Knob to adjust the meter reading to zero.

c) Introduce a methane sample of a known concentration (between 90 and 100 ppm not to exceed 100 ppm) and adjust trimpot R-32 so the meter reading corresponds to the known sample.

d) This sets the instrument gain for methane with the panel mounted gain adjustment (GAS SELECT) set at a reference number of 300.

e) Turn off HYDROGEN SUPPLY VALVE to put out flame.

f) Leave CALIBRATE Switch on X10 position and use CALIBRATE ADJUST (zero) Knob to adjust meter reading to 4 ppm.

g) Place CALIBRATE Switch in X1 position and using trimpot R-31 adjust meter reading to 4 ppm.

h) Move CALIBRATE Switch to X10 position again. Use CALIBRATE ADJUST (zero) Knob to adjust meter to a reading of 40 ppm.

i) Move CALIBRATE Switch to X100 position and use trimpot R-33 to adjust meter reading to 40 ppm.

j) Move CALIBRATE ADJUST (zero) Knob to adjust meter reading to zero.

k) Unit is now balanced from range to range, calibrated to methane, and ready to be placed in normal service.

SAFETY PRECAUTIONS

The OVA 128 has been tested and certified by Factory Mutual Research Corporation (FM) as safe for use in Class I, Division 1, Groups A, B, C and D hazardous atmospheres. Similar foreign certifications have been obtained, including BASEEFA. Special restrictions must be strictly adhered to, to ensure the certification is not invalidated by actions of operating or service personnel.

All flame ionization hydrocarbon detectors are potentially hazardous since they use hydrogen or hydrogen mixtures in the detector cell. Mixtures of hydrogen and air are flammable over a wide range of concentrations whether an inert gas such as nitrogen is present or not. Therefore, the recommended precautions and procedures should be followed for maximum safety. Safety considerations were a major factor in the design of the Organic Vapor Analyzer (OVA).

All connections are of the permanent type as opposed to quick disconnect. To protect against external ignition of flammable gas mixtures, the flame detection chamber has porous metal flame arrestors on the sample input and the exhaust ports as well as on the hydrogen inlet connector. The standard battery pack and other circuits are internally current limited to an intrinsically safe level.

No Modifications Permissible

It is imperative that operation and service procedures described in this manual be carefully followed in order to maintain the intrinsic safety which is built into the OVA. NO MODIFICATION TO THIS INSTRUMENT IS PERMISSIBLE. Therefore, component replacement must be accomplished with approved parts.

Electrical Protection

The 12 V battery power supply circuit is current limited to an instrinsically safe level. Fuses are not utilized and all current limiting resistors and other components which are critical to the safety certification are encapsulated to prevent inadvertent replacement with components of the wrong value or specification. Under no circumstances should the encapsulation be removed.

Fuel Supply System

The OVA fuel tank has a volume of approximately 75 cm which, when filled to the maximum rated pressure of 2300 psig, holds approximately 5/8 ft of gas. The fuel used in the OVA should be PREPURIFIED or ZERO grade hydrogen (certified total hydrocarbons as methane <.5 ppm recommended.)

Hydrogen gas gains heat when expanding and, therefore, should not be rapidly released from a high pressure tank to a low pressure environment. Flow restrictors are incorporated in the hydrogen refill fitting and hydrogen is restricted on the output side of the tank by the low flow rate control system. In addition, a special flow restrictor is incorporated in the FILL/BLEED valve of the hydrogen filling hose assembly. These precautions limit the flow rate of the hydrogen to prevent ignition due to self-heat from expansion.

Precautions should be taken during hydrogen filling or hydrogen emptying operations to ensure that there are no sources of ignition in the immediate area. Since the instrument tank at 2300 psig holds only 5/8 ft of hydrogen, the total quantity, if released to the atmosphere, would be quickly diluted to a non-flammable level. There is, however, the possibility of generating flammable mixtures in the immediate vicinity of the instrument during filling or emptying operations if normal care is not exercised.

Detector Chamber

The input and output ports of the flame ionization chamber have sintered metal flame arrestors. The chamber is ruggedly constructed of Teflon such that even if highly explosive mixtures of hydrogen and air are inadvertently created in the chamber and ignited, the chamber would NOT rupture.

MAINTENANCE

This section describes the routine maintenance schedule and provides procedures for trouble-shooting an instrument malfunction.

CAUTION: Maintenance personnel should be thoroughly familiar with instrument operation before performing maintenance. It is essential that all portions of this manual relating to safety of operation, servicing and maintenance, be thoroughly understood. There should be no potential igniters or flame in the area when filling, emptying or purging the hydrogen system and the instrument should be turned off.

Extreme care should be exercised to ensure that required parts replacement is accomplished with the parts specified by Foxboro. NO MODIFICATIONS ARE PERMITTED. DISASSEMBLE INSTRUMENT ONLY IN A NON-HAZARDOUS ATMOSHPHERE.

Routine Maintenance *(Refer to Figure 5)*

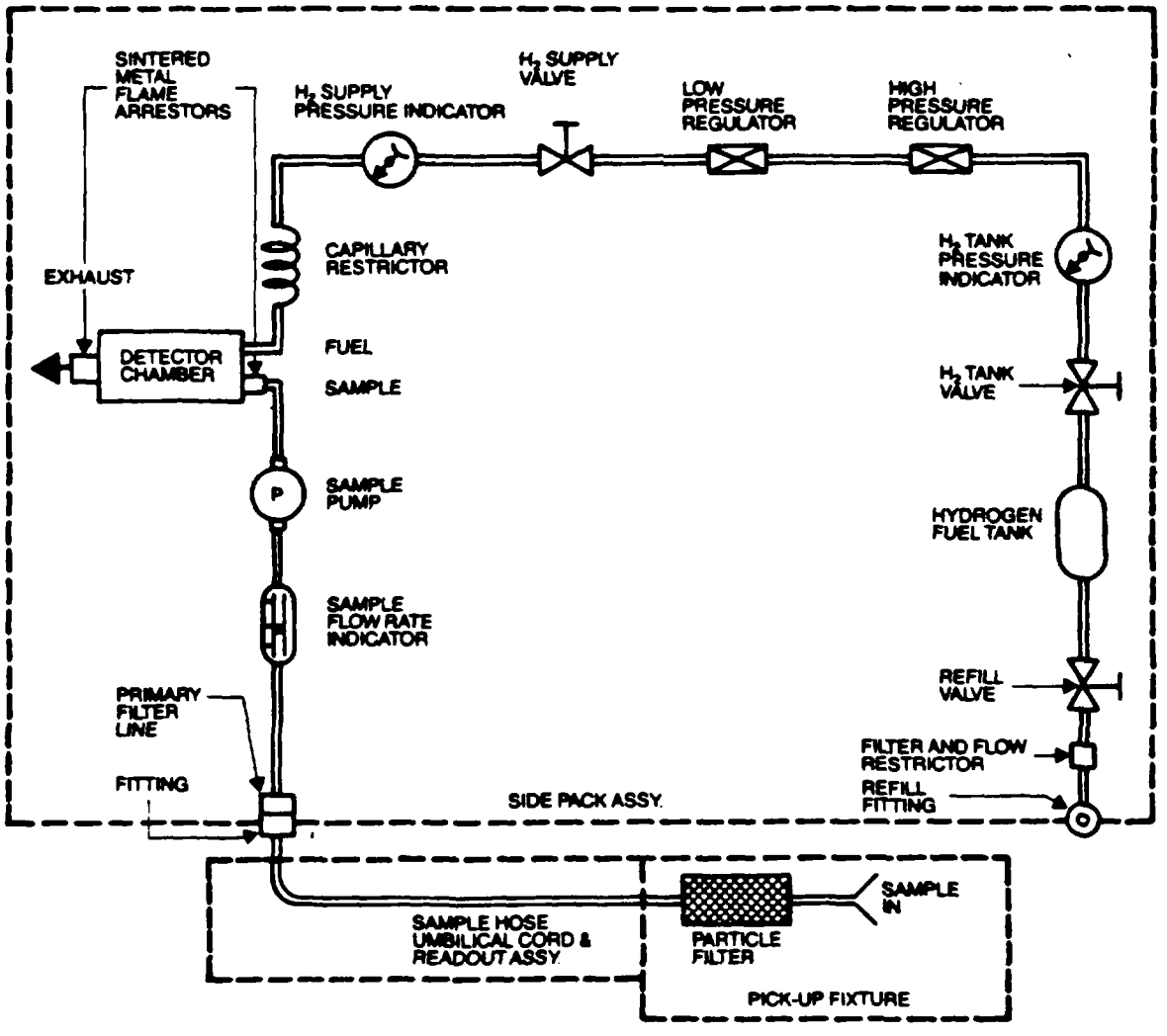


FIGURE 5
BLOCK DIAGRAM - GAS HANDLING SYSTEM

Primary Filter

This filter is located behind the sample inlet connector (Fitting Assembly) on the Side Pack Assembly and is removed for cleaning by using a 7/16 inch thin wall socket to unscrew the Fitting Assembly. The filter cup, "O" ring and loading spring will then come out. The porous stainless filter cup can be cleaned by blowing out or washing in solvent. If a solvent is used, care should be taken to ensure that all solvent is removed by blowing out or heating the filter. Reassemble in reverse order ensuring that the "O" ring seal on the F'tting Assembly is intact.

Secondary Filter

A particle filter is located in each pick-up fixture. One of these filters must be in the sample line whenever the instrument is in use. The OVA 128 uses a porous metal filter which can be replaced or cleaned.

Mixer/Burner Assembly Filter

A porous metal particle filter is incorporated in the Mixer/Burner Assembly which screws into the Preamp Assembly. This filter is used as the sample mixer and inlet flame arrestor in the chamber. The filter should not become contaminated under normal conditions but can be cleaned or the assembly replaced if necessary.

Access to this filter or output surface does not require removing the instrument from the case. For access, remove the safety cover using a hex key wrench (supplied) then unscrew the exhaust port. The Filter Assembly can now be seen on the side of the chamber (Preamp Assembly) and can be cleaned with a small wire brush.

Exhaust Flame Arrestor

A porous metal flame arrestor is located in the exhaust port of the detector chamber (Preamp Assembly). It acts as a particle filter on the chamber output and restricts foreign matter from entering the chamber. This filter may be cleaned by removing the exhaust port. For access, see Mixer/Burner section above. Note that the filter is captive to the exhaust port. Clean the filter with a solvent or detergent and ensure that it is dry and completely baked out at 120°F before reinstalling.

Sampling Fixtures

Sampling fixtures should be periodically cleaned with an air hose and/or detergent water to eliminate foreign particle matter.

If a solvent is used, the fixture should be subsequently cleaned with detergent and baked out at 120°F to eliminate residual hydrocarbons from the solvent.

Hydrogen Tank Supply & Refill Valves

After some time, the Teflon washers under each valve packing nut can "cold flow" (move with pressure) and allow hydrogen to leak. Leakage can be determined by using Leak-Tec, Snoop or a soap solution around the valve stems. This leakage can usually be stopped by tightening the compression nut (adapter) as outlined below.

a) Unscrew the packing nut with a 7/16 inch wrench
b) Unscrew the valve
c) Replace the compression rings

This compression is against soft material and only a small amount of force is necessary to sufficiently compress the Teflon washers. If, after tightening, leakage still occurs, it would be advisable to replace the two Teflon washers, as follows:

a) Drain hydrogen system slowly and to the extent necessary to work on the leaking valve(s). Observe safety precautions. There should be no potential igniters in the area.

b) Remove all three (3) knob screws and knobs.

c) Remove the compression nut on the valve that is not sealing properly. Remove the stem by unscrewing it from the valve body. Observe the sandwich of metal and Teflon washers and note their order.

d) Visually check the Kel-F™ seat on the stem for cracks or foreign material. Wipe clean, if necessary, with a lint free cloth (no solvents or oils) and replace if damaged.

e) Remove the washers and replace the Teflon washers (the factory procedure is a light wipe of HYDROCARBON FREE silicone grease).

f) Replace the stem assembly in the valve body and tighten lightly.

g) Push the washers down into the compression area in the same order as noted upon removal. Replace the compression nut and tighten snuggly.

h) Close the low pressure valve and fill the tank assembly. Check valves for leaks. Tighten again, if necessary, and reassemble the unit.

Air Sampling System Maintenance

A potential problem associated with the OVA instrument is that leaks can develop in the air sample pumping system. These leaks can result in dilution or loss of sample, causing low reading of vapor concentration and slow response.

The OVA is equipped with a flow gauge that provides a method to check for air leaks. Assemble the pickup probe selected for use to the readout assembly and then position the sidepack vertically so the flow gauge may be observed. Cover the end of the pickup probe with your finger and observe that the ball in the flow gauge goes to the bottom, indicating no air flow (if ball has slight chatter while on bottom, this is acceptable). Cover the center of the chamber exhaust port with your thumb and again observe the ball going to the bottom. Another simple check is to expose the pickup probe to cigarette smoke or a light vapor (butane) and observe that the meter responds in approximately 2.0 seconds. It should be noted that slow meter response may also indicate a restriction in the air sampling system.

Failure of the ball to go to the bottom when the inlet is blocked indicates a leak in the system between the probe and the pump inlet or the inlet check valve. To isolate the problem, remove parts, one at a time, and again block off the air inlet. Remove the pickup probe(s) and cover the air inlet at the Readout Assembly. If the ball goes to the bottom, check that the "readout to probe" seal washer is in place and replace the probes, holding them back against this seal while tightening the nut. Recheck, and if leakage is still present, it is probably in the probe (pickup fixture), which should be repaired or replaced.

If leakage is indicated as being past the readout handle when the connection to the sidepack is tight, disconnect the sample line at the fitting on the sidepack and cover this inlet with your finger. If the flow gauge ball goes to the bottom, the problem should be a leak in the umbilical cord/Readout Assembly, which should be investigated and repaired. There is also the possibility of a leaking check valve in the pump which would not show up on this test. If the leakage is not found in the umbilical cord, it is most likely in the pump check valve. The pump should be replaced.

If the ball does not go to the bottom, the leak will be either in the flow gauge or it's connecting tubing. Visually check that the tubing is connected and if so, the flow gauge should be repaired or replaced. Check the "O" ring installation in the sample inlet connector (Fitting Assembly).

As an alternate approach, leaks on the inlet side of the pump can be detected by using alcohol on a "Q" Tip and lightly swabbing the connections one at a time or by directing organic vapor or smoke at the potential leakage points and observing the meter response or audible alarm.

Leaks (beyond the pump) are easier to locate, as any of the commercially available leak detection solutions can be used. Cover the exhaust port, which will place the exhaust system under pressure, and check each connection, one at a time. Replace the Teflon tubing or retape the threaded connections with Teflon joint tape. Check the igniter and Mixer/Burner Assembly where they screw into the detector, the high voltage terminal screw on the side of the Mixer/Burner and exhaust port itself. If after these checks, the flow gauge ball still will not go to the bottom with the exhaust blocked, the problem is likely a leaking exhaust check valve in the pump, which should be repaired or replaced.

Contaminating Control

On occasion, the background reading may be relatively high under normal ambient conditions. Ambient background readings will vary somewhat depending on the geographical location where the instrument is being used. However, the background reading normally should be in the range of 3 to 5 ppm as methane. The acceptable background reading consists of 1 to 1½ ppm of methane which is present in the normal air environment. In addition to the measurement of a normal methane background, there will normally be 2 to 4 ppm of equivalent methane background caused by acceptable levels of contamination in the hydrogen fuel and/or hydrogen fuel handling system resulting in a total equivalent methane reading of 3 to 5 ppm in clean air.

If the background reading goes above 5 ppm to 6 or 7 ppm, this is normally still acceptable since any measurement is additive to that background reading, i.e., 2 ppm on top of 5 or 2 ppm on top of 7 provides the same differential reading, however, the lower background is obviously desirable.

The background reading is zeroed out or nulled - even though in reality the background still exists. The background reading is measured by zeroing the meter with the flame out and noting the meter indication after the flame is on.

The cause for a high background reading is usually associated with contamination in the hydrogen fuel system. This will, of course, cause a background reading since this is the function of the basic detector "to measure contamination entering the detector chamber". In addition, contamination present in the hydrogen will many times leave a small unobservable deposit on the burner face which can continue to generate a background reading when the detector is in operation and the burner assembly is heated.

Another possible cause of contamination is the Mixer/Burner Assembly when the contamination is trapped in the porous bronze sample filter. This is not a common problem and usually only happens when an unusually high level of contaminant is drawn into the assembly. Another possible cause of high background reading is contamination in the air sample line to the detector. This is uncommon but can be the source of the problem.

NOTE: An OVA that has the Chromatograph Option can have high background caused by saturation or contamination of the activated charcoal filter, which is in the line during chromatograph analysis, or of the column which is in the hydrogen line at all times.

Analysis and Correction

Prior to analyzing the problem, the OVA should be checked for proper electronic operation. It should be ensured that the instrument is calibrated to methane as referenced.

If, after checking that the OVA is properly calibrated, the background is still higher than normal for ambient conditions, the following procedure should be followed to isolate the cause of the problem:

a) Let the OVA run for a period of time (15 to 30 minutes) and see if the background level decreases as a function of time. The background could go down as a result of clearing line contamination which is removable simply by the normal flow of air through the sample line.

b) Take a reading in a known, relatively clean air environment. Normally, outside air environment is clean enough to assess by comparison whether the background reading is internal to the instrument or is present in the location where the instrument is being used.

c) If the OVA has the Gas Chromatograph Option, depress the sample inject valve, so that the activated charcoal is in the line, and observe whether the background reading goes down and stays steady after elution of the air peak. The reading should always go down or stay the same but never increase when the sample valve is depressed, since the charcoal filter will remove trace elements of organic vapors in the air sample heavier than C_2. If another activated charcoal filter is available, this may be attached to the end of the probe to scrub the air so that a clean air sample is supplied to the detector. The external activated charcoal filter can be used on any instrument, with or without chromatograph, for providing a clean air sample to assess background level.

d) If the background cannot be reduced by any of the previous steps, remove the safety cover and the exhaust port of the detector chamber (on the bottom of the case) and clean the cavity and the electrode using the small wire brush supplied with the analyzer. This will remove any small quantities of contamination which could be the source of the background vapor. After cleaning, replace the exhaust port and safety cover and reignite the OVA. If detector contamination was the cause, the problem should be immediately resolved and the ambient back ground will drop to an acceptable level.

e) If the high background is still present, the various parts of the sample flow line such as pickup probes, umbilical cord to the instrument, etc., should be investigated by the process of elimination to see if the contamination can be isolated.

Serious contamination in the air sample line is very uncommon, however, if very large doses of low vapor pressure compounds are sampled, there is a possibility of residual contamination. This would eventually clear itself out but may take a considerable period of time. A typical cause for high background from the sample line is a contaminated Mixer/Burner Assembly. If heavy contamination of the Mixer/Burner is indicated, replace the Mixer/Burner Assembly.

f) In the event of contamination in the pump or other internal parts of the sample flow lines which cannot be removed, the sample flow components have to be disassembled and cleaned. This is normally a factory operation, however, components such as the pump can be replaced in the field along with any contaminated tubing.

g) High background readings on OVA's which include the Gas Chromatograph Option can be caused by other sources of contamination. If the charcoal filter mounted on the instrument panel is saturated, contaminated air would be supplied to the detector and raise the ambient level background. To check for this, refill the cartridge with fresh charcoal, Foxboro P/N CSC004. This would determine if the charcoal was the source of the background reading. It is also possible that a high background reading could be due to contamination in the column. This could be caused by compounds slowly eluting from a column which has become contaminated. The easiest way to check for column contamination is to replace the column with a clean column or a short empty piece of column tubing and see if the high background reading drops.

h) If the above steps do not correct the high background, the cause will normally be contamination in the hydrogen fuel system.

Contamination in the hydrogen fuel system is usually the direct result of contaminated hydrogen gas or contamination introduced during the filling operation. Filling hose contamination can be caused by storing the hose in a contaminated area.

To remove contamination, the fuel system should be purged with hydrogen. Effective purging is accomplished by disconnecting the capillary tube fitting to the manifold block which has the low pressure gauge (Hydrogen Supply Pressure Gauge and Hydrogen Supply Valve). This disconnects the capillary tubing from the hydrogen line so that hydrogen may be purged at a reasonable rate from the tank assembly through the regulators, gauges and valves. After disconnecting the capillary, the hydrogen tank can be filled in the normal manner. The tank valve and hydrogen supply valve can then be opened which will bleed the hydrogen from the tank through the hydrogen fuel system, purging contamination which is in vapor form. There is the possibility that contamination has been introduced into the hydrogen fuel system which is not readily purged by the hydrogen gas, but this is unlikely. After purging with clean hydrogen two or three times, the capillary tube should be reconnected and the background again checked. Five or ten minutes should be allowed before assessing the background reading, since contaminated hydrogen can be trapped in the capillary tube.

If another clean instrument is available, the fuel system from the clean instrument can be connected to the contaminated instrument to verify whether the problem is associated with the hydrogen fuel supply system. The interconnection should be made to the capillary tube of the contaminated instrument.

Troubleshooting

Table 1 presents a summary of field troubleshooting procedures. If necessary, the instrument can be easily removed from the case by unlocking the four (4) ¼ turn fasteners on the panel face and removing the refill cap. The battery pack is removed by taking out the four (4) screws on the panel and disconnecting the power connector.

Factory Maintenance

To ensure continuous trouble-free operation, a periodic factory maintenance, overhaul, and recalibration is recommended. The recommended schedule is every six to nine months. This maintenance program includes replacement of plastic seals and parts as required, pump overhaul, motor check, sample line cleaning, hydrogen leak check, recalibration, and detailed examination of the unit for any other required maintenance and repair.

Recommended Spare Parts

Item	Description	Part Number		Recommended Quantity
1	Igniter	510461-1		2
2	Pump Assembly	510223-6		1
3	Cup, Filter (3/8 inch OD, ss)	510318-1	(5/pkg.)	1
4	Mixer/Burner Assembly	510513-1		1
5	Wafer, Teflon, H_2 Valve	510160-1	(10/pkg.)	1
6	Washer, Brass, H_2 Valve	510160-2	(10/pkg.)	1
7	Exhaust Port Assembly	510530-1		1
8	Battery Pack Assembly	510542-1		1
9	Sample Line Assembly	510316-1		1
10	Particle Filters	510116-1		1

TABLE 1

PROBLEM	TROUBLE SHOOTING PROCEDURE	REMEDY
1) Low sample flow rate on flow indicator. Nominally 2 units on flow gauge. (See also 6 below)	a) Check primary filter in sidepack and particle filters in the pickup assembly.	Replace or clean filter if clogged.
	b) Determine assembly containing restriction by process of elimination, i.e., remove probe, remove Readout Assembly, remove primary filter, etc.	Investigate the assembly containing this restriction to determine cause of blockage. Clean or replace as required.
	c) If the restriction is in the Side Pack Assembly, further isolate by disconnecting the sample flow tubing at various points, i.e., pump output chamber, etc. NOTE: The inherent restrictions due to length of sample line, flame arrestors, etc., must be taken into account when troubleshooting.	If in the detector chamber, remove and clean or replace porous metal flame arrestors. If pump is found to be the problem, remove and clean or replace.
2) Hydrogen flame will not light. (See also 6 below)	a) Check sample flow rate (see 1 above)	If sample flow rate is low, follow procedure 1 above.
	b) Check igniter by removing the chamber exhaust port and observing the glow when the IGNITE BUTTON is depressed.	If igniter does not light up, replace the plug. If igniter still does not light, check the battery and wiring.
	c) Check for rated Hydrogen Supply Pressure. (Listed on calibration plate on pump bracket).	If low, remove battery pack and adjust to proper level by turning the allen wrench adjustment on the low pressure regulator cap.
	d) Check hydrogen flow rate by observing the psi decrease in pressure on the Hydrogen Tank Pressure gauge. The correct flow rate will cause about 130 psi decrease in pressure per hour. (Approximately 12 cm^3/min at detector).	The most likely cause for hydrogen flow restriction would be a blocked or partially blocked capillary tube. If flow rate is marginally low, attempt to compensate by increasing the Hydrogen Supply Pressure by one-half or one psi. If flow rate cannot be compensated for, replace capillary tubing.
	e) Check all hydrogen plumbing joints for leaks using soap bubble solution. Also, shut off all valves and note pressure decay on hydrogen tank gauge. It should be less than 350 psi per hour.	Repair leaking joint.

TABLE 1

PROBLEM	TROUBLE SHOOTING PROCEDURE	REMEDY
	f) Check to see if hydrogen supply system is frozen up by taking unit into a warm area.	If there is moisture in the hydrogen supply system and the unit must be operated in subfreezing temperatures, purge the hydrogen system with dry nitrogen and ensure the hydrogen gas used is dry.
	g) Remove exhaust port and check for contamination.	If the chamber is dirty, clean with ethyl alcohol and dry by running pump for approximately 15 minutes. If hydrogen fuel jet is misaligned ensure the porous metal flame arrestor is properly seated.
	h) Check spacing between collecting electrode and burner tip. Spacing should be 0.1 to 0.15 inches.	Adjust by screwing Mixer/Burner Assembly in or out. This spacing problem should only occur after assembling a Mixer/Burner Assembly to a Preamp Assembly.
3) Hydrogen flame lights but will not stay lighted.	a) Follow procedures 2(a), (c), (d), (e), (g) and (h) above. Also refer to 5 below.	
4) Flame-out alarm will not go on when hydrogen flame is out.	a) Check instrument calibration setting and GAS SELECT control setting.	Readjust as required to proper setting. Note that the flame-out alarm is actuated when the meter reading goes below zero.
	b) Remove exhaust port and check for leakage current path in chamber (probably moisture or dirt in chamber).	Clean contamination and/or moisture from the chamber using a swab and alcohol, dry chamber by running pump for approximately 15 minutes.
	c) If above procedures do not resolve the problem, the probable cause is a malfunction in the preamp or power board assemblies.	Return preamp chamber or power board assembly to the factory for repair.
	d) Check that volume control knob is turned up.	Adjust for desired volume.

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	c) If the restriction is in the Side Pack Assembly, further isolate by disconnecting the sample flow tubing at various points, i.e., pump output chamber, etc. NOTE: The inherent restrictions due to length of sample line, flame arrestors, etc., must be taken into account when troubleshooting.	If in the detector chamber, remove and clean or replace porous metal flame arrestors. If pump is found to be the problem, remove and clean or replace.
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TABLE 1

PROBLEM	TROUBLE SHOOTING PROCEDURE	REMEDY
5) False flame-out alarm.	a) Flame-out alarm is actuated when signal goes below electronic zero (with flame on). This can be due to inaccurate initial setting, drift, or a decrease in ambient concentration. Verify if this is the problem by zeroing meter with flame out and reigniting.	When using the X1 range adjust meter to 1 ppm, rather than zero, be sure instrument has been zeroed to "lowest expected ambient background level".
6) Slow response, i.e., time to obtain response after sample is applied to input is too long.	a) Check to ensure that probe is firmly seated on the rubber seal in the readout assembly.	Reseat by holding the probe firmly against the rubber seat and then lock in position with the knurled locking nut.
	b) Check sample flow rate per procedure 1 above.	See 1 above.
7) Slow recovery time, i.e., too long a time for the reading to get back to ambient after exposure to a high concentration or organic vapor.	a) This problem is normally caused by contamination in the sample input line. This requires pumping for a long period to get the system clean of vapors. Charcoal in the lines would be the worst type of contamination. Isolate through the process of elimination. (See 1(b)).	Clean or replace contaminated sample line or assembly as required.
	b) Check flame chamber for contamination.	Clean as required.
8) Ambient background reading in clean environment is too high.	a) A false ambient background reading can be caused by hydrocarbons in the hydrogen fuel supply system. Place finger over sample probe tube restricting sample flow and if meter indication does not go down signficantly the contamination is probably in the hydrogen fuel.	Use a higher grade of hydrocarbon free hydrogen. Check for contaminated fittings on filling hose assembly.
	b) A false ambient background reading can also be caused by a residue of sample building up on the face of the sample inlet filter. If the test in 8(a) above produces a large drop in reading, this is usually the cause.	Remove the exhaust port (it is not necessary to remove instrument from case). Use the small wire brush from the tool kit or a knife blade and lightly scrub surface of sample inlet filler.

TABLE 1

PROBLEM	TROUBLE SHOOTING PROCEDURE	REMEDY
	c) A false ambient background reading can also be caused by hydrocarbon contamination in the sample input system. The most likely cause would be a contaminant absorbed or condensed in the sample line. NOTE: It should be emphasized that running the instrument tends to keep down the buildup of background vapors. Therefore, run the unit whenever possible and store it with the carrying case open in clean air.	Clean and/or replace the sample input lines. Normally the false reading will clear up with sufficient running.
9) Pump will not run.	a) Check that there is no short circuit in wiring.	If no short circuit, pump motor is defective.
10) No power to electronics but pump runs.	a) Short circuit in electronics.	There is a short in the electronics assembly. Return OVA to factory or authorized repair facility.
11) No power to pump or electronics	a) Place battery on charger and see if power is then available. Recharge in a non-hazardous area only.	If power is available, battery pack is dead or open. Recharge battery pack. If still defective, replace battery pack.

GAS CHROMATOGRAPH (GC) OPTION

The Model OVA 128 CENTURY Organic Vapor Analyzer provides efficient and accurate indication of total organic compound concentrations on a continuous sampling basis. However, in areas where mixtures of organic vapors are present, it often becomes necessary to determine the relative concentration of the components and/or to make quantitative analysis of specific compounds.

To provide this capability, a gas chromatograph (GC) option is available. See Figure 6 for the location of the major components and controls associated with the GC option. When the GC option is used, the capability of the OVA includes both qualitative and on-the-spot quantitative analysis of specific components present in the ambient environment. The Recorder, which is used with the GC option, is described separately.

This section is applicable only to an OVA with the optional gas chromatograph system.

Modes of Operation

The OVA with GC option has two modes of operation. The first mode is the measurement of total organic vapors in the same manner as described for the basic OVA instrument. This mode is referred to as the "Survey Mode". The OVA is in the "Survey Mode" of operation whenever the Sample Inject Valve is in the "out" position.

The second mode of operation is called the "GC Mode". The OVA is in this mode of operation any time a sample has been injected into the GC system and the sample is being transported through the GC column. This section provides a brief description of how a gas chromatograph (GC) operates and specifically, how the model OVA 128 performs the required operations. A comprehensive discussion of gas chromatography theory, column selection, and data analysis is beyond the scope of this manual.

The OVA with GC option can be utilized for many types of analysis in the outdoor or indoor ambient environment or for specific laboratory type analysis. The OVA was not designed to compete with the research or process gas chromatograph but to compliment these instruments or eliminate their need in field applications.

This manual is intended to provide the operator with information to operate and maintain the OVA. Foxboro publishes Application/Technical Notes to assist the operators in applying the instrument to field monitoring situations.

All flame ionization detector (FID) gas chromatographs require certain elements for their operation. These elements include three flow regulated gas supplies as follows: 1) A carrier gas to transport the sample through the column; 2) Hydrogen gas for operation of the FID; 3) A clean air supply to support combustion to the FID. In addition, a method for injecting a known volume of sample air (aliquot) to be analyzed is required.

In standard gas chromatographs these three (3) flow regulated gases are individually supplied from pressurized cylinders equipped with regulators and flow control apparatus. The Model 128 GC system differs in that the hydrogen fuel for the FID is also used as the carrier gas. The clean air supply is simply the normal air sample pumped to the FID. During the GC analysis, this air is scrubbed in a charcoal filter to provide the clean air supply. The end result is that no additional gas supplies are required to add the GC option to the basic OVA instrument.

A valving arrangement is incorporated to provide a method for transferring a fixed volume of air into the GC system for analysis. The sample air injected into the GC column is the same sample being analyzed by the OVA for total organic vapor concentration. Therefore, the instrument provides the unique capability to observe the total organic vapor concentration of the sample prior to injecting it into the GC system. This operating feature is invaluable in field work where the environment is continually changing and where valuable GC analysis time must be expended only on the sample of concern.

OVA Columns

Columns are available in 4, 8, 12, 24, 36 and 48 inch lengths as standard offerings with any of the column packings listed below. Longer lengths are available in 12-inch increments on a non-standard basis. To order a column simply use the general part number for a column which is 510454 followed by a dash (-), the Foxboro packing material designation, a second dash and the desired length in inches. A sample column designation is 510454-G-24. This would represent a 24 inch column with 10% OV 101 on chromosorb W, HP 60/80 mesh. If a specific application arises which calls for a column material not listed below, please contact Foxboro. We will be happy to check on its availability.

Foxboro Designation	Material
A	20% Dioctyl Phthalate on Chromosorb-P, AW 60/80 Mesh
C	Chromosorb 101, 60/80 Mesh
D	20% Ucon 50 HB 280 on Chromosorb-P, AW 60/80 Mesh
E	20% Carbowax 400 on Chromosorb-P, AW 60/80 Mesh
F	5/1.75% Diethylhexyl Sebecate/Bentone 34 on Chomosorb W, AW 60/80 Mesh
G	10% OV-101 on Chromosorb W, HP 60/80 Mesh
T	10% 1,2,3-Tris (2-cyanoethoxy) Propane on Chromosorb P, AW 60/80 Mesh
B	3% Diisodecyl Phthalate on Chromosorb W, AW 60/80 Mesh
PT	Poropak T, 60/80 Mesh
Q	Poropak Q, 60/80 Mesh
H	20% Carbowax 20M on Chromosorb P, AW 60/80 Mesh
J	n-Octane on Porasil C, 80/100 Mesh
N	Porapak N, 60/80 Mesh

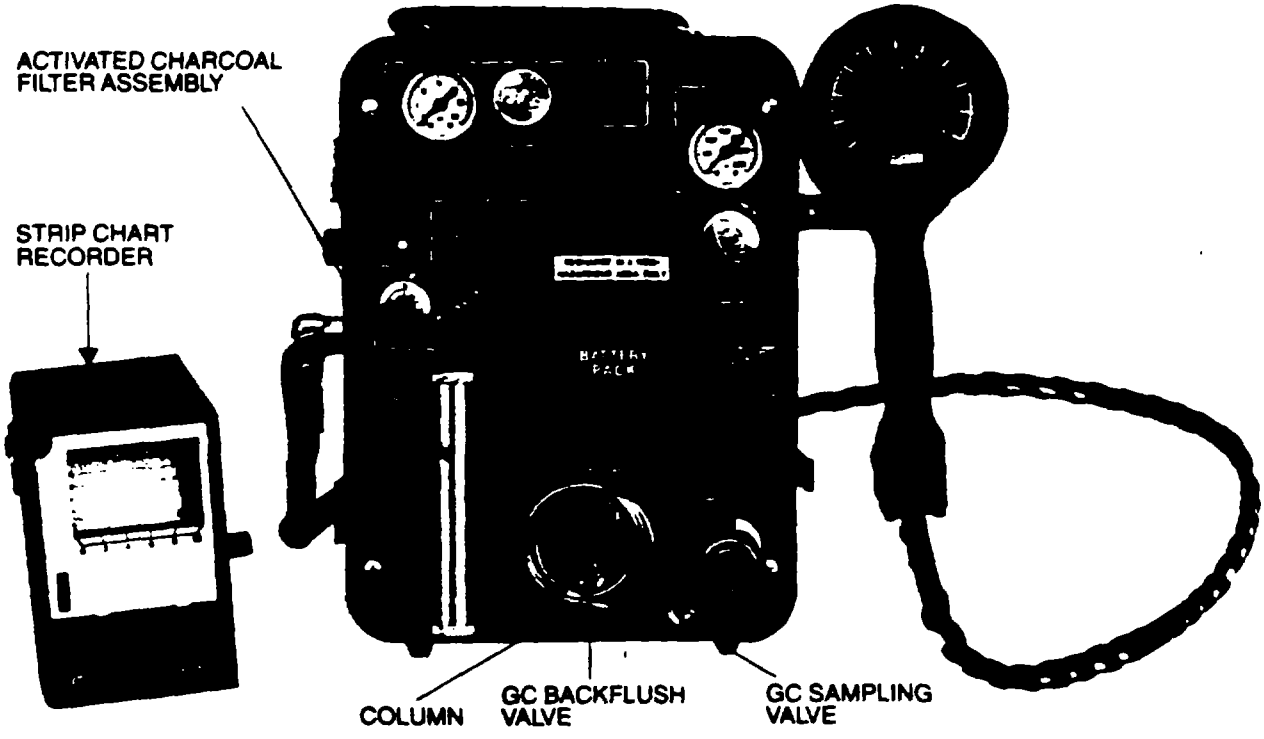


FIGURE 6
ADDITIONAL CONTROLS & COMPONENTS - GC OPTION

Sample Flow

Figure 7 is a flow diagram illustrating the flow paths of the hydrogen fuel, sample air supply, and GC injected sample aliquot.

Two push-pull valves are used in the GC system; the Sample Inject Valve and the Backflush Valve.

Block D illustrates the flow paths with the Sample Inject Valve in the "out" position. With this valve in the "out" position, the OVA functions in its normal manner as a total organic vapor analyzer.

Block C illustrates the flow paths after the Sample Inject Valve is moved to the "in" position to initiate the GC Mode.

The hydrogen flow path is now through the sample loop which enables hydrogen to sweep the air sample from the loop and carry it through the GC column.

Also note that the sample air going to the FID chamber is now routed through the activated charcoal filter where essentially all organic vapor contamination is removed from the air. The activated charcoal filter will effectively absorb most organic vapors with the exception of methane and ethane. The functions of the Sample Inject Valve are, therefore, to transfer a fixed volume sample of the air being monitored into the hydrogen stream and to reroute the sample air supply through a filter (scrubber).

The Backflush Valve has no prepositioning requirement to function. It can be in either the "in" or "out" position at the time a sample is injected into the GC system for analysis. The Backflush Valve simply reverses the direction of the hydrogen flow through the GC column.

Regardless of the operating mode, hydrogen always flows through the column to the FID detector and the sample air supply always flows to the FID detector to provide oxygen for the hydrogen flame.

The recommended hydrogen flow rate is 12 cm /min for proper FID operation and as a standard flow rate for generating GC reference/calibration data. This hydrogen flow rate is adjusted by varying the Hydrogen Supply Pressure, which is the hydrogen pressure at the input of the flow control capillary tube of the OVA. The pressure is changed by adjusting the set screw in the bonnet of the low pressure regulator, accessible by removing the battery pack from the instrument panel. To monitor the hydrogen flow rate, connect a bubble flowmeter to an end of the GC column which has been disconnected from the panel fitting and move the Backflush Valve so that hydrogen is flowing out of the column. Primary hydrogen flow control is accomplished by the capillary tube of the OVA. However, the flow restriction of a GC column will also affect the hydrogen rate and the effect will vary with column length, type of packing and packing methods. The nominal Hydrogen Supply Pressure is around 10 psig and the pressure drop across a typical 24 inch long column packed with 60/80 mesh material is approximately 1 to 1.5 psig. Normally, when the hydrogen flow rate is set at 12 cm^3/min with a standard 24 inch long column, no adjustment needs to be made when using columns from four (4) inches to four (4) feet long. Longer columns may require hydrogen flow adjustment for proper operation. Adjustment would be required if and when precisely controlled analysis was being conducted or when the hydrogen flow was too low to keep the flame burning.

The sample air flow rate is not adjustable and is nominally 1.0 liter/minute. This flow rate should remain relatively constant. A sample flow gauge is provided on the OVA panel to monitor the sample flow rate. (Note: Panel gauge is not calibrated in L/min). When the Sample Inject Valve is in the "in" position, there may be a slight increase or decrease in sample air flow rate (0 to 15%). This change will normally not affect operation of the instrument as long as the flow rate is consistent from analysis to analysis. Basically, if the flow rate is consistent between calibration and end usage, there will be suitable precision in the measurements.

GC Analysis

1) SAMPLE INJECTION

When the Sample Injection Valve is depressed, the air in the sample loop is injected into the hydrogen stream which transports the sample through the column for separation of its components and to the flame chamber for analysis. This small volume of injected sample is qualitatively analyzed based on the retention time of the individual components of that sample while passing through the column. Quantitative analysis can then be accomplished by peak height or peak area analysis methods.

2) THE COLUMN

The column consists of tubing packed with a material which physically interacts with organic vapors and retards the passage of the vapors through the column. Since the packing material has a different attraction for each organic substance, each component in a mixture of gases will be slowed down to a different extent.

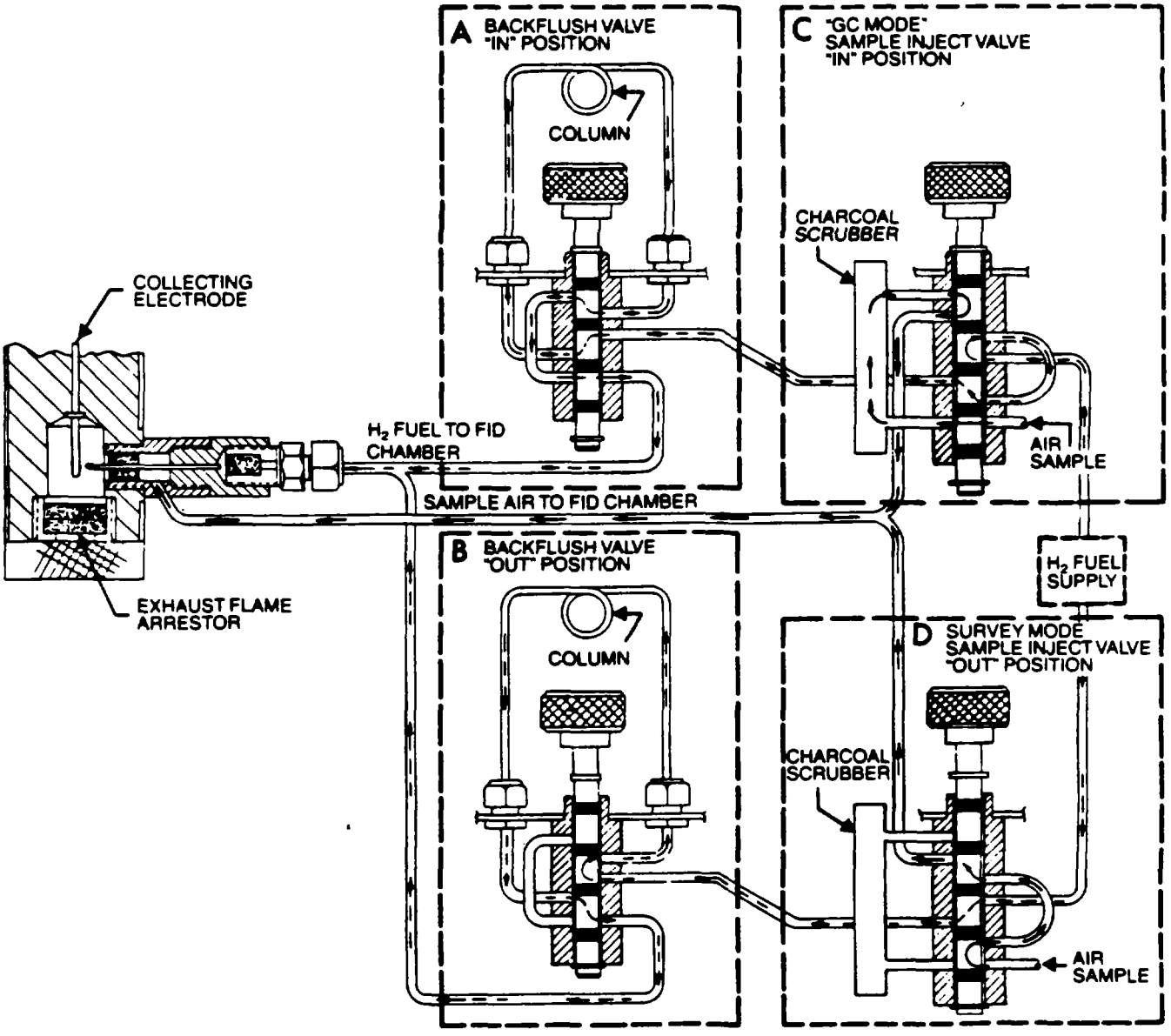


FIGURE 7
FLOW DIAGRAM - GC OPTION

The net effect is that each component elutes from the column at a different time. The components are then fed to the detector which gives a response to the meter or to an external strip chart recorder.

A portable isothermal pack (PIP) can be used for temperature control and/or isothermal analysis. This is described further under PIP kit option.

3) QUALITATIVE ANALYSIS

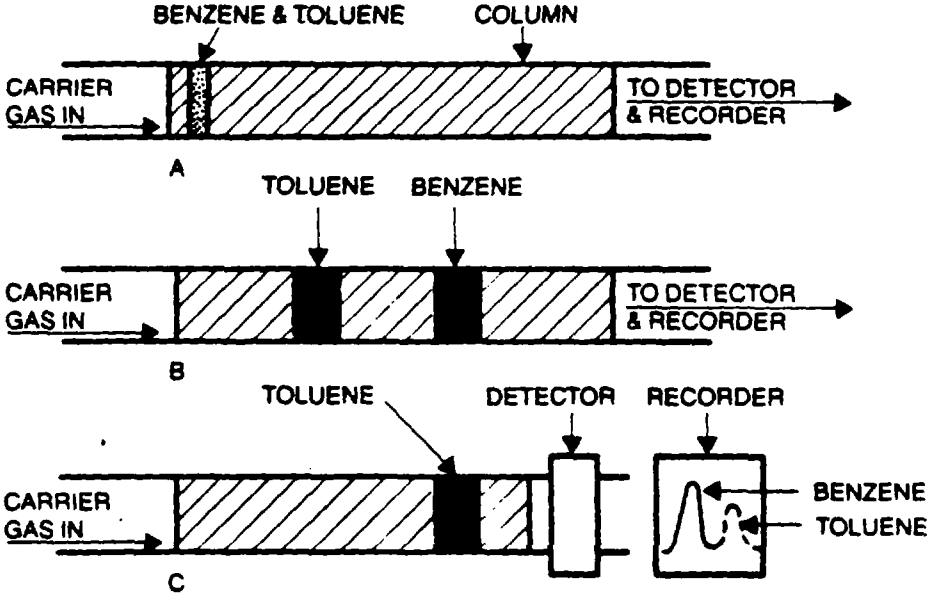
As each organic substance has a unique interaction with the column packing material, the time that the substance is retained on the column is also unique and thus characteristic of that particular substance. The "retention time" (RT) is primarily dependent on the type of packing material, the length of the column, the flow rate of the gas carrying the mixture through the column and the temperature range of the system.

When these variables are controlled, the retention times can be used to identify each of the components in a mixture. Because of these variables, it is usually necessary to establish retention times for each instrument by making a test with the pure substances of interest or to refer to established time data charts prepared in advance for that specific instrument. In those cases where retention times of the components are too close together for a good analysis, an adjustment in one or more of the operating variables will effect a sufficient difference in retention times to enable meaningful analysis.

4) QUANTITATIVE ANALYSIS

The detector response to any organic component is proportional to the quantity of material passing through the detector at a given time. For an eluted component, a plot of concentration vs. time forms a bell-shaped curve.

When using a strip chart recorder, the curve drawn on the paper is triangularly shaped and the area under the peak is related to the amount of substance being analyzed.



PICTORIAL SEPARATION OF BENZENE AND TOLUENE – "A" AT BEGINNING OF SEPARATION; "B" DURING SEPARATION; "C" BENZENE HAS ALREADY PASSED THE DETECTOR AND IS RECORDED. TOLUENE (DOTTED LINES) WILL APPEAR ON RECORDER AS IT PASSES THE DETECTOR.

FIGURE 8
TYPICAL COLUMN SEPARATION SEQUENCE

5) BACKFLUSH

The column Backflush Valve is provided to reverse the flow of the carrier gas (hydrogen) through the column. It is necessary that the column be backflushed after each individual analysis except under certain special conditions. The primary purpose of the backflush function is to clear the column of heavy compounds (with long retention times) which would contaminate the column and cause interferences to future GC analysis. The Backflush Valve has no prepositioning requirement; it is reversed from either position it was in during GC analysis. The Backflush Valve should be actuated immediately after the peak of the last compound of interest elutes. Figure 8 illustrates the function of the Backflush Valve.

In the GC system, the backflush is "to the detector". This is possible because the carrier gas and detector fuel are the same, i.e., hydrogen. It provides a convenient means of quantifying the total compounds in the backflush by simply recording the peak that elutes during the backflush operation. For field instruments, this quantitative backflush information is valuable since it provides a direct means of observing the condition of the column and seeing when the column is clean and the detector response has returned to baseline. The time required for the backflush is usually 1.2 to 1.5 times the GC analysis time.

6) SURVEY TO GC MODE

There is an inherent advantage to integrating the GC system to the basic total Organic Vapor Analyser (OVA). The OVA provides a direct reading of total organic vapors in the air being sampled, which gives the operator information about the sample being injected into the GC system. This information can be used to predict and verify the peaks that result during the GC analysis, including the backflush peak.

This feature eliminates expending valuable GC analysis time where there is no contamination of concern (comparable to taking noise measurements in quiet corners). It also enables the operator to select the most appropriate location to conduct an analysis, normally the area of highest concentration.

GC MODE OPERATING PROCEDURES

The gas chromatographic analysis mode (GC Mode) of operation can be initiated at any time during a survey by simply depressing the Sample Inject Valve. After completion of the analysis and backflush operations, the Sample Inject Valve is pulled out and the survey continued or another sample injected. Note that when the Sample Inject Valve is in the survey mode (out position) the OVA operates in the same manner as an OVA which does not incorporate the GC option.

Controls/Indicators

Refer to Figure 6.

1) Sample Inject Valve - This two (2) position valve (shown schematically in Figure 7) is used to select either Survey Mode (valve out) or GC Mode (valve in).

2) Backflush Valve - This two (2) position valve (shown schematically in Figure 7) is used to reverse the flow of hydrogen through the column to:

   a) Backflush the column for cleaning.

   b) Quantitatively measure total compounds after a selected point. Example: Separation of methane from non-methane hydrocarbons to read total non-methane hydrocarbon level.

3) Column - Separates components of a gas mixture so that each component of the mixture elutes from the column at a different time.

4) Activated Charcoal Filter Assembly - This assembly functions only in the GC Mode (Sample Inject Valve "in") as shown schematically in Figure 7). It removes organic compounds (except methane and ethane) by absorption from the sample air supply.

Turn on Procedure

Place the Sample Inject Valve in the "out" position and put the OVA instrument in operation per "Operating Procedures" for the survey mode. NOTE: Leave the hydrogen fuel and pump "on" for three (3) to four (4) minutes before attempting ignition to allow time for hydrogen purging of the column.

Survey Mode

When using the OVA in the Survey Mode, ensure that the Sample Inject Valve remains in the full "out" position and that the Backflush Valve is either full "in" or full "out". Note that when changing from the GC Mode to the Survey Mode, the OVA output reading will continue to change until all compounds have been eluted from the GC column. Therefore, under normal field conditions, the GC column should be backflushed for clearing, which takes approximately 1.2 to 1.5 times the forward analysis time. The backflush peak may be observed returning to baseline, after which the Sample Inject Valve may be moved to the Survey Mode (out) position.

When the compound(s) being analyzed are known to be the only compound(s) present in the air sample, backflushing may be omitted.

GC Mode Operation

In normal GC analysis, a strip chart recorder is used to record the output concentration from the OVA as a function of time. This record, called a chromatogram, is utilized for interpretation of the GC data.

a) OPERATION

   1) Turn on recorder and push Sample Inject Valve "in" with a fast, positive motion. This starts the GC analysis which is automatic up to the point of backflushing. *NOTE: Rapid* and positive motion should be used when moving either the Sample Inject or Backflush Valves. On occasion, the flame in the FID detector may go out, which would be indicated by a sharp and continued drop of the concentration level. If this occurs, reignite the flame and continue the analysis. NOTE: A negative "air" peak typically occurs shortly after sample injection and should not be confused with flame-out.

   2) The negative air peak and various positive compound peaks indicated on the OVA readout meter and the strip chart recorder represent the chromatogram.

3) After the predetermined time for the analysis has elapsed (normally immediately after the peak of the last compound of concern), rapidly move the Backflush Valve to its alternate position (in or out). Leave the instrument in this condition until the backflush peak returns to baseline, then pull the Sample Inject Valve to the "out" position. If no backflush peak appears, pull the Sample Inject Valve out after being in the backflush condition for a period at least twice as long as the analysis time. The OVA is now in the Survey Mode and ready for survey or injection of another sample into the GC system.

b) INTERPRETATION OF RESULTS

The OVA 128 with GC option is intended for applications where there are a limited number of compounds of interest and the compounds are normally known. Under these conditions, the operator must know the retention time and peak height characteristics of the compounds under specific operating conditions. To calibrate the OVA in the GC Mode, determine, by test, the retention time and peak area (using peak height analysis) for the compounds of concern. These tests should be conducted on the column to be utilized and over the concentration and temperature range of concern. When representative characteristic data is available, such as in the Application/Technical Notes, a spot calibration check is normally all that is required.

It should be noted that under normal field conditions, the vapor concentrations vary continually as a function of time, location, and conditions. Field measurements for industrial hygene work are normally associated with a threshhold level around a preestablished concentration. Surveys for locating fugitive emission sources present a continually varying situation. Under these conditions, it is desirable to have a simple method of interpreting the GC data for on-the-spot analysis and decision making. High precision is normally not a requirement for these type analyses since the environment is continually changing. The methods presented in this section are designed to provide a means for typical field analysis. When the OVA is used under laboratory conditions, standard laboratory methodology may be used for greater precision.

Technical Discussion

The chromatogram is a chart recorder trace of the organic vapor concentration from the Organic Vapor Analyzer (OVA) as a function of time. A typical chromatogram is illustrated in Figure 9 and is a series of triangular shaped peaks originating from and returning to a fixed baseline. Qualitative interpretation of a chromatogram involves identifying a peak by analyzing the time it took for the peak to appear after initial injection [referred to as retention time (RT)] and comparing this RT to reference data. Quantitative interpretation involves analyzing the area under the peak and relating this area to calibration data of peak area versus concentration for that specific compound under the conditions present during the GC analysis.

It can be seen that interpretation of a chromatogram requires the use of calibration reference data. GC reference data is always generated empirically, i.e., through tests. Foxboro Application/Technical Notes may be used as a reference for selecting columns and interpreting chromatograms. However, simple tests must be conducted to obtain the required reference data.

a) QUALITATIVE ANALYSIS

Under a given set of operating conditions the retention time is characteristic of that particular substance and can be used to identify specific compounds. It will be necessary to calibrate retention times by making tests with the pure compounds of interest.

The retention time (RT) is defined as that period of time from injection until the time of maximum detector response for each substance. Retention time is measured from the time of sample injection to the time the apex of the triangle shaped curve is obtained on the strip chart recorder. (See Figure 9). The strip chart recorder operates on a clock mechanism such that the distance along the baseline is proportional to time. While retention times are characteristic for each compound, it is possible that two materials could have the same retention times. Thus, if there is any question as to the identity of the vapor, it may be necessary to verify identification by retention times on different columns.

Use of a longer column will increase the retention times of those components it is capable of separating. The time between peaks will also be increased. This is especially useful if a component comes through too fast or if desired peaks are so close that they overlap.

b) COLUMN SELECTION

Two columns are supplied with the instrument. These are general purpose columns which are useful in a wide variety of applications. If they do not achieve separations for a particular application, it may be necessary to select other packing materials or longer columns. Foxboro will assist in this selection or prepare a custom column if necessary.

If columns are made by the user or purchased from other sources, ensure that the packing density does not create too large a pressure drop. A large pressure drop can result in flame-out problems.

c) TEMPERATURE EFFECT ON RETENTION TIME

An increase in temperature will decrease column retention time (RT) and vice versa. Normally retention time (RT), as a function of temperature, changes linearly over the range of 0 to 40°C. For complex qualitative analysis, a calibration plot of RT versus temperature will be required. In typical usage, such as inside a factory, the effect of temperature can be compensated for during chromatogram interpretation. A single component tracer compound can be sampled at any time to provide a "key" for other compound identification.

d) CARRIER GAS FLOW RATE AFFECT ON RETENTION TIME

An increase in carrier gas flow rate will decrease retention time. For reproducible data, the carrier gas (hydrogen) flow rate must be recorded in association with a chromatogram. Primary control of the hydrogen flow rate is accomplished in the OVA by regulating the hydrogen pressure across a capillary tube. The hydrogen flow rate is also affected by the restriction of the GC column but most columns have a limited effect. The hydrogen flow rate is factory set at 12 cm /minute with a typical 24 inch column.

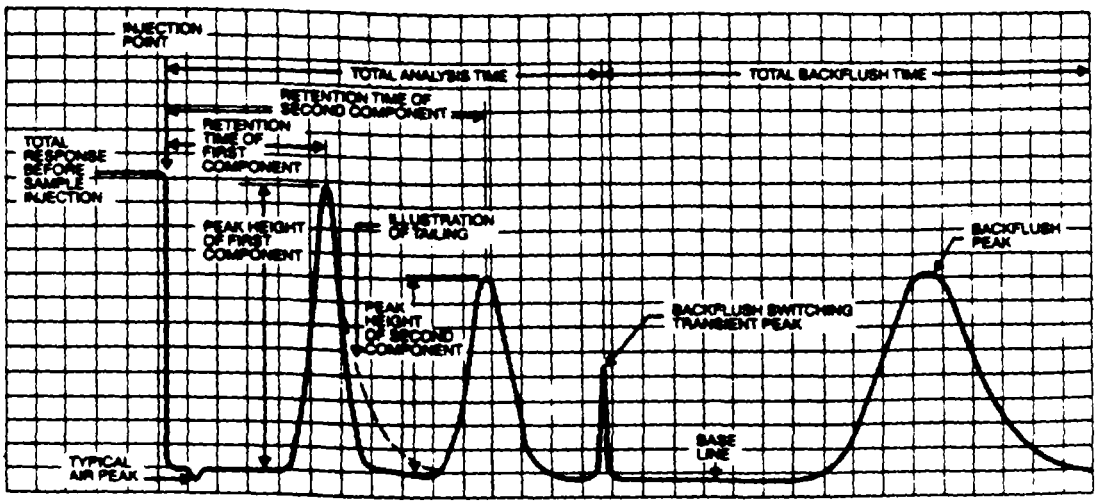


FIGURE 9
TYPICAL CHROMATOGRAM

e) QUANTITATIVE ANALYSIS

In general, the more triangularly symmetrical the peak, the better the peak height analysis capability. However, many GC peaks have "tailing" as illustrated in Figure 9. Peak height calibration is an acceptable method for quantitative analysis as long as the area under the tail is small compared with the total peak area. If severe tailing occurs, empirical calibration data generated through tests may be required to plot the peak height versus the concentration curve.

Only peak height analysis will be discussed in this manual. The method involves injecting a known concentration of the compound and recording the peak height under the test conditions. Peak height characteristics can be established for various columns and various temperatures. Normally, both retention time and peak height characteristics will be measured.

When peak area measurements are desired, the areas may be measured using an integrator on the OVA output signal. Other manual methods may also be used, such as counting squares, weighing curves or simple triangulation. When the GC peaks have good symmentry, triangulation (area equals 1/2 base x height) is a convenient method.

Calibration Data

When conducting tests to obtain GC calibration data, the following information should be recorded.

a) Column - description and serial number as applicable.
b) Temperature - column temperature, normally room ambient.
c) Chart speed - distance/unit time.
d) Carrier flow rate - hydrogen flow rate through the column (cm /min).
e) Sample concentration - ppm for each compound,
f) Sample volume - OVA by serial number or typically 0.25 cm for standard value.
g) Recorder scaling - ppm per unit deflection.
h) Range - range of OVA being used, i.e. X1, X10, X100.
i) OVA serial number.

To obtain a calibration point, inject a known concentration sample into the GC system and record the resulting chromatogram peak. The retention time for the peak may be scaled from the record or timed with a stop watch. The peak height may be scaled from the record or the OVA readout meter may be observed during the elution of the peak. Figure 10B presents the format of a chart which may be used to record calibration data. Experience has indicated that the peak height response of a compound is linear within the concentration range of 0 to 160 ppm. Therefore, a single calibration point, preferable around the concentration of concern, is normally all that is required to plot peak height response in ppm as a function of compound concentration. Data for other compounds on the same column may also be plotted along with their associated retention times, percent relative response in the total organic Survey Mode, TLV, etc. It is recommended that copies of the actual chromatograms be kept with the charts for observing the peak shapes, peak interferences, etc. It should be noted that a chromatogram can be utilized like a fingerprint for compound identification or peak height and shape comparison. Transparent overlays are an aid in chromatogram analysis.

When temperature variations are anticipated, data should be taken at several points and recorded on the chart as a new curve or as a relative change as a function of temperature as illustrated in Figure 10B.

Preparing and using the calibration chart is very straightforward. As an example, once the elution sequence of a group of compounds is determined, a mixture of 100 ppm of each can be prepared and run on the GC for chart data. The retention time of each compound and the peak height of each can be read directly from the chromatogram and the data put on the chart. If temperature data is to be taken, additional chromatograms may be run with the same sample and the RT and peak height as a function of temperature.

When complex mixtures such as gasoline are analyzed, it may be desirable to keep the record of the backflush peak for future reference and peak area comparison. It is also recommended that the total organic vapor concentration reading on the OVA be recorded for each calibration sample used. This reading is used for arriving at relative response numbers and as a check on sample preparation precision.

Routine Maintenance

a) COLUMN

Any column can be contaminated with compounds having long retention times. This will result in high background readings. This condition can be checked by installing a new column or a blank column (tubing only). If this reduces the background reading, the contaminated column should be baked at 100°C (212°F) for three (3) to four (4) hours in a drying oven while passing nitrogen through the column. Higher temperatures may permanently damage the column packing.

When installing any column, avoid touching the ends, as this may cause contamination. Also, ensure that the fittings are tight to avoid hydrogen leakage.

IMPORTANT: The following simple test may be run to determine whether the GC column is contaminated. While in a clean ambient air background, place the Sample Inject Valve in the "in" (GC Mode) position. Observe the background reading on the meter or recorder. After one (1) to two (2) minutes, change the position of the Backflush Valve and again observe the background reading. If the background reading went down and then started to increase in one to two minutes, the column is probably contaminated and needs to be cleaned. Note that if hydrogen flows into one end of the column for a period of time, the contamination is pushed into the column.

Then when the hydrogen flow is reversed, the exhaust end of the column will be clean until the contamination is again pushed through. Remember that to clean a column the purge gas must be run through the column in one direction until all contamination is removed. NOTE: Contaminated columns can be avoided by backflushing the column after every analysis.

b) CHARCOAL FILTER ASSEMBLY

After repeated use, the Charcoal Filter Assembly will become saturated. Periodically, the operator should check the effectiveness of the activated charcoal.

This can easily be done by operating the unit with the Sample Injection Valve "in" and passing the probe near a concentrated sample of the compound being analyzed. The readout should remain nearly steady (should not rise more than 0 to 2 parts per million (ppm)). If rise is more than 2 ppm, replace the old charcoal with new activated charcoal. Care should be taken to completely fill the tube to prevent a path for sample to bypass the charcoal. The life of the charcoal depends on the time (length) of exposure and the concentration level during that exposure. When changing charcoal, be sure that any fine charcoal dust is removed from the assembly.

Another test of the charcoal filter is to note the background reading with the Sample Inject Valve "out" and then note the reading with the valve "in". The level should never be higher when the valve is in the "in" position and the charcoal filter is in the air line. If the reading with the valve in the "in" position is higher, the charcoal filter is probably contaminated and acting like a contamination emitter.

Trouble Shooting

Table 2 presents recommended field trouble shooting procedures which are associated with the GC system. These procedures are in addition to those found in the basic OVA section of the manual.

TABLE 2

PROBLEM	TROUBLE SHOOTING PROCEDURE	REMEDY
1) Low sample flow rate on flow indicator.	a) Check Teflon tubing on valve assembly for kinks, etc.	Straighten or replace teflon tubing.
	b) Check flow rate with valve in down position.	Check for over restriction of charcoal filter.
2) Hydrogen flame will not light.	a) Check column connections on top of unit to make sure they are tight.	Tighten fittings.
	b) Check column for sharp bends or kinks. (Hydrogen flows through this column at all times and a sharp bend will compact packing too tightly for proper hydrogen flow).	Replace column.
	c) Check charcoal filter fittings to make sure they are tight.	Tighten fittings.
	d) Check hydrogen flow rate from the column.	Adjust hydrogen pressure to obtain 12 cm^3/min flow rate.
	e) Check that the Inject and Backflush Valves are both completely in or out. A partially activated valve will block the hydrogen and air flow paths.	Ensure both valves are either completely in or out.
	f) If a new column was installed prior to problem identification, check for proper hydrogen flow rate through the column (should be approximately 12 cm /min).	Increase hydrogen pressure to obtain proper hydrogen flow rate or if column is excessively restrictive, replace or repack the column.
3) Ambient background reading in clean environment is too high.	a) Check for contamination in charcoal filter assembly. This can be detected if ambient reading increases when going in to the chromatographic mode.	Replace activated charcoal in charcoal filter assembly.
	b) Check for contamination in column.	Replace or clean column.
	c) Check for contamination in column valve assembly.	Remove valve stems and wipe with clean lint-free cloth. Heat valve assembly during operation to vaporize and remove contaminants.
4) Flame-out when operating either valve.	a) Ensure valves are being operated with a quick, positive motion.	Operate valve with a positive motion.

TABLE 2

PROBLEM	TROUBLE SHOOTING PROCEDURE	REMEDY
	b) Either hydrogen or air may be leaking around one or more of the valve quad rings. Assess by tests and "O" ring inspection.	Remove stems and lightly coat with silicone grease, only on contact surface of the "O" ring. Wipe off excess (do not remove quad rings).
	c) Damaged or worn quad rings causing leak.	Replace quad rings and grease as above.
5) Excessive peak tailing	a) Change or clean GC; see if problem disappears.	Ensure columns are clean prior to use. If one of the same type of column tails are worse than others, repack the column or discard.
	b) Inspect GC valves for excessive silicone grease or contamination.	Excessive lubricant or foreign matter in the valve assembly can cause excessive tailing. Clean valve assemblies and lightly relubricate as required. Lubricant should be put only on the outside contact surface of the "O" ring. Do not get grease into the "O" ring grooves.

Recommended Spares

The following spare parts and supplies are recommended to support the GC system and recorder. These are an addition to the spare parts list for the basic OVA described in the "OVA MAINTENANCE" section.

ITEM DESCRIPTION	PART NO.
1) Quad Rings	510496-1 (10/pkg.)
2) Tubing, .148 in ID .020 wall	12942
3) Tubing, Teflon .120 in ID .030 wall	12941
4) Activated Charcoal	CSC-004
5) "O" Ring for Charcoal Scrubber	U0118CE
6) Chart Paper (linear)	CSC-008 (6/rls/pkg)

ACCESSORIES

Recorder Accessory

A portable Strip Chart Recorder is available for use with the OVA (reference Figure 11). The recorder is powered from the OVA battery pack and the output can be scaled to match the OVA readout meter, thereby providing a permanent record for subsequent analysis or reference. P/N 510445-4 is FM certified intrinsically safe. P/N 510445-6 is BASEEFA certified.

The recorder can be used with the OVA to provide a long term monitoring profile of total hydrocarbon or can be used with the Gas Chromatograph Option to provide a chromatogram.

Features

The recorder prints dry (no ink) on pressure sensitive chart paper. The recorder is equipped with two gain ranges and an electronic zero adjustment. The HIGH gain position is normally used to provide a means of scale expansion.

Controls and Connections

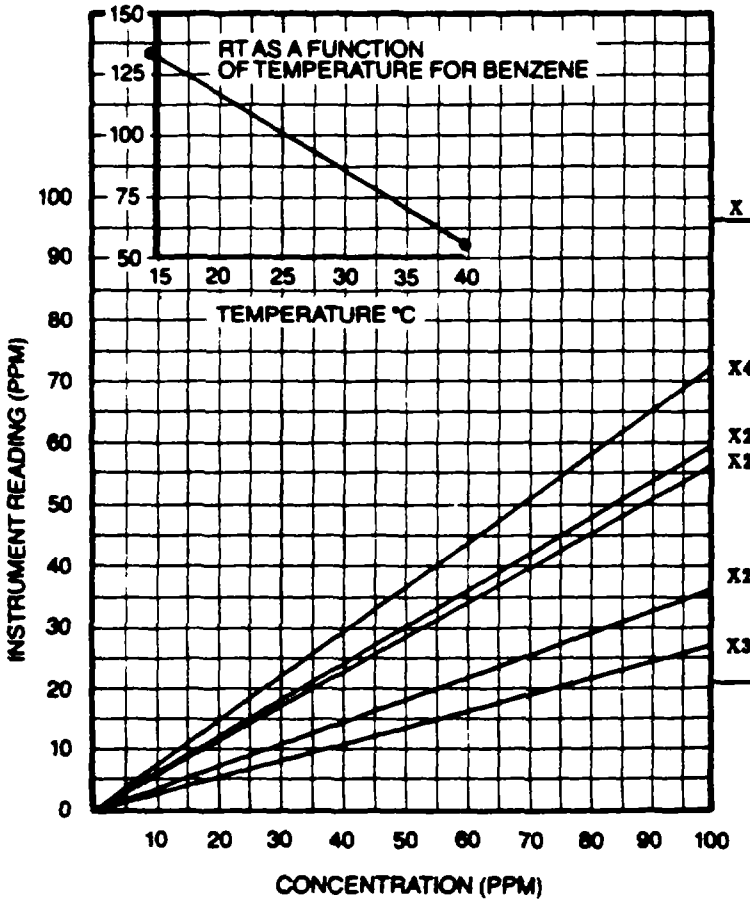
Described below are the functions of recorder controls and connectors.

1) HIGH-LOW Switch - This switch, located on the right hand side of the recorder, provides 2 ranges. The LOW range is set for the same full scale reading as the OVA readout meter. The HIGH range can be set to give an increased sensitivity to the recorder without effecting the OVA calibration.

2) ZERO ADJUST Knob - This potentiometer, located on the right hand side of the recorder, permits "nulling" of the background reading on the recorder without affecting the calibration of the OVA displayed on the OVA readout. In the full clockwise position, the recorder will display the same reading as the OVA meter. Counterclockwise rotation will reduce the reading on the recorder.

3) POWER CONNECTOR - This 126 series, 5 pin connector provides power and signal to the recorder, as follows:

PIN	FUNCTION
B	Input Signal
E	pos. 12VDC input
H	Ground



Column G-48 Chromatograph OVA-128
Temperature 25°C Carrier Flow 12 mL/sec.
Injection: Volume 2.5 mL Type valve

X	Compound	R.R (%)	RT (sec)	TLV (ppm)
X4	Heptane	80	471	400
X2	Pentane	100	90	1000
X2	Hexane	90	198	100
X2	Benzene	150	291	1
X3	Toluene	120	762	200

NOTE: 1. Concentration used for test is 100 ppm or as indicated.

2. X = Concentration multiplier

FIGURE 10A
CALIBRATION CHART

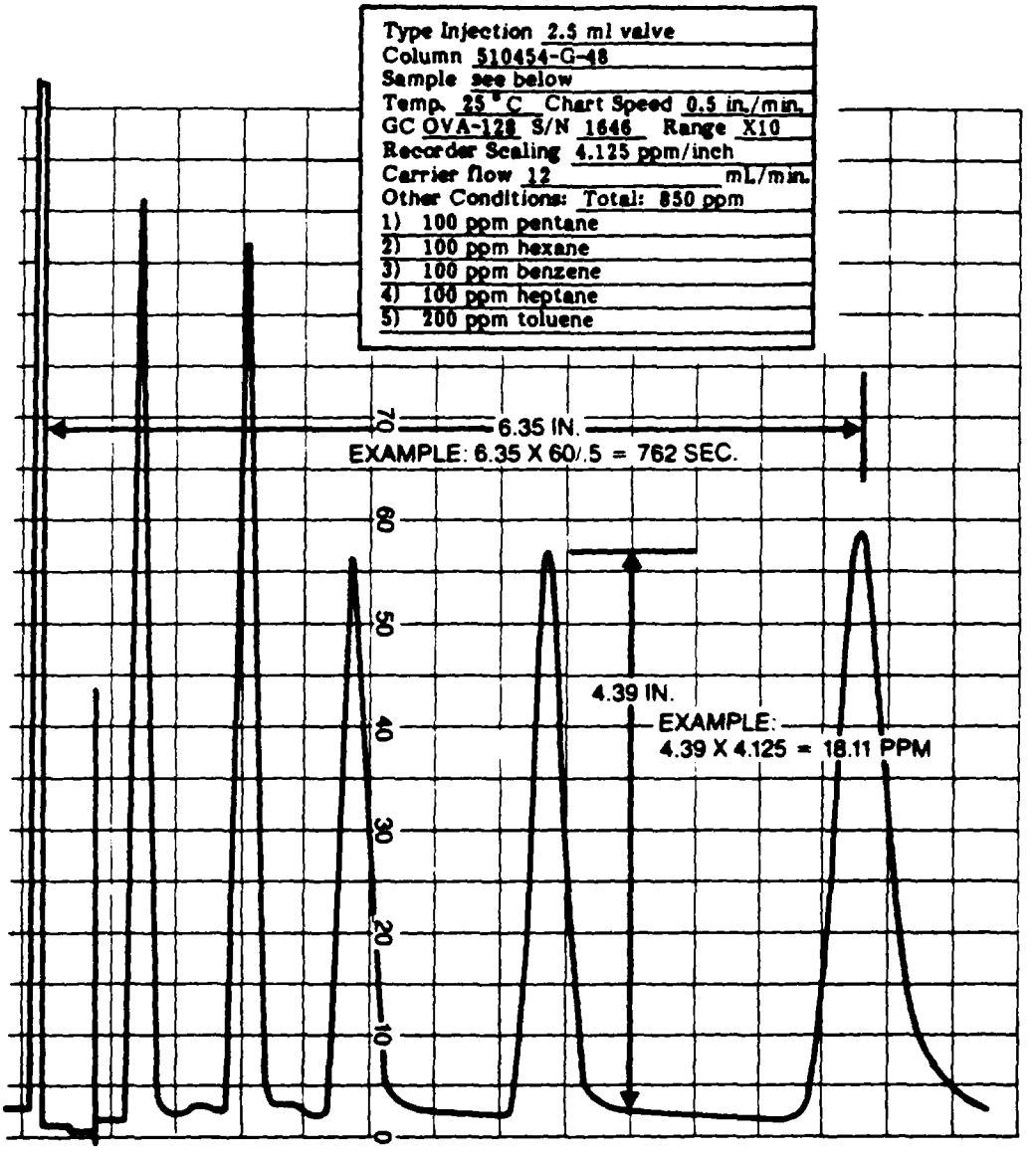


FIGURE 10B
CHROMATOGRAM

Calibration

Electronic and mechanical adjustments, other than the operational adjustments on the side panel, are provided to calibrate and align the recorder. (See Figure 11).

MECHANICAL ZERO ADJUSTMENT

A) Snap out the front panel nameplate using a small blade screwdriver in the left hand slot) for access to mechanical zero adjust screw, place HIGH-LOW Switch in OFF position.

B) Unscrew knurled fastener at top of front panel to open recorder. Pull down plastic chassis latch on right side to release sticker bar tension on paper and adjust mechanical zero as required. Replace nameplate, chassis latch and resecure front panel.

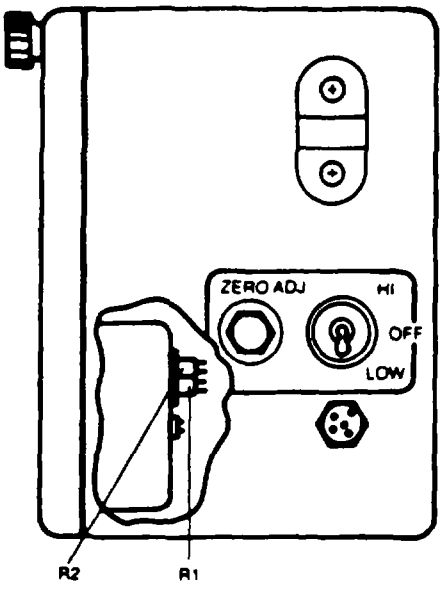


FIGURE 11
RECORDER CONTROLS AND ADJUSTMENTS

GAIN ADJUSTMENT

Separate adjustments are provided for the HIGH and LOW ranges on the recorder. (Refer to Figure 11 for location).

a) Connect recorder to OVA and adjust OVA for full scale reading on readout (about 5 VDC).
b) Loosen knurled fastener on upper left of the front panel and pull front panel down.
c) Place HIGH-LOW Switch in LOW and adjust R1 until recorder prints full scale.
d) Place HIGH-LOW Switch in HIGH and adjust OVA to read the desired full scale with front panel CALIBRATE ADJUST Knob, typically half scale on the readout. Adjust R2 until recorder reads full scale. NOTE: Full scale adjustment of the recorder for 1/2 scale on the OVA gives a gain increase of two (2) in the height of the peak on the chromatograms. This is the factory set point for the HIGH gain range; however, other points can be set as desired with a gain of three being the maximum obtainable without amplifier loading.

Maintenance and Routine Operations

Refer to the manufacturer's (Gulton) manual on the recorder which is enclosed with each recorder when shipped.

Changing Chart Speeds

The recorder is equipped with a 16 RPM motor which gives a writing speed of four (4) strikes per second. The chart advance speed is determined by the gear train assembly number used. The inches per hour for each gear train is given in the table on page 9 of the Gulton recorder manual. Refer to the bottom line of the chart adjacent to drive motor 16 and note for example that a number 1 gear train has a chart speed of 8"/hour.

a) To change the paper speed, open the recorder, remove gear box spring (on left side), move gear box in direction of arrow on its case and lift out from top. Do not force out from bottom. Insert new gear, bottom first, slide into position against arrow direction. Replace gear box spring.

Activated Charcoal Filter Accessory

The Activated Charcoal Filter Assembly is an accessory which can be installed on the OVA Readout Assembly or attached at the end of the telescoping probe. The filter is typically filled with activated charcoal which acts as an absorbent and effectively filters out organic vapors other than methane or ethane.

A screw cap on the probe end is removed for refilling the filter with activated charcoal or other filtering media.

Applications of the filter include:

1) Obtaining a clean air sample for zero baseline check and adjustment.

2) Running "blank" chromatograms to assess instrument contamination.

3) Rapid screening of methane and non-methane organic vapors.

4) Selective screening for natural gas surveys.

5) As a moisture filter when filled with a desiccant such as silica gel.

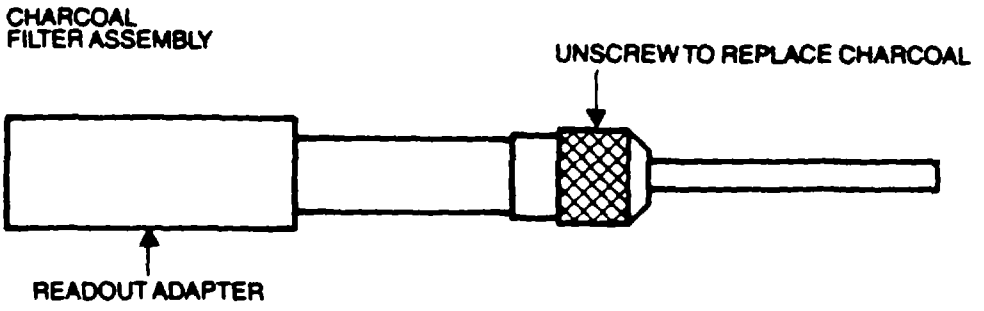


FIGURE 12
ACTIVATED CHARCOAL FILTER ASSEMBLY

A press fit adapter on the back of the filter assembly is removed when installing the unit on the telescoping probe. When replacing the cap end after refilling, one wrap of ¼ inch teflon tape should be used to seal the threads.

The life of the filter will depend on the time in use and the concentrations of the compounds being filtered. Under typical industrial air monitoring conditions, the filter will last for many days of continuous sampling. See Figure 12.

Sample Dilutor Accessory

An adjustable sample dilutor assembly, P/N 511745-1 is an accessory. The dilutor is supplied with a 10:1 dilution orifice as standard. Orifices for 25:1, P/N 511770-2, and 50:1, P/N 511770-3, dilution are also available.

In operation, the dilutor is attached to the end of the telescoping probe or connected by external tubing to the input fitting of the OVA side pack. Dilution of the air being monitored is accomplished by stream splitting through the use of a needle valve on the sample input. An activated charcoal scrubber is inserted in the main air supply line to the OVA and scrubs the air of organic vapors. It also creates a slight vacuum at its output side of the scrubber and the vacuum at this point draws the sample air through the needle valve where it mixes with the main air supply going to the OVA detector.

The dilution valve provides a means of sampling vapor levels above the lower explosive level (LEL) and in oxygen deficient atmospheres. These conditions can occur in normal leak or source survey as the operator gets close to the leak or vapor source or in monitoring various manufacturing or material handling processes. Approximately 14% oxygen is required to sustain operation of the FID in the OVA.

Setting Dilution Rate

Prepare a sample in a bag at a high level, typically 1,000 to 5,000 ppm. Any suitable gas can be used, such as butane from a cigarette lighter; however, a compound similar to those to be measured provides greater accuracy. The actual concentration of the gas does not have to be known, since the dilution rate is simply a relative level.

Obtain an OVA reading on the vapor sample with the dilution valve removed. Then install the valve, loosen the jam nut and turn the needle valve until the meter reading corresponds to the original reading divided by the dilution factor desired. Retighten the jam nut.

It should be noted that when the dilution valve is used for natural gas leak survey and pinpointing, the charcoal filter will not remove the methane from the dilution air supply. Care should be taken so that natural gas is not allowed to enter the main air inlet. (See Figure 13.)

OVA Septum Adapter Accessory

A Septum Adapter, P/N 510645-1, is available for direct on-line sample injection to the GC column inlet. The Septum Adapter mounts directly on the OVA front panel and sample injections from .025 to 2.5 cm may be made using a gas tight syringe.

This provides a range of sensitivity of approximately 10% to 1000% of the OVA standard valve, which has a sample loop volume of approximately 0.25 cm . Syringe injection can cause flame-out, however, the OVA may be reignited after the injection is made. The air in the sample must elute from the column before reignition. The time for the air peak to elute is a function of the column length and the volume of the sample injected. For example, a 1 cm sample into a 12" column will require approximately 5 seconds; and, a 2.5 cm sample into a 48" column will require approximately 20 seconds.

The Septum Adapter also provides a means whereby samples from oxygen deficient atmospheres or process streams can be injected directly into the chromatograph. Headspace analysis may also be accomplished using the Septum Adapter and a syringe.

OVA Portable Isothermal Pack (PIP) Accessory

A column can separate an exceptionally wide variety of components if the separations are made at different temperature ranges. In addition, peak heights and retention times can vary with column temperature. The PIP option was developed to control column temperature, without affecting the analyzer's intrinsic safety specifications and without compromising the analyzer's portability.

When the Septum Adapter is installed on the OVA, the normal GC sample valve may still be used alternatively with the syringe injection. In addition to variable sample size and sensitivity, syringe injections will normally provide greater symmetry and reduce tailing of chromatogram peaks as compared with the standard valve injection.

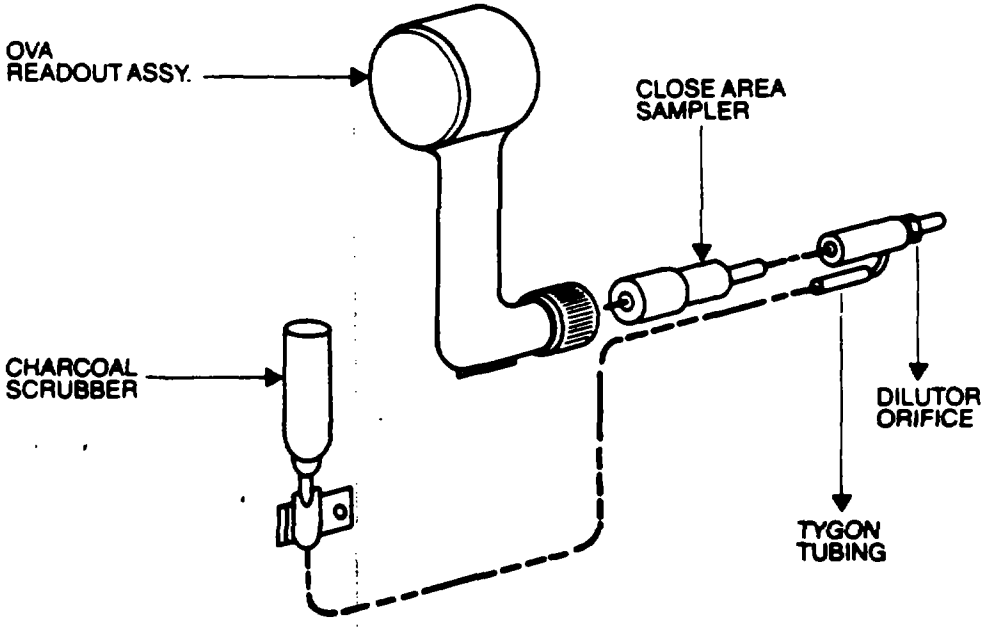


FIGURE 13
OVA SAMPLE DILUTOR

Parts List

PL 611-132 January 1987

CENTURY OVA 128
PORTABLE ORGANIC VAPOR ANALYZER

Style A

Model Code

OVA 128 = CENTURY Portable Organic Vapor Analyzer

Type
-A = Basic Flame Ionization Detector for Total Hydrocarbons Monitoring
-B = Gas Chromatograph (GC) with Two Columns
-C = GC with Tri Columns for Benzene Analysis

Battery Charger
1 = 120 V ac, 60 Hz
2 = 220 V ac, 50 Hz
3 = None

Electrical Classification
E = FM Certified for use in Class I, Groups A, B, C, and D, Division 1 Hazardous Environments
F = BASEEFA Certified

Optional
A = Strip Chart Recorder - FM Certified
B = Strip Chart Recorder - BASEEFA Certified

TO ORDER PARTS CALL FOXBORO AT 800-321-8322 OR 203-853-1616.

FOXBORO®

WILLIAMS-RUSSELL & JOHNSON, INC.

OVA 128 Analyzer

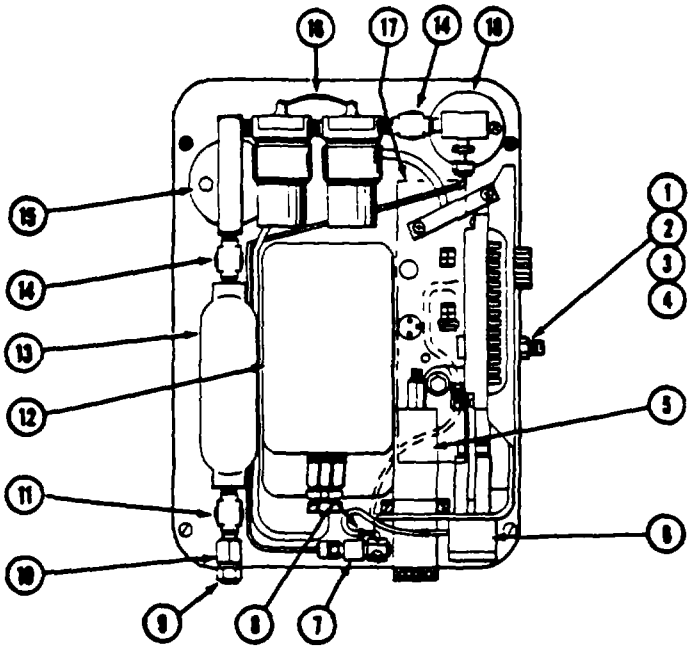


Figure R1326

Item	Part No	Qty	Part Name
--		1	Instruction, MI 611-132
--	510580-1	1	Instrument Case
1	510382-1	1	Connector Fitting
2	12741	1	Spring
3	004484	1	O-Ring
4	620090	1	Filter, Cup (Pkg of 5)
5	510600-1	1	Linear Preamplifier
-	510530-1	1	Flame Arrestor Assembly (located in exhaust port of detector chamber)
-	CR007KK	1	Flame Arrestor Filter (Pkg of 10)
-	510461-1	1	Igniter
6	CR007LB or 510223-6	1	Pump Assembly
-	510063-1	1	Diaphragm, Teflon
-	620107	1	Pump Valve (Pkg of 10)
7	510513-1	1	Mixer Burner Assembly
8	CR007KU	2	Spring Connector
9	620010	1	Cap, H_2

Item	Part No	Qty	Part Name (Cont.)
10	511161-1	1	N_2 Fill Adapter, Male
11	620045-1	1	Valve Assembly, N_2 Refill
-	CR007KA	A/R	Wafer, Teflon (Pkg of 10)
-	CR007KB	A/R	Wafer, Brass (Pkg of 10)
-	CR007KC	1	Valve Seat
12	510542-1	1	Battery Pack
13	510055-1	1	Cylinder Assembly
14	TR200TB	2	Supply Valve, N_2 Tank
15	013028	1	Gauge, H.P.
16	510073-1	1	Capillary Tube Assembly
17	510590-1	1	Power Control Board
18	012990	1	Gauge, L.P
-	510435-1	1	Charcoal Filter Assembly (see Note 1)
-	510496-1	1	Quad Rings (Pkg of 10) (see Note 2)

Notes: (1) For analyzers with Gas Chromatograph (GC Option) only.
(2) For analyzers with GC Option only. Rings are used in the GC Backflush Valve and the GC Sampling Valve.

Readout Assembly

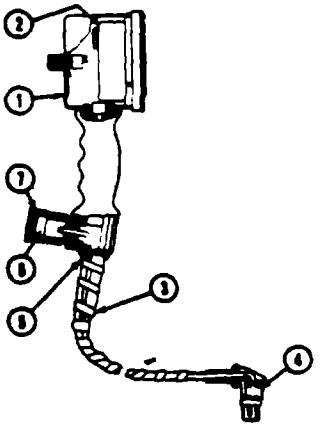


Figure R1327

Item	Part No	Qty	Part Name
-	620067-3	1	Meter Assembly Retrofit
1	510510-2	1	Readout Assembly, 128
2	620074-3	1	Meter Assembly
3	012700	3 Ft	Spiral Wrap, 0.25
4	510316-1	1	Sample Line Assembly
5	510376-1	1	Sample Line Support Connector
6	510033-1	1	Sleeve, Readout Handle
7	510032-1	1	Nut, Readout Handle

MB 121 Printed in U.S.A. 0187

A55-1

Quality Control Checklist for OVA Pre-Case Installation

Date	2/16/88
Inspector	[redacted]
Instrument Model	128FC
Instrument Serial Number	50963
Battery Charged, Indication in the Battery OK Region	✓
Sample Flow, 1.5 Units/minute min.	✓
Hydrogen Low Pressure Setting (8 to 12 psi)	✓

Gas Calibration Check (Calibration performed at 20° to 25°C):

128

Multiplier	Gas PPM	Read PPM	Limits PPM 20°-25°C	Limits PPM 10°-40°C
X1	7	7.2 *	± 2	± 2
X10	93	93 *	± 10	± 20
X100	977	970 *	± 100	± 200

* If the OVA 128 Readout Meter is pegged against the stop at the high end of the scale, refer to Gas Calibration Check, step m.

Note: Inspector must use same gases as those used for calibration.

Concentration and Flameout Alarm:

Speaker	✓
Earphone	✓

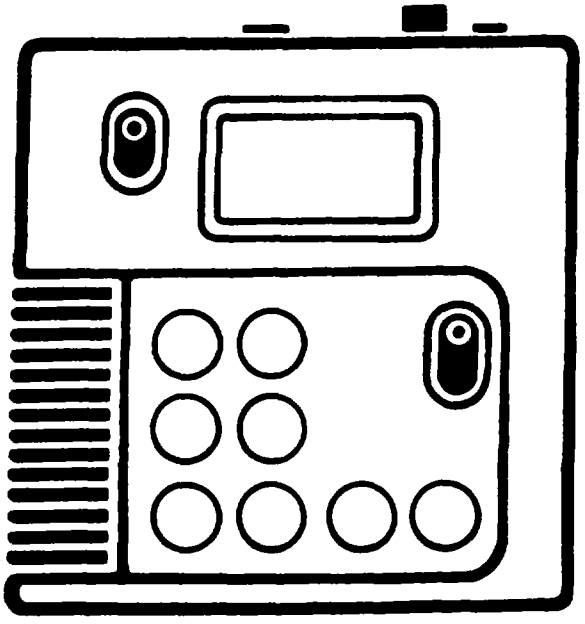
APPENDIX 4.3

SA 250 pH METER AND AUTOMATIC TEMPERATURE COMPENSATION PROBES

ORION

Orion Research Incorporated
Laboratory Products Group

SA 250 pH METER
INSTRUCTION MANUAL



CONTENTS

GENERAL INFORMATION

Introduction

The ORION SA 250 pH Meter is an advanced, portable pH meter with many features previously found only on bench-top meters.

Automated functions such as autocalibration, prompting, automatic temperature compensation, and diagnostic operator assistance codes make the SA 250 Meter very easy to use.

With your choice of .1 or .01 pH resolution, you decide if you need speed or better accuracy.

The meter comes with a ROSS Combination pH Electrode and ATC probe for fast, accurate results, no matter what the temperature difference between samples and standards.

Created for the outdoor, process, or active lab environment, the meter is lightweight, with a no-slip grip, large LCD display and has a rugged splash and dust-resistant housing. The SA 250 Meter meets or exceeds tests to Department of Transportation and Mil specs for shock, vibration, and moisture.

See **Figure 1**.

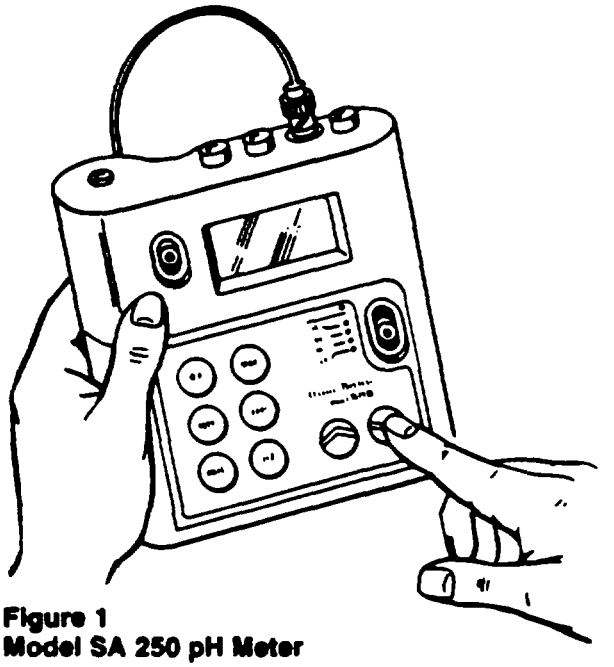


Figure 1
Model SA 250 pH Meter

INSTRUMENT DESCRIPTION

Refer to **Figure 2**.

1 **ON/OFF Switch** Controls power to the meter. Memory is maintained even when the instrument is turned off.

2 **LCD Display** SA 250 pH Meter automatically displays data on an easy-to-read 3 1/2 digit LCD.

3 **Mode Switch** Used to select mV, temp, pH .1, or pH .01 modes.

4 **Keys** Eight touch keys are used to control the meter. Each key is labelled as to the function performed. The following table summarizes the function of each key:

Key	Function
sample	Press to display pH of the sample.
cal	Press to start the calibration sequence.
iso	Press to display current isopotential point.
slope	Press to display slope in percent of theoretical.
enter	Press to enter a value into the meter memory.

The following keys, **X10**, ∧, ∨, are used to change the numeric display. This process is called scrolling.

X10	Increases the displayed value to the next decade – for example: pH 6.14 would increase to 7.00. At the upper end of the scale pressing **X10** will cause the display to wrap around – for example: pH 19.00 would go to –2.00.
∧ **up**	Increases the value displayed by increments equal to the least significant digit.
∨ **down**	Decreases the value displayed by increments equal to the least significant digit.

If the ∧ or ∨ key is pressed and held, the next significant digit will change.

The **sample**, **cal**, **iso**, and **slope** keys function only while the **mode** control is in either **pH .1** or **pH .01**.

The ∧ or ∨ keys function in **temp**, **pH .1**, or **pH .01** modes.

5 **Electrode Input**: Accepts BNC connector from combination or sensing electrodes. A separate pin tip input accepts reference electrodes.

6 **ATC Probe Jack**: Accepts ATC probe for automatic temperature compensation.

7 **Line Converter Jack**: Accepts an AC line converter for use without batteries.

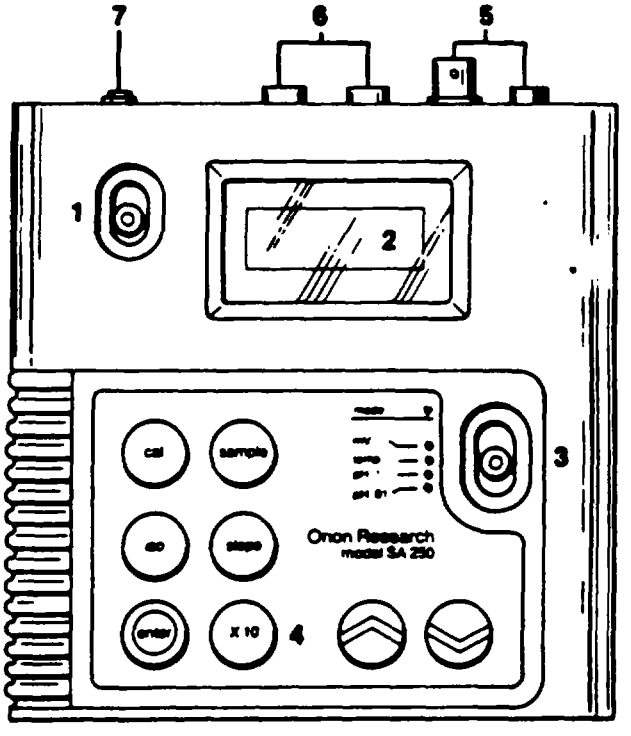


Figure 2
SA 250 Meter Controls

INSTRUMENT SET-UP

Support Rod

See **Figure 3**.

1. Attach support rod base to side of meter carrying case and tighten clamp screw.
2. Insert support rod into base. Tighten rod by turning clockwise.
3. Attach electrode holder to top of support rod.

Power Source

The ORION SA 250 pH Meter operates on one 9 volt nonrechargeable alkaline battery. If the SA 250 pH Meter is left on while using battery power, there will be approximately 30 hours of continuous life. Optional AC line converters are available for both 110 and 220 volt mains. Refer to **ORDERING INFORMATION**.

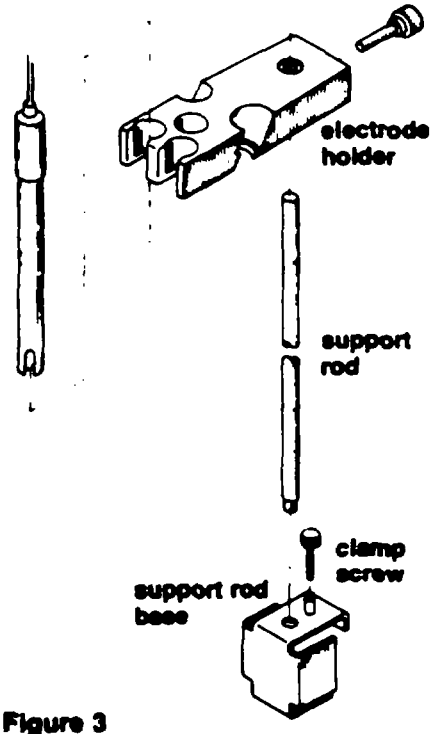


Figure 3
Support Rod and Clamp

Battery Installation

See **Figure 4**.

1. Remove access panel on back of meter, by sliding cover towards bottom of meter.
2. Attach battery connector clip to battery terminals, install battery and replace access panel.

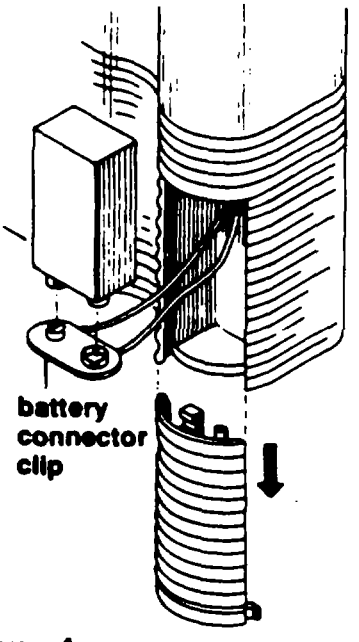


Figure 4
Battery Installation

Meter Check Out Procedure

1. Slide power switch to **ON** position. Attach BNC Shorting Plug (Orion Cat. No. 090045) to BNC connector on top of meter. Refer to **Figure 5**.
2. If using optional AC line converter, connect it to meter and appropriate power source. Proceed to step 4.
3. If **LO BAT** indicator on LCD remains on, the battery must be replaced.
4. Slide **mode** switch to **mV**. Display should read ***0 ± 0.3***.
5. Slide **mode** switch to **temp**. Display should read ***25.0***. If ***25.0*** is not displayed, scroll, using ^, v, and **X10** keys, until ***25.0*** is displayed and press **enter**
6. Slide **mode** switch to **pH .01**. Press **iso**. Display should read the letters ***ISO*** then a value of ***7.00***. If ***7.00*** is not displayed, scroll until ***7.00*** is displayed and press **enter**.
7. Press **slope**. Display should read the letters ***SLP*** then a value of ***100.0***. If ***100.0*** is not displayed, scroll until ***100.0*** is displayed and press **enter**.
8. Press **sample**. Observe the letters ***pH*** then a steady reading of ***7.00 ± 0.02*** should be obtained. If not, press **cal** and scroll until ***7.00*** is displayed and press **enter**. Press **sample** and observe a reading of ***7.00***.
9. Remove the shorting plug. After a successful completion of steps 1-8 the meter is ready to use with an electrode.

Electrode Connections

Refer to **Figure 5**.

1. Attach electrodes with BNC connectors to sensor input by sliding connector onto input, pushing down and turning clockwise to lock into position. Connect reference electrodes with pin tip connectors by pushing connector straight into reference input.

NOTE: If using a combination electrode with a BNC connector, the reference pin-tip jack is not used (4 in Figure 5).

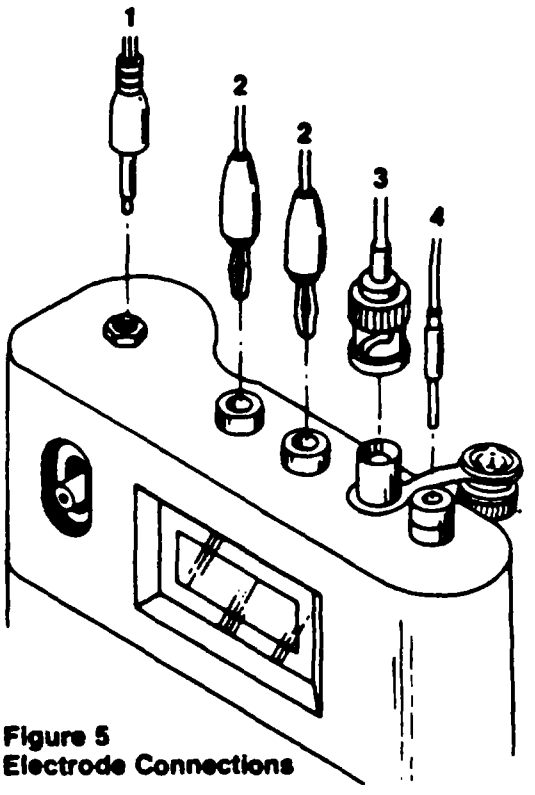


Figure 5
Electrode Connections

Legend

1 AC line converter to line converter jack
2 ATC plugs to ATC jacks
3 BNC connector to sensor input (shown with shorting plug disconnected)
4 Reference pin-tip plug to reference input

MEASUREMENT PROCEDURES

pH Measurements

See **Figure 6**.

A calibration with one or two buffers should be performed before pH is measured. It is recommended that a calibration with two buffers be performed at the beginning of each day to determine the correct slope of the electrode. This serves the dual purpose of determining if the electrode is working properly and storing the slope value in the meter's memory. Perform a one buffer calibration every two hours to compensate for electrode drift.

Check the stored value for ***ISO*** before calibration. Unless the isopotential point of the electrode is known verify that the display reads ***7.00***. If not, scroll until ***7.00*** is displayed and press **enter**. See **Isopotential Point**.

There are two ways of calibrating the SA 250 Meter, autocalibration or manual calibration.

NOTE: It is recommended to select either autocalibration or manual calibration and not use a combination of the two methods. Following is a description and instructions for each method.

Autocalibration

Autocalibration is a feature of the SA 250 Meter that automatically recognizes the 7.00, 4.01 and 10.01 buffers with a range of ± 0.5 pH units. The user waits until the pH display is stable and presses **enter**. The SA 250 Meter automatically calibrates to the correct buffer value using temperature compensation. Do not scroll when using autocalibration.

While calibrating, the SA 250 Meter compares actual values to theoretical values to determine if the buffer is within range. Buffers greater than ± 0.5 pH units from the correct value will trigger an operator assistance code.

It is recommended that an ATC probe be used for autocalibration. If an ATC probe is not used, all samples and buffers should be at the same temperature or use manual temperature compensation. See **Temperature Mode**.

Autocalibration With Two Buffers

1. Connect electrode(s) to meter. Slide the **mode** switch to either **pH .1** or **pH .01**. Choose either 4.01 and 7.00, or 7.00 and 10.01 buffers, whichever will bracket your expected sample range.
2. Place electrode(s) into either 4.01, 7.00 or 10.01 buffer.
3. Press **cal**. The display will alternate between ***.1.*** and the pH value of the buffer, indicating this is the first buffer and a value has not been entered. Wait for a stable pH display and press **enter**. The correct display will freeze for 3 seconds then advance to ***.2.*** indicating the meter is ready for the second buffer.
4. Rinse electrode(s) and place into a second buffer. Wait for a stable pH display and press **enter**.

   After the second buffer value has been entered the letters ***PH*** will be displayed. The meter is now calibrated and automatically advances to **sample** mode.
5. Rinse electrode(s), place into sample. Record pH directly from the meter's display.

Autocalibration With One Buffer

1. Check slope term by pressing **slope**. If necessary, scroll and enter the correct value. If slope value is unknown, either enter 100.0 or perform a two buffer calibration. A single buffer calibration does not change the slope term.
2. Connect electrode(s) to meter. Slide **mode** switch to either **pH .1** or **pH .01**.
3. Place electrodes into either 4.01, 7.00 or 10.01 buffer.
4. Press **cal**. The display will alternate between ***.1.*** and the pH value of the buffer, indicating this is the first buffer and a value has not been entered.
5. Wait for a stable pH reading and press **enter**.

   After **enter** is pressed the correct display will freeze for 3 seconds then advance to ***.2.***, indicating the meter is ready for the second buffer. By pressing **sample** the letters ***PH*** will be displayed, indicating the meter has advanced into the sample mode.
6. Rinse electrode(s) and place into sample. Read the pH directly from the display.

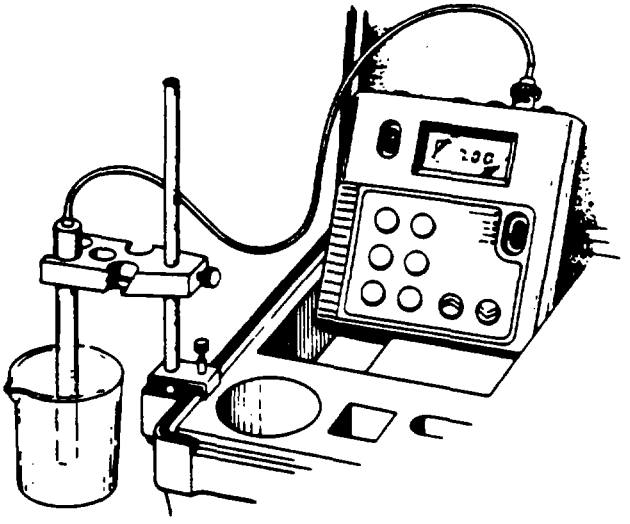


Figure 6
Optional Way to Set Up SA 250 Meter for Sample Measurements

Manual Calibration

To calibrate with buffers other than 4.01, 7.00 or 10.01, use the manual calibration technique. The calibration sequence is the same as autocalibration, except buffer values are scrolled in.

It is recommended that an ATC probe be used. If an ATC probe is not used, all samples and buffers should be the same temperature or use manual temperature compensation. See **Temperature Mode**.

Please note that even if scrolling is not necessary, scroll one digit and return to correct value before pressing **enter**. Otherwise meter will assume autocalibration is to be used.

Manual Calibration With Two Buffers

1. Connect electrode(s) to meter. Slide **mode** switch to either **pH .1** or **pH .01**. Choose two buffers that will bracket your expected sample range.
2. Place electrode(s) into the first buffer.
3. Press **cal**. The display will alternate between ***.1.*** and the pH value of the buffer, indicating this is the first buffer and a value has not been entered.
4. Wait for a stable pH display. Using ^, v or **X10** keys, scroll in the correct value and press **enter**.

   The display will freeze for 3 seconds then advance to ***.2.*** indicating the meter is ready for the second buffer.
5. Rinse electrode(s) and place into the second buffer. Wait for a stable pH display. Scroll in the correct value and press **enter**.

   After the second buffer value has been entered the letters ***PH*** will be displayed. The meter is now calibrated and automatically advances to the **sample** mode.
6. Rinse electrode(s) and place into sample. Record pH directly from the meter's display.

Manual Calibration With One Buffer

1. Verify slope by pressing **slope**. If necessary scroll in correct value, using ^, v and **X10** keys, and press **enter**. If correct slope is unknown, either enter ***100.0*** or perform a two buffer calibration.
2. Connect electrode(s) to meter. Slide **mode** switch to either **pH .1** or **pH .01**.
3. Place electrodes into the buffer.
4. Press **cal**. The display will alternate between ***.1.*** and the pH value of the standard, indicating this is the first buffer and a value has not been entered.

   Wait for a stable pH display, scroll until the correct value is displayed and press **enter**.

   The display will freeze for 3 seconds then advance to ***.2.*** indicating the meter is ready for the second buffer. By pressing **sample** the letters ***PH*** will be displayed. The meter is now calibrated and automatically advances to **sample** mode.
5. Rinse electrode(s) and place into sample. Read the pH directly from the display.

NOTE FOR MANUAL CALIBRATION: In the event that scrolling was started but the value was not entered and the mode switch was changed, either a P1 or a P2 will be displayed upon returning to the pH mode. P1 indicates that a value has not been entered for the first buffer while P2 indicates a value has not been entered for the second buffer.

Slope

By pressing the **slope** key the slope is displayed as a percent of theoretical. A properly functioning electrode will have a 92% to 102% slope. See **Troubleshooting**, if the slope is out of range. The slope value is retained in the meter's memory until another two buffer calibration is performed or another value is entered. A one buffer calibration does not change the slope value.

At the beginning of each day and every time a different electrode is used a two buffer calibration should be performed for accurate measurements.

To enter a slope value:

1. Slide the **mode** switch to either **pH .1** or **pH .01**.
2. Press the **slope** key.
3. Scroll, using ^, v or **X10** keys, until the correct value is displayed.
4. Press **enter**.

Isopotential Point

The isopotential point is the pH at which the potential (mV) of the electrode will not vary with temperature.

For the majority of pH electrodes the isopotential point is pH 7.00. There are some exceptions where the operating range used for a particular electrode is primarily at one end of the pH scale.

If your pH electrode has an isopotential point other than 7.00, the correct value may be entered as follows:

1. Slide **mode** switch to **pH .1** or **pH .01**.
2. Press **iso**.
3. Scroll, using ∧, ∨, or **X10** keys, until correct value is displayed.
4. Press **enter**.

A two buffer calibration should be performed after an isopotential point value has been changed. It is good practice to verify the isopotential point whenever the meter has been turned on.

Temperature Mode

Sliding the **mode** switch to **temp** will display the temperature in °C. When the temperature is outside of the operating range – 5.0 to 105.0°C, an operator assistance code will be displayed, ***E-1*** for below – 5°C, or ***E 1*** for above 105°C.

During a calibration or sample measurement, the **mode** switch can be changed to **temp**. When an ATC probe is connected the temperature can be monitored and automatic temperature compensation will take place.

To use manual temperature compensation:

1. Using a thermometer accurate to ± 1°C determine the temperature of the solutions to be measured.
2. Slide **mode** switch to **temp**.
3. Scroll, using ∧, ∨ or **X10** keys, until the correct temperature value is displayed.
4. Press **enter**.
5. Return **mode** switch to either **pH .1** or **pH .01**.

When an ATC probe is not connected, the last entered value of temperature is displayed. If a temperature value has not been entered since the removal of an ATC probe, a default value of 25°C is displayed.

Potentiometric Measurements

Potentiometric titrations are performed in **mV** mode using either pH, ion-selective or redox electrodes. Detailed instructions for any ORION Electrode are given in the electrode instruction manual. Titration instructions are included in ORION Redox Electrode (Model 96-78 or 97-78) Instruction Manual, or in standard analytical texts. Electrodes that have a U.S. Standard Connector need a U.S. Standard to BNC Adaptor which are available from Orion (Cat. No. 090033).

Dissolved Oxygen Measurements

Dissolved oxygen measurements are displayed in ppm O_2 when ORION Model 97-08 Dissolved Oxygen Electrode is used with ORION SA 250 Meter. Follow these instructions for calibrating the electrode.

1. Connect the Model 970899 to meter and leave electrode mode switch "off".
2. Unplug and do not use an ATC probe.
3. Set the **mode** switch of the SA 250 Meter to **temp** and scroll in 25.0°C, press **enter**.
4. Set the **mode** switch to **pH .1** or **pH .01**.
5. Press the **slope** key. Scroll until the value ***100.0*** appears and press **enter**.
6. Press the **iso** key and verify that it is ***7.00***. If not, scroll in the value ***7.00*** and press **enter**.
7. Press the **cal** key. Scroll in the value ***7.00*** and press **enter**.
8. Press **sample**.
9. Turn the **mode** switch on the electrode to BT CK. Good battery operation is indicated by a reading of ***13.00*** or greater on the meter.
10. Turn the mode switch on the electrode to ZERO. *Use the zero calibration control on the electrode* to set the meter to read ***0.00***.
11. Insert the reservoir (funnel) into a BOD sample bottle containing enough water to just cover the bottom. Insert the electrode, making sure that the electrode tip is *not* immersed in the water and does not have water droplets clinging to the outside of the membrane. Let stand approximately 30 minutes to ensure water saturation of air in BOD bottle. This bottle should be used for electrode storage between measurements.
12. Turn the electrode mode switch to the AIR position. If measurements are being made at sea level, use the AIR calibration control on the electrode to set the pH meter reading to the prevailing barometric pressure in mm Hg (divided by 100). If the barometric pressure is unknown, if the elevation is above sea level or if the sample has a salinity greater than 2 parts per thousand, consult **Table 1** found in the Model 97-08 Instruction Manual to obtain the correct AIR setting.
13. Turn electrode mode switch to H_2O for sample analysis.

OPERATOR ASSISTANCE CODES

Operator assistance codes are used to inform the user of an out of range value. The following table outlines the operator assistance codes that are available in the SA 250 pH Meter and suggests a remedy. The table is divided according to the modes of the meter.

Code	Problem	Remedy
MV MODE		
E 1 ***E-1***	mV out of range	1. If occurs when electrodes are out of solution, code will disappear when electrodes are returned to solution. 2. Verify electrodes are properly connected and filled. 3. Dilute standards or samples. 4. Review calibration and operating procedures.
TEMP MODE		
E 1 ***E-1***	Temp out of range	1. Verify ATC probe is properly connected.
pH .1 or pH .01 MODES while in sample function		
E 1 ***E-1***	mV, temp or pH out of range	1. Go to mV mode and check. If mV is out of range, perform remedy steps described above for mV mode. 2. Go to temp mode and check. If temp is out of range, perform remedy steps described above for temp mode. 3. Check the sample. 4. Check slope and iso values. 5. Recalibrate.
While in cal function:		
E 1 ***E-1***	mV, temp or pH out of range	1. Go to mV mode and check. If mV is out of range, perform remedy steps described above for mV mode. 2. Go to temp mode and check. If temp is out of range, perform remedy steps described above for temp mode. 3. Check the buffer. 4. Check iso value.
E21	Slope not in the range 80.0 to 100.0%	1. Press enter to acknowledge code and repeat calibration using fresh buffers. 2. Clean electrode and refill reference. 3. Refer to electrode instruction manual for check out.
E31	First cal point out	1. Press enter and repeat calibration using fresh buffers. 2. Check iso, slope, and temp values. 3. Verify electrodes are properly connected.
E35 ***E36***	pH Autocalibration error. Electrode voltage being measured is greater than ±0.5 pH units from nominal value for the pH buffer	1. Press enter and repeat calibration using fresh buffers. 2. Clean electrodes and refill reference. Recalibrate. 3. Perform a manual calibration. Certain electrodes may operate out of acceptable range for pH autocalibration.

TROUBLESHOOTING GUIDE

Malfunction	Possible Cause	Remedy
No Display	No power to meter	1. Check that switch is in ON position. 2. Replace battery. 3. Check that adaptor is receiving power and is plugged in securely.
Erratic readings or reading out of range	Meter or electrode failure	1. Follow meter checkout procedure. 2. Follow instructions in electrode instruction manual.
Unable to calibrate	Isopotential error	1. Verify iso.
Unable to calibrate in autocalibration	Certain electrodes may operate outside the limits of ±0.5 pH units.	1. Try scrolling value to within range and press **enter** to cal if ***E 1*** or ***E-1*** appearing. 2. Check temp, slope, and iso and repeat.

Orion Technical Service Chemists can be consulted for troubleshooting advice by calling 800-225-1480 or 617-242-3900. Outside North America contact your local authorized Orion Representative.

INSTRUMENT WARRANTY

ORION RESEARCH INCORPORATED warrants this instrument will operate for one year from the date of purchase when used under normal laboratory conditions, and in accordance with the operating limitations and maintenance procedures given in the instruction manual. In the event of failure within the warrant period, Orion, or its Authorized Dealer, will, at Orion's option, repair or replace the non-conforming instrument at no charge to the customer.

THE WARRANTY DESCRIBED ABOVE IS EXCLUSIVE AND IN LIEU OF ANY OTHER WARRANTY, WHETHER STATUTORY, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO, ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE AND ALL WARRANTIES ARISING FROM COURSE OF DEALING OR USAGE OF TRADE, EXCEPT TITLE. THE BUYER'S SOLE AND EXCLUSIVE REMEDY IS FOR REPAIR, OR REPLACEMENT OF THE DEFECTIVE INSTRUMENT OR PART, OR REFUND OF THE PURCHASE PRICE; BUT IN NO EVENT SHALL ORION (ITS CONTRACTORS AND SUPPLIERS OF ANY TIER) BE LIABLE TO THE BUYER OR ANY PERSON, IN CONTRACT OR IN TORT (INCLUDING NEGLIGENCE) FOR SPECIAL, INDIRECT, INCIDENTAL OR CONSEQUENTIAL DAMAGES.

Representations and warranties made by any person, including dealers, representatives and employees of Orion, which are inconsistent or in conflict with the terms of this warranty shall not be binding upon Orion unless in writing and signed by one of its officers.

REPAIR AND SERVICE

A Return Authorization Number must be obtained from Orion Laboratory Products Customer Service before returning any product for in-warranty or out-of-warranty repair, replacement or credit.

Consult your authorized Orion dealer, or:

ORION RESEARCH INCORPORATED
The Schrafft Center
529 Main Street, Boston, Massachusetts 02129
TELEPHONE 617-242-3900
TELEX 4430019

In Europe, the Middle East, and Africa contact your authorized Orion dealer, or:

ORION RESEARCH AG
Fähnlibrunnenstrasse 3
CH-8700 Kusnacht, Switzerland
TELEPHONE 01-910-7858
TELEX 825767

ORDERING INFORMATION

Cat. No.	Description
910001	pH Electrode Storage Solution, 475 ml bottle
910004	pH 4 Buffer Packets, box of 25 packets, each packet making 200 ml of buffer
910007	pH 7 Buffer Packets, box of 25 packets, each packet making 200 ml of buffer
910009	pH 9 Buffer Packets, box of 25 packets, each packet making 200 ml of buffer
910104	pH 4.01 Buffer, 475 ml bottle
910107	pH 7.00 Buffer, 475 ml bottle
910110	pH 10.01 Buffer, 475 ml bottle
910071	pH Solutions Bulk Pack, for use with Ag/AgCl internal pH electrodes, includes four 910110, four 910107, one 910001, two 900011, and three flip-top spout dispensers
910074	pH Solutions Bulk Pack, for use with Ag/AgCl internal pH electrodes, includes four 910104, four 910107, one 910001, two 900011, and three flip-top spout dispensers
810002	pH Solutions Bulk Pack, for use with ROSS pH Electrodes, includes four 910110, four 910107, one 910001, two 810007, and three flip-top spout dispensers
810003	pH Solutions Bulk Pack, for use with ROSS pH Electrodes, includes four 910104, four 910107, one 910001, two 810007, and three flip-top spout dispensers
700001	Pure Water pH Test Kit includes four 475 ml bottles L.I.S.* pH Buffer a, 6.97; two 475 ml bottles L.I.S.* pH Buffer b, 4.10; two 50 ml bottles pHiX adjustor, one 1 ml syringe, one holding tray, instruction card and Application Procedure No. 501. (* Low Ionic Strength)
910002	Electrode holder
917001	Automatic temperature compensator – epoxy outer body
917002	Automatic temperature compensator – glass outer body
090033	U.S. Standard electrode to BNC meter connector adaptor
090045	Shorting plug
020120	110V AC line adaptor
020121	220V AC line adaptor

Cat. No.	Description
020041	Neck strap and meter holder for "hands-free" use
020042	Carrying case with foam insert, without meter or accessories
020044	Accessory pack, incudes two 60 ml bottles and one 150 ml beaker
020045	Rod, electrode holder and stand for "out-of case" bench top use

NOTICE OF COMPLIANCE

WARNING: This meter may radiate radio frequency energy and if not installed and used properly, that is, in strict accordance with the manufacturer's instructions, may cause interference to radio communications. It has been tested and found to comply with the limits for a Class A computing device pursuant to Subpart J of Part 15 of FCC Rules, which are designed to provide reasonable protection against such interference in a commercial environment. Operation of the meter in a residential area may cause interference in which case the user at his own expense will be required to take whatever measures may be required to correct the interference.

SPECIFICATIONS

mV
−999 to 999

Temperature
−5.0 to 105.0°C

pH
−2.00 to 19.99

Isopotential
0.01 to 19.99

Slope
80 to 110%

Relative Accuracy
pH .1° ± .1, ± 0.05% whichever is greater
pH .01° ± .01, ± 0.05% whichever is greater
mV ± 1.0

Temperature
± 1.0

Display
3 1/2 digit LCD

Inputs
Single, ATC

Power Requirements
One 9 Volt alkaline battery or line adaptor for either 110 or 220V AC, 50/60 Hz wall outlet

Input Impedance
> 100,000 megohms

Instrument Drift
< 50 microvolts/°C

Input Bias Current
< ± 1 pico amps at 25°C and < ± 4 pico amps over full operating range

Environmental Requirements
5 to 45°C and 5 to 80% relative humidity, non-condensing

Meter Dimensions
14 cm X 14 cm X 4 cm

Meter Weight
0.5 kg

Meter Case
Splash and dust resistant, chemical resistant

Carrying Case
38.1 cm X 27.9 cm X 11.4 cm

Carrying Case Weight
1.8 kg

• After calibration with two buffers according to **MEASUREMENT PROCEDURES**

If the line converters that Orion supplies, Cat. No. 020121 and 020120, are not available, any line converter meeting the following specifications may be used.

Converter for 120 VAC to 9 VDC

This specification describes an AC-to-DC power supply for use with ORION products.

Electrical Specifications

1. The power supply shall furnish rectified, filtered, unregulated DC voltage.
2. The input voltage shall be 100-130 VAC, 47-63 Hz.
3. The open circuit output voltage shall not exceed 15.5 VDC at an input voltage of 130 VAC, 60 Hz.
4. The unit shall produce an output voltage not less than 9.0 VDC with a load of 200 MADC at an input voltage of 115 VAC, 60 Hz.

Mechanical Specifications

1. The power supply shall plug into two blade wall outlets that are standard in North America for 115 VAC service.
2. Output cord shall terminate in a standard 3.5 mm diameter phone plug. The tip shall be negative, the sleeve positive.

Safety

1. The power supply shall be UL listed and CSA approved.

Converter for 220 VAC to 9 VDC

This specification describes an AC-to-DC power supply for use with ORION Products.

Electrical Specifications

1. The power supply shall furnish rectified, filtered, unregulated DC voltage.
2. The input voltage shall be 200-240 VAC, 47-63 Hz.
3. The open circuit output voltage shall not exceed 15.5 VDC at an input voltage of 240 VAC, 50 Hz.
4. The unit shall produce an output voltage not less than 9.0 VDC with a load of 200 MADC at an input voltage of 220 VAC, 50 Hz.

Mechanical Specifications

1. Suggested cord length is 1.5 meters long.
2. Output cord shall terminate in a standard 3.5 mm diameter phone plug. The tip shall be negative, the sleeve positive.

ORION

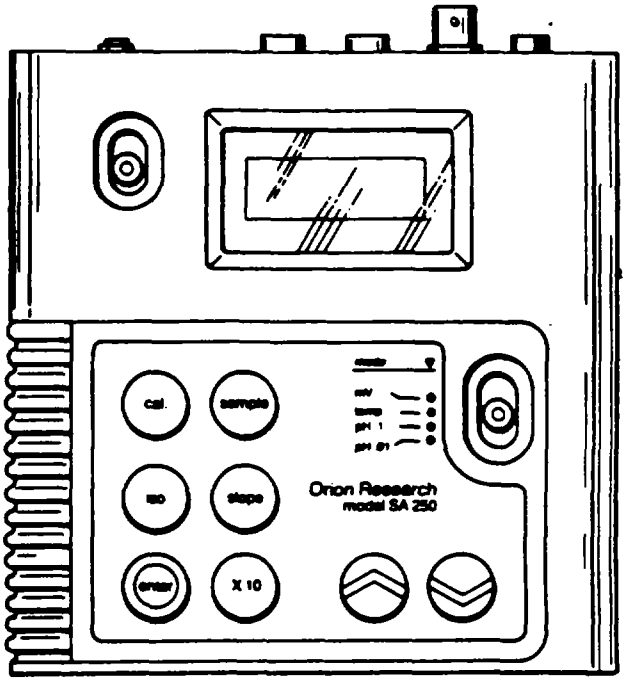
Orion Research Incorporated
Laboratory Products Group

SA 250 pH METER
TRAINING GUIDE

The ORION SA 250 Meter is an advanced portable pH meter with many features previously found only in bench-top meters.

- Autocalibration recognizes and enters 4.01, 7.00, or 10.01 pH buffers. Other buffer values can be manually entered.
- Choice of .1 or .01 pH resolution. You choose speed or better accuracy.
- Prompting you through 1 or 2 point calibration to sample measurement.
- Assistance codes diagnose errors.
- Superior design for outdoor, process, or active lab environments.
- Durable splash, dust, and corrosion-resistant housing.
- Lightweight, no slip grip for hand-held operation.
- Convenient carrying case with ROSS pH Electrode, ATC probe, and all the accessories you need for immediate start-up.

Turn this card over for instructions on a calibration with two buffers using the ATC probe. Consult the meter instruction manual for initial check out, specifications, and further operational information.



ORION

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Laboratory Products Group

AUTOMATIC TEMPERATURE COMPENSATION PROBES INSTRUCTION MANUAL

Orion Cat. No. 917001
Automatic Temperature Compensation Probe (epoxy outer body)

Orion Cat. No. 917002
Automatic Temperature Compensation Probe (glass outer body)

ORION

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Printed in U S A Part No 502700-015 Form IMATCP/6840

INTRODUCTION

ORION Automatic Temperature Compensation (ATC) Probes transmit a signal to the pH meter, which automatically corrects pH measurements for variation in electrode slope due to temperature change. The 917001 and 917002 ATC Probes are designed for use with the following ORION Meters:

SA 230	501	811
231	SA 520	EA 920
SA 250	SA 720	EA 940

These probes may also be used with other meters requiring a PT-100 type thermistor automatic temperature compensator with dual banana plugs.

The 917001 ATC Probe has a break resistant epoxy body. The epoxy is not recommended for use in organic solvents, but may be used on an intermittent basis in methanol or ethanol.

The 917002 ATC Probe is an all glass probe. This probe is preferred for use in solutions containing organic solvents or at temperatures over 80°C.

For automatic temperature compensation and temperature measurement procedures, consult the appropriate meter instruction manual.

SPECIFICATIONS

Temperature Range
917001: 0-80°C
917002: −5 to 100°C (ATC), 120° (TEMP only)

pH Range
0 to 14 pH

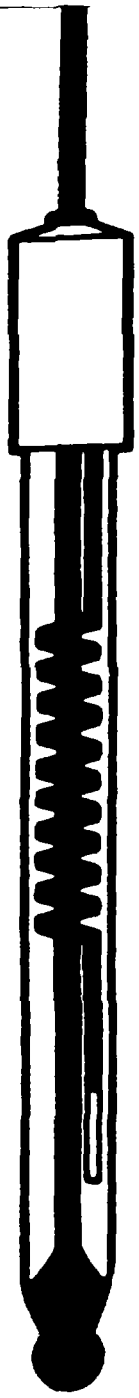
Accuracy
±0.1°C or 1%, whichever is greater

Storage
Store in air

Connector
Dual banana plugs

Size
Probe length: 15 cm
Cable length: 100 cm
Probe diameter: 8 mm

Specifications subject to change without notice



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ROSS pH ELECTRODE INSTRUCTION MANUAL

ORION

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Printed in U S A Part No 502700-098 Form IMROSS/6830

CONTENTS

GENERAL INFORMATION

Introduction

This manual contains instructions for the ROSS® series of pH electrodes. Operation and maintenance instructions for the following electrodes are included:

Model No.	Description
80-05	ROSS Reference Half Cell, glass body
81-01	ROSS pH Half Cell, 0-14 pH, glass body
81-02	ROSS Combination pH Electrode, 0-14 pH, glass body
81-03	Semimicro ROSS Combination pH Electrode, 0-14 pH, glass body
81-04	ROSS Combination pH Electrode, 0-14 pH, glass body with rugged bulb
81-15	ROSS Semimicro Combination pH Electrode, 0-14 pH, epoxy body
81-35	ROSS Combination Flat Surface pH Electrode, 0-14 pH, epoxy body
81-55	ROSS Combination pH Electrode, 0-14 pH, epoxy body with bulb guard
81-56	Same as above with BNC connector
81-63	ROSS Combination Spear-tip pH Electrode, 0-14 pH, glass body
81-66	ROSS Combination pH Electrode with sleeve reference junction, 0-14 pH, glass body

The ROSS series of electrodes provide readings stable to 0.01 pH in less than 30 seconds, even in the extreme case of samples varying from one another by 50°C or more. Results are three to five times more accurate than those obtained with conventional electrodes. And, because drift is less than 0.002 pH per day, restandardization is minimized.

ROSS Electrodes are available with various connectors. See **ORDERING INFORMATION**, or consult the Orion pH Electrode Catalog and price list. For more information contact your local ORION Distributor, or call Orion Customer Service.

Required Equipment

Meter – Any ORION pH or ion selective meter, or other pH/ISE meter with appropriate connectors.

Combination pH Electrode or pH and Reference Electrode Half Cells – Use the ORION Model 81-01 ROSS pH Half Cell only with a ROSS Reference Half Cell Electrode, Model 80-05.

Thermometer – Readable to ±0.5°C.

Beakers – Plastic or glass.

Magnetic Stirrer – Suggested for precision measurements.

Required Solutions

pH Buffers – Two are recommended for precise measurement. The first, near the electrode isopotential point (pH 7), and the second near the expected sample pH (e.g., pH 4 or 10).

ROSS Internal Filling Solution – 3M KCl, Orion Cat No. 810007. ***Do not use any filling solution which contains silver*** (Electrode damage may result.)

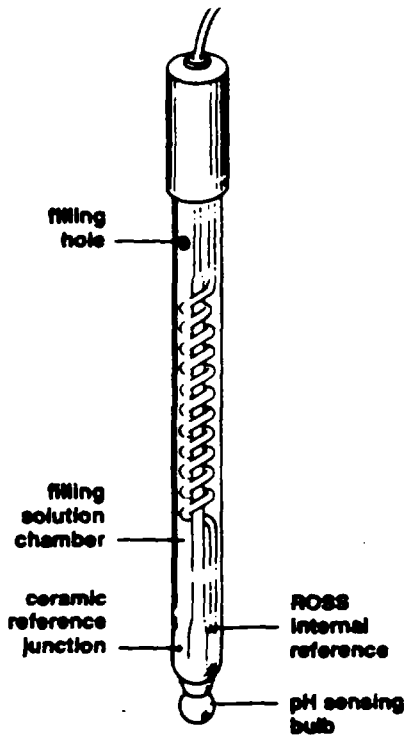


Figure 1
ROSS Combination Electrode – Cat. No. 81-02

USING THE ELECTRODE

Set up

Electrode Preparation

1. Remove the protective shipping cap from sensing element and save for storage. Remove plastic covering from sleeve junction of Model 81-66.
2. Clean any salt deposits from exterior by rinsing with distilled water.
3. Uncover filling hole and add ROSS Filling Solution, Orion Cat. No. 810007, to electrode. See **Figure 2**. To maintain an adequate flow rate, the level of filling solution must always be above the reference junction and at least one inch above the sample level on immersion. The filling hole should be open whenever the electrode is in use.
4. Place the electrode in the electrode holder and suspend in air for 15 minutes to thoroughly wet the reference junction. Once the junction is wet, do not allow the electrode to dry out.
5. Shake down the electrode (as a clinical thermometer) to remove air bubbles.
6. Soak electrode in pH Electrode Storage Solution, Orion Cat. No. 910001, for one hour. If ORION Storage Solution is not available, use 200 ml pH 7 buffer to which about 1 g KCl has been added, as a temporary substitute.
7. Connect electrode to meter.

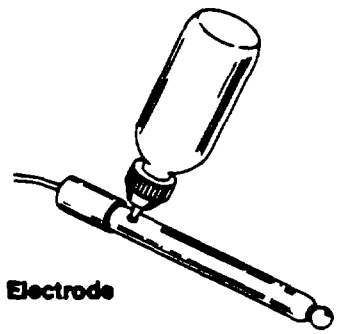


Figure 2
Filling an Electrode

Before Analysis

Sample Requirements

One of the benefits of the ROSS pH Electrode is that the filling solution composition may be changed depending on sample requirements.

The ROSS pH Electrode Filling Solution, Orion Cat. No. 810007 is 3M KCl. For solutions which precipitate in the presence of chloride ion, the ROSS pH Electrode could be filled with 10% KNO_3.

Samples should be aqueous if using epoxy body electrodes (e.g., Models 81-55 or 81-35).

In organic solutions, use an all-glass ROSS Electrode. For good results a minimum of 20% water must be present in the sample. If there is a great deal of drift when using the ROSS Electrode filled with ROSS Filling Solution (Orion Cat. No. 810007), try filling the ROSS Electrode with a mixture of 2 parts methanol and 8 parts ROSS Electrode Filling Solution

Measuring Hints See **Figure 3**

- Always use fresh buffers for calibration. Choose buffers that are no more than 3 pH units apart.
- Check electrode slope daily by performing two-buffer calibration. Slope should be 92 to 102%.
- Only use ROSS Internal Filling Solution, Orion Cat. No. 810007, for ROSS Combination pH and Reference Electrodes. Do not use any filling solution which may contain silver.
- Remove filling hole cover during measurement to ensure uniform flow of filling solution.
- Between measurements, rinse electrodes with distilled water and then with the next solution to be measured.
- Stir all buffers and samples.
- Place a piece of insulating material (e.g., styrofoam or cardboard) between magnetic stirrer and beaker to prevent error from transfer of heat to sample. Since ROSS Electrodes respond faster than conventional electrodes, changes in pH which result from temperature changes will be noticed.
- Avoid rubbing or wiping electrode bulb, to reduce chance of error due to polarization.
- Model 81-35 may be used on any moist surface or in liquids. See **Figure 4**.
- Model 81-63 should not be forced into solids; cut an X into sample and insert electrode. Always immerse electrode to the same depth. See **Figure 5**.
- Model 81-66 is shipped with parafilm between the ground glass sleeve and cone. Carefully remove parafilm before use. Immerse the entire sleeve assembly when measuring. See **Figure 6**.

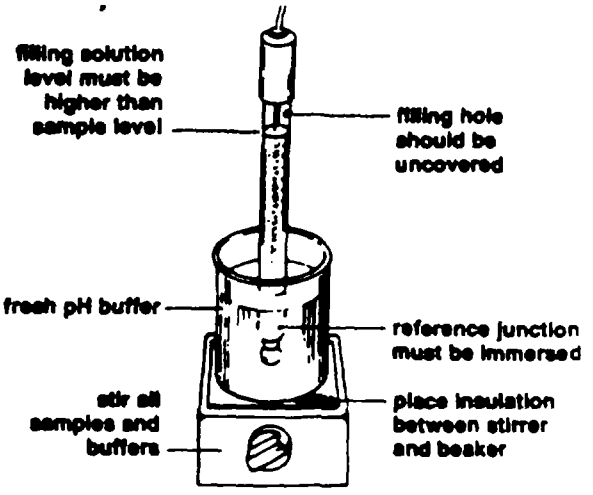


Figure 3
Measuring Hints

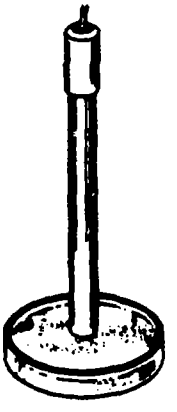


Figure 4
Use of Model 81-35

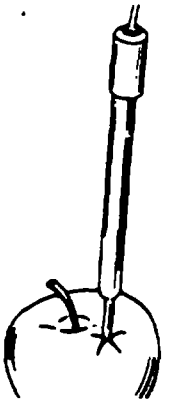


Figure 5
Use of Model 81-6

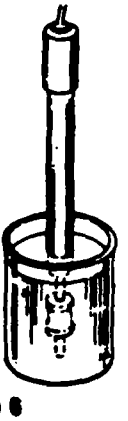


Figure 6
Use of Model 81-66

pH Calibration & Measurement

General Calibration Procedure

For detailed calibration and temperature compensation procedures, consult your meter instruction manual.

Single Buffer Calibration

1. Ensure that all buffers are at room temperature. If samples are at varying temperatures, temperature compensation is recommended. (See meter instruction manual).
2. Set up meter according to meter instruction manual.
3. Rinse electrode first with distilled water and then with the buffer being used for calibration (the buffer should be near the expected sample pH.) Place the electrode in the buffer.
4. Wait for a stable display. Set the meter to the pH value of the buffer at its measured temperature. See **Table 1**. (A table of pH values at various temperatures is supplied on the buffer bottle.) Proceed to **pH Measurement** section.

Two Buffer Calibration

This procedure is recommended for precise measurement.

1. Ensure that all buffers are at the same temperature. If samples are at varying temperatures, temperature compensation is recommended. (See meter instruction manual).
2. Select two buffers which bracket the expected sample pH. The first should be near the electrode isopotential point (pH 7) and the second near the expected sample pH (e.g., pH 4 or pH 10).
3. Rinse electrode first with distilled water and then with pH 7 buffer. Place the electrode in pH 7 buffer.
4. Wait for a stable display. Set the meter to the pH value of the buffer at its measured temperature. (A table of pH values at various temperatures is supplied on the buffer bottle.) See **Table 1**.
5. Rinse electrode first with distilled water and then with the second buffer. Place the electrode in the second buffer.
6. When display is stable, set meter to the actual pH value of the buffer as described in the meter instruction manual.
7. If all steps are performed correctly, proceed to the **pH Measurement** section. If any of the above procedures does not work, refer to **Troubleshooting**.

pH Measurement

1. Calibrate the electrode as described in previous section.
2. Rinse the electrode with distilled water and then with sample.
3. Place the electrode in the sample.
4. When the display is stable, record sample pH.

Table 1
pH Values of Buffers at Various Temperatures

Nominal value at 25°C	Temperature											
	0°C	5°C	10°C	20°C	30°C	40°C	50°C	60°C	70°C	80°C	90°C
1.68	1.67	1.67	1.67	1.67	1.68	1.69	1.71	1.72	1.74	1.77	1 79
3.78	3.86	3.84	3.82	3.79	3.77	3.75	3.75				
4.01	4.00	4.00	4.00	4.00	4.02	4.03	4.06	4.08	4.13	4.16	4 21
6.86	6.98	6.95	6.92	6.87	6.85	6.84	6.83	6.84	6.85	6 86	6 88
7.00	7.11	7.08	7.06	7.01	6.98	6.97	6.97				
7.41	7.53	7.50	7.47	7.43	7.40	7.38	7.37				
9.18	9.46	9.40	9.33	9.23	9.14	9.07	9.01	8.96	8.92	8.89	8 85
10.01	10.32	10.25	10.18	10.06	9.97	9.89	9.83				

Electrode Storage

To ensure a quick response and free-flowing liquid junction, the sensing element and reference junction must not be allowed to dry out.

Short-term Storage (up to one week)
Soak electrode in pH Electrode Storage Solution, Orion Cat. No. 910001. If ORION Storage Solution is not available, use about 200 ml pH 7 buffer to which about 1 gram KCl has been added, as a temporary substitute.

Long-term Storage
The reference chamber should be filled and the filling hole securely covered. Cover the sensing element and/or reference junction with its protective cap containing a few drops of storage solution. The Model 81-66 also requires that the ground glass sleeve and cone be separated and the liquid junction securely covered with a plastic film. Before returning the electrode to use, prepare it as a new electrode.

Electrode Maintenance

Weekly

1. Inspect the electrode for scratches, cracks, salt crystal build-up, or membrane/junction deposits.
2. Rinse off any salt build-up with distilled water, and remove any membrane/junction deposits as directed in the cleaning procedures below.
3. Drain the reference chamber, flush it with fresh ROSS Filling Solution, Orion Cat. No. 810007, and refill the chamber.

Cleaning Electrode
General — Soak in 0.1M HCl or HNO_3 for half an hour, followed by soaking in storage solution for at least one hour.

Removal of Membrane/Junction Deposits

Protein — Soak in 1% pepsin in 0.1M HCl, for 15 minutes.*

Inorganic — Soak in 0.1M tetrasodium EDTA solution for 15 minutes.*

Grease and Oil — Rinse with mild detergent or methanol solution.*

* *After any of these cleaning procedures, drain and refill the reference chamber and soak the electrode in storage solution for at least one hour.*

TROUBLESHOOTING

Troubleshooting Guide

Follow a systematic procedure to isolate the problem. The pH measuring system can be divided into four components for ease in troubleshooting: pH meter, electrodes, sample/application, and operator error.

pH meter
The meter is the component which is easiest to eliminate as a possible cause of error. ORION pH meters are provided with an instrument checkout procedure and shorting strap for convenience in troubleshooting. Consult your pH meter instruction manual for directions.

Electrodes
To test electrode operation:

1. Connect electrode to a working meter.
2. Set function switch to absolute mV mode.
3. Immerse electrode in fresh pH 7 buffer.
4. Displayed value should be 0 ± 30 mV.
5. Rinse electrode and immerse in fresh pH 4 buffer.
6. Displayed value should be approximately 160 mV greater than in step 4.

If electrode fails this procedure, clean thoroughly as directed in **Maintenance**.

If electrode response is slow or drifting, drain and refill with fresh ROSS Filling Solution, Orion Cat. No. 810007. See **Measuring Hints**.

If cleaning and maintenance fail to rejuvenate the electrode:

1. For separate pH and reference half cells, substitute each electrode (one at a time) with a known working electrode and repeat test procedure. By process of elimination, determine which electrode should be replaced.
2. For combination electrodes, replace the entire electrode.

Sample/Application
The electrode and meter may operate with buffers but not with your sample. In this case, check sample composition for interferences, incompatibilities, or temperature effects.

Operator Error
If trouble persists, review operating procedures. Reread calibration and measurement sections, to be sure proper technique has been followed.

Troubleshooting (cont.)

Assistance

If after checking each component of your measuring system the source of the trouble remains unknown, call Orion's Technical Service Chemists.

In the United States (except Massachusetts, Alaska, and Hawaii) 1-800-225-1480. In Massachusetts, Alaska, and Hawaii or Canada, call 617-242-3900.

In Europe, the Middle East, and Africa contact your local authorized Orion dealer, or:

ORION RESEARCH AG
Fahnlibrunnenstrasse 3
CH-8700 Küsnact, Switzerland
TEL 01-910-7858 / TLX 57829

Elsewhere, contact your authorized Orion dealer or:

ORION RESEARCH INCORPORATED
Laboratory Products Group
The Schrafft Center
529 Main Street, Boston, MA 02129 U.S.A.
TLX 4430019

ELECTRODE CHARACTERISTICS

Temperature Effects

The most common cause of error in pH measurement is temperature. Ordinary electrodes drift with temperature changes. The ROSS pH Electrode eliminates the stability problems associated with the use of conventional electrodes in samples of varying temperature.

There are, however, two effects of temperature change that should be kept in mind.

1. Electrode slope will change with varying temperature. This slope change may be compensated for either manually, or, automatically with an automatic temperature compensator (ATC) probe and properly designed pH meter. Consult your pH meter instruction manual for details.
2. Buffer and sample pH values vary with temperature because of their temperature dependent chemical equilibrium. The problem of *differing* pH values is easily solved by calibrating the electrode with characterized standard buffers whose true pH values at different temperatures are known. Buffer values at different temperatures are given in **Table 1**. The problem of the sample equilibrium varying with temperature in an uncharacterizable manner will always remain. Therefore, pH values should be reported along with the temperature at which the measurement was made.

Interferences

Sodium ion is the principal interference of the pH electrode causing increasing error at higher pH (lower hydrogen ion activities) and at higher temperatures. Because the ROSS pH membrane is composed of special low sodium error glass, error due to sodium is negligible when measuring at pH values less than 12. When measuring at pH values greater than 12, add the correction value from the nomograph in **Figure 7** to the observed pH reading.

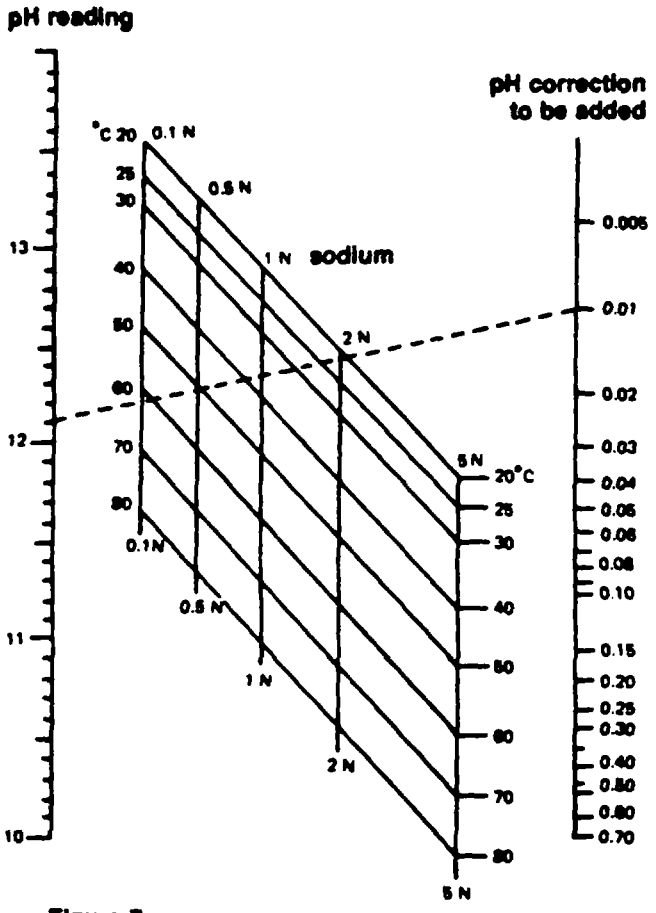


Figure 7
Typical Sodium Error Observed at pH > 12

Example:

pH reading	12.10
Sodium concentration	0.5N
Temperature	50°C
Correction	0.01
Corrected pH reading	12.11

ORDERING INFORMATION

Electrodes

ROSS Electrodes are available with a variety of connectors. For more information, consult your ORION pH Electrode Catalog and price list or your local ORION Distributor

Model Number	Description	Type of Connector
800500	ROSS Reference Half Cell, glass body	Pin-tip
810100	ROSS pH Half Cell, glass body	U S Std
8101BN	Same as above	BNC
810200	ROSS Combination pH Electrode, glass body	U S Std
8102BN	Same as above	BNC
810300	Semimicro ROSS pH Electrode, glass body	U S Std
8103BN	Same as above	BNC
810400	ROSS Combination pH Electrode, glass body with rugged bulb	U S Std
8104BN	Same as above	BNC
811500	Semimicro ROSS Combination pH Electrode, epoxy body	U S Std
8115BN	Same as above	BNC
813500	ROSS Combination Flat Surface pH Electrode, epoxy body	U S Std
8135BN	Same as above	BNC
815500	ROSS Combination pH Electrode, epoxy body with bulb guard	U S Std
815600	Same as above	BNC
816300	ROSS Combination Spear-tip pH Electrode, glass body	U S Std
8163BN	Same as above	BNC
816600	ROSS Combination pH Electrode, sleeve reference junction, glass body	U S Std
8166BN	Same as above	BNC

Accessories

Cat. No.	Description
810002	pH Solutions Bulk Pack for use with ROSS pH Electrodes. Contains: two 50 ml bottles ROSS pH Electrode Internal Filling Solution, one 475 ml bottle of Electrode Storage Solution, four 475 ml bottles of pH 7.00 Buffer, four 475 ml bottles of 10.01 Buffer, three flip-top spout dispensers, and instruction sheet
810003	pH Solutions Bulk Pack for use with ROSS pH Electrodes. Contains: two 50 ml bottles of ROSS pH Electrode Internal Filling Solution, one 475 ml bottle of Electrode Storage Solution, four 475 ml bottles of 7.00 Buffer, four 475 ml bottles of 4.01 Buffer, three flip-top spout dispensers, and instruction sheet
810007	ROSS Internal Filling Solution, 3M KCl, five 50 ml bottles
910001	pH Electrode Storage Solution, 475 ml
910004	pH 4 Buffer Packets, box of 25
910007	pH 7 Buffer Packets, box of 25
910009	pH 9 Buffer Packets, box of 25
910104	pH 4.01 Buffer, 475 ml
910107	pH 7.00 Buffer, 475 ml
910110	pH 10.01 Buffer, 475 ml

SPECIFICATIONS

Electrode*	Length (excluding cap)	Diameter
80-05	120 mm	12 mm
81-01	120 mm	12 mm
81-02	120 mm	12 mm
81-03	165 mm	6 mm
81-04	120 mm	12 mm
81-15	165 mm	6 mm
81-35	120 mm	12 mm
81-55	120 mm	12 mm
81-56	120 mm	12 mm
81-63	110 mm	5 mm (tip)
81-66	120 mm	12 mm

* ROSS Electrodes operate in a 0-100°C temperature range, 0-14 pH range

Isopotential points are at pH 7. Standard cap diameters are 16 mm and cap lengths are 30 mm

APPENDIX 4.4

DISSOLVED OXYGEN METER
YSI MODEL 57

INSTRUMENT BATTERIES

The instrument batteries are two "C" size carbon-zinc cells located inside the instrument on the meter end. These should be replaced when the RED LINE knob is at its extreme adjustment or at least annually. The amount of remaining adjustment is an indication of the battery condition. The batteries are replaced by removing the screws on the rear cover of the instrument and removing the two batteries at the end of the instrument near the meter. When installing the new batteries the plus (+) end fits into the red washer on the battery holder. (See Figure 11.)

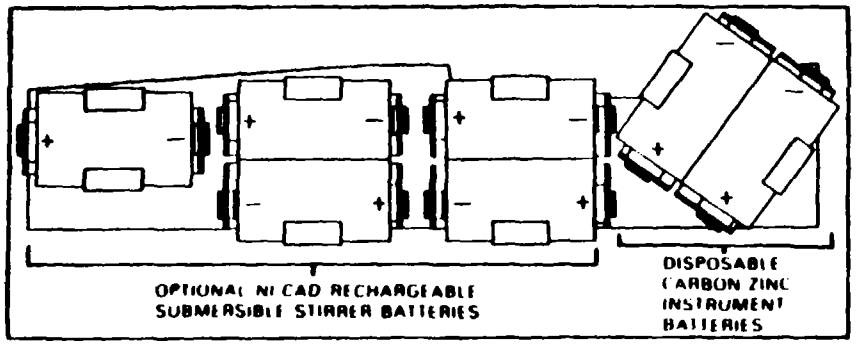


FIGURE 11

WARRANTY AND REPAIR

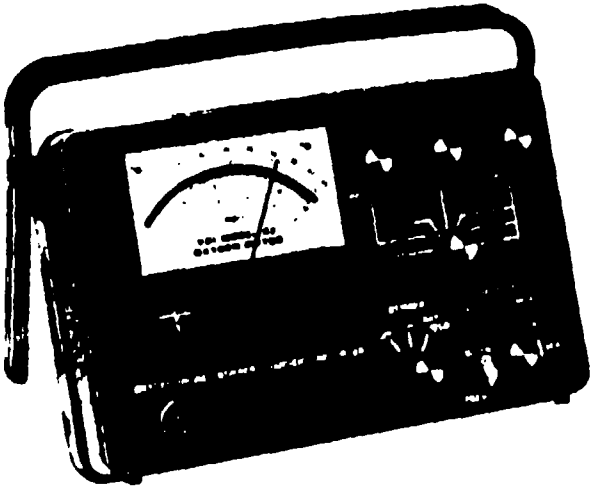
All YSI products carry a one-year warranty on workmanship and parts, exclusive of batteries. Damage through accident, misuse, or tampering will be repaired at a nominal charge, if possible, when the item is returned to the factory or to an authorized YSI dealer.

If you are experiencing difficulty with any YSI product it may be returned for repair, even if the warranty has expired. YSI maintains complete facilities for prompt servicing for all YSI products.

SERVICE DEPARTMENT
YELLOW SPRINGS INSTRUMENT CO., INC.
P.O. BOX 279
YELLOW SPRINGS, OHIO 45387, U.S.A.
PHONE (513) 767-7241
TELEX 20-5437

ITEM 056003 P/N A057168 EP 9 87

INSTRUCTION MANUAL
YSI MODEL 57
DISSOLVED OXYGEN METER



Scientific Division
Yellow Springs Instrument Co., Inc.
Yellow Springs, Ohio 45387 • Phone 513-767-7241 • Telex 20-5437

PRICE INCLUDING HANDLING $5.00

SUMMARY OF OPERATING INSTRUCTIONS

1. CALIBRATION

A. Switch instrument to OFF and adjust meter mechanical zero
B. Switch to RED LINE and adjust.
C. Prepare probe for operation, plug into instrument, wait up to 15 minutes for probe to stabilize. Probe can be located in calibration chamber (see instruction manual) or ambient air.
D. Switch to ZERO and adjust.
E. Adjust SALINITY knob to FRESH.
F. Switch to TEMP and read.
G. Use probe temperature and true local atmospheric pressure (or feet above sea level) to determine correct calibration values from Table I and II. (See pages 13 and 14).

EXAMPLE: Probe temperature = 21°C; Altitude = 1000 feet. From Table I the calibration value for 21°C is 8.9 mg/l. From Table II the altitude factor for 1000 feet is approximately .96. The correct calibration value is:

8.9 mg/l X .96 factor = 8.54 mg/l

H. Switch to desired dissolved oxygen range 0-5, 0-10, or 0-20 and with calibrate control adjust meter to correct calibration value determined in Step G.

NOTE: It is desirable to calibrate probe in a high humidity environment. See instruction manual for more detail on calibration and other instrument and probe characteristics.

2. MEASUREMENT

A. Adjust the SALINITY knob to the salinity of the sample.
B. Place the probe and stirrer in the sample and switch the STIRRER control to ON.
C. When the meter has stabilized switch to the appropriate range and read D.O.
D. We recommend the instrument be left on between measurements to avoid necessity for repolarizing the probe.

3. GENERAL CARE

A. Replace the instrument batteries when unable to adjust to red line. Use (2) Eveready No. 935 "C" size or equivalent.
B. In the BATT CHECK position the voltage of the stirrer batteries is displayed on the red 0-10 scale. Do not discharge below 6.0 Volts. Recharge for 14-16 hrs. with YSI No. 5728 charger.
C. Membrane will last indefinitely, depending on usage. Average replacement is 2-4 weeks. Probe should be stored in humid environment to prevent drying out.
D. Calibrate daily.

TABLE OF CONTENTS

GENERAL DESCRIPTION

The YSI Model 57 Dissolved Oxygen Meter is intended for dissolved oxygen and temperature measurement in water and wastewater applications, but is also suitable for use in certain other liquids Dissolved Oxygen is indicated in mg/l (milligrams per liter) on 0-5, 0-10 and 0 20 mg/l scales Temperature is indicated in °C on a -5° to +45°C scale The dissolved oxygen ranges are automatically temperature compensated for solubility of oxygen in water and permeability of the probe membrane, and manually salinity compensated

The probes use Clark-type membrane covered polarographic sensors with built in thermistors for temperature measurement and compensation A thin, permeable membrane stretched over the sensor isolates the sensor elements from the environment, but allows oxygen and certain other gases to enter When a polarizing voltage is applied across the sensor, oxygen that has passed through the membrane reacts at the cathode, causing a current to flow

The membrane passes oxygen at a rate proportional to the pressure difference across it Since oxygen is rapidly consumed at the cathode, it can be assumed that the oxygen pressure inside the membrane is zero Hence, the force causing the oxygen to diffuse through the membrane is proportional to the absolute pressure of oxygen outside the membrane If the oxygen pressure increases, more oxygen diffuses through the membrane and more current flows through the sensor A lower pressure results in less current

SPECIFICATIONS

I. **Instrument**

Oxygen Measurement

Ranges 0-5, 0-10 and 0-20 mg/l (0-2 5, 0-5 and 0-10 mg/l with YSI 5776 High Sensitivity Membrane)

Accuracy ±1% of full scale at calibration temperature (±0 1 mg/l on 0-10 scale), or 0 1 mg/l (whichever is larger)

Readability 025 mg/l on 0 5 scale, .05 mg/l on 0-10 scale, 0 1 mg/l on 0-20 scale

Temperature Measurement

Range -5° to +45°C

Accuracy ±0 5°C plus probe which is ±0 1°C

Readability 0.25°C

Temperature Compensation

±1% of D O reading for measurements made within ±5°C of calibration temperature

±3% of D O reading over entire range of -5 to +45°C probe temperature

System Response Time

Typical response for temperature and D O readings is 90% in 10 seconds at a constant temperature of 30°C with YSI 5775 Membranes D O response at low temperature and low D O is typically 90% in 30 seconds YSI 5776 High Sensitivity Membranes can be used to improve response at low temperature and low D O concentrations If response time under any operating conditions exceeds two minutes, probe service is indicated

Operating Temperature Range

Instrument and probe operating range is 5° to +45°C Large ambient temperature changes will result in 2% loss of accuracy unless Red Line and Zero are reset

Recorder Output

0 to 114 136 mV Recorder should have 50,000 ohms minimum input impedance

Power Supply

The YSI Model 57 is powered by two disposable "C" size carbon zinc batteries (Eveready 935C or equal) providing approximately 1000 hour operation

II **Probe**

Cathode Gold

Anode Silver

Membrane .001" FEP Teflon
(.0005" FEP Teflon available)

Electrolyte Half saturated KCl

Temperature Compensation (See SPECIFICATIONS, I Instrument)

Pressure Compensation Effective 1/2% of reading with pressures to 100 psi (230 ft sea water)

Polarizing Voltage 0 8 volts nominal

Probe Current Air at 30°C = 19 microamps nominal
Nitrogen at 30°C = 15 microamps or less

III **Accessories and Replacement Parts**

YSI 5720A — Self Stirring BOD Bottle Probe

YSI 5750 Non Stirring BOD Bottle Probe

YSI 5739 Oxygen Temperature Probe for field use Combine with one of the following 4 cables for desired lead length

Detachable leads for use with YSI 5739

YSI 5740-10	10' Cable
YSI 5740-25	25' Cable
YSI 5740 50	50' Cable
YSI 5740 100	100' Cable
YSI 5740 150	150' Cable
YSI 5740 200	200' Cable

YSI 5721 — Battery and charger pack operates YSI 5791A and 5795A Submersible Stirrers

YSI 5791A — Submersible Stirrer for field use

YSI 5795A — Submersible Stirrer

YSI 5075A — Calibration Chamber for use with field probe,

YSI 5890 *Carrying Case*

YSI 5775 Membrane and KCl Kit, Standard — includes 2 each 15 membrane packets (.001" thick standard membranes) and a 30 ml bottle KCl with Kodak photo flo

YSI 5776 Membrane and KCl Kit High Sensitivity — includes 2 each 15 membrane packets (.0005" thick membranes) and a 30 ml bottle KCl with Kodak photo flo

YSI 5680 — Probe Reconditioning Kit

YSI 5945 — "O" Ring Pack — includes (6) "O" rings for each YSI DO Probe
YSI 5486 — Beater Boot Kit — includes (1) A-05486 Boot, (1) A-05484 Tip, (2) A-05485 Spring. Used only on 5720A and discontinued 5420A.
YSI 5986 — Diaphragm Kit for use only with YSI 5739 D O Probe
YSI 5735 — Adaptor makes it possible to use YSI 5739, YSI 5720A and YSI 5750 Probes with discontinued YSI Models 51A, 54RC and 54BP

OXYGEN PROBES AND EQUIPMENT

There are three oxygen probes for use with the YSI Model 57 Dissolved Oxygen Meters. Descriptions of where they are used are contained in the following paragraphs.

I. YSI 5739 D.O. Probe

The YSI 5739 probe is designed for use with the 5740 detachable cable and replaces the discontinued YSI 5418, 5419, 5718 and 5719 probes (See Figure 1)

For user convenience the probe is equipped with a disconnecting cable to facilitate changing cable lengths and replacing damaged cables or probes. The probe and cable assembly is held together with a threaded retaining nut. The connection is *not* designed for casual disconnection and should only be disconnected when necessary.

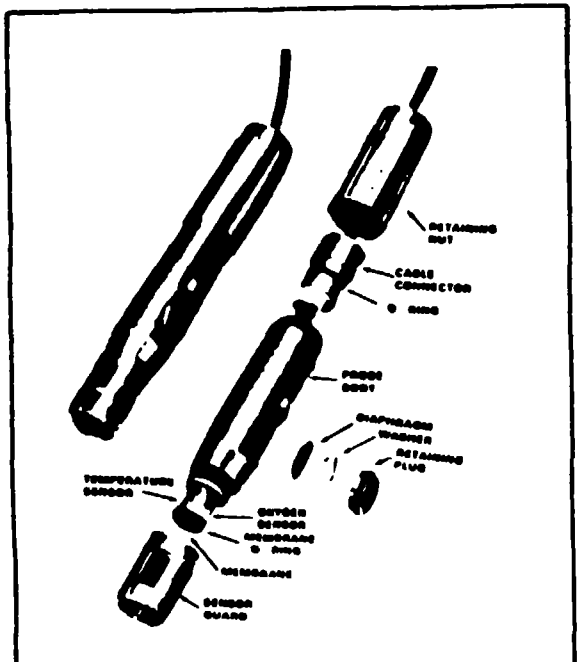


FIGURE 1

To disconnect the cable unscrew the retaining nut and slide it down the cabl to expose the connector. Pull gently on the cable and connector until the connec tor comes away from the probe body.

To reassemble, inspect the connector and "O" ring for cleanliness. If the "O ring is frayed or damaged remove it by squeezing it in the groove causing it t bulge, then roll it out of the groove and off the connector. A replacement "O" rin is supplied with the cable.

Push the connector into the probe body, rotating it until the two halves mat A light coating of vaseline or silicone grease on the "O" ring will mak reasssembly easier. Air trapped between the connector halves which may caus them to spring apart slightly, is normal. Screw on the retaining nut, *hand tigh only*. NOTE: If erratic readings are experienced, disconnect the cable and inspec for water. If present, dry out and reconnect, replacing the "O" ring, if necessar

Pressure Compensation

The vent on the side of the probe is part of a unique pressure compensatin system that helps assure accurate readings at great depths of water. Pressur compensation is effective to 1/2% of reading with pressures to 100 psi (230 f water). The quantity of air bubbles trapped under the membrane determines hov serious the pressure error will be, which is why proper preparation of the probe essential. (See OPERATING PROCEDURES.) The system is designed to accom modate a small amount of trapped air and still function properly, but the amoun should be kept to a minimum.

The compensating system normally does not require servicing and should no be taken apart. However, if electrolyte is leaking through the diaphragm or there is an obvious puncture, the diaphragm must be replaced. A spare supplied with the probe. Using a coin unscrew the retaining plug and remove th washer and the diaphragm, flush any salt crystals from the reservoir, install th new diaphragm (convolution side in), replace the washer, and screw in the retain ing plug.

II. YSI 5720A B.O.D. Bottle Probe

The YSI 5720A B.O.D. Bottle Probe replaces the discontinued YSI 5420A B.O.D. Bottle Probe for measuring dissolved oxygen and temperature in standar B.O.D. bottles. It is provided with an agitator for stirring the sample solution available in models for 117VAC (95-135VAC, 50-60 Hz) or 230VAC (190 250VAC, 50-60 Hz) operation. (See Figure 2)

When using the probe, plug the agitator power supply into line power and th probe plug into the instrument. With the agitator turned off place the tapere probe end into the B.O.D. bottle and switch agitator "ON" with switch on top o probe. The probe should be operated with a minimum of trapped air in the B.O.D bottle. A slight amount of air in the unstirred region at the top of the bottle ma be neglected, but no bubbles should be around the thermistor or oxygen sensor.

Stirrer Boot

The probe uses a flexible stirring boot to transmit motion from the sealed motor housing to the sample. If the boot shows signs of cracking or other damage likely to allow leaking into the motor housing, the boot must be replaced.

In fresh water applications boot life is normally several years, but this may be shortened by exposure to hydrocarbons, moderate to strong acids or bases

II. Preparing the Instrument

It is important that the instrument be placed in the intended operating position vertical, tilted, or on its back — before it is prepared for use and calibrated (See Figure 7) Readjustment may be necessary when the instrument operating position is changed After preparing the probe proceed as follows

1. With switch in the OFF position, adjust the meter pointer to Zero with the screw in the center of the meter panel Readjustment may be necessary if the instrument position is changed
2. Switch to RED LINE and adjust the RED LINE knob until the meter needle aligns with the red mark at the 31°C position
3. Switch to ZERO and adjust to zero with zero control knob
4. Attach the prepared probe to the PROBE connector of the instrument and adjust the retaining ring finger tight
5. Before calibrating allow 15 minutes for optimum probe stabilization Repolarize whenever the instrument has been OFF or the probe has been disconnected.

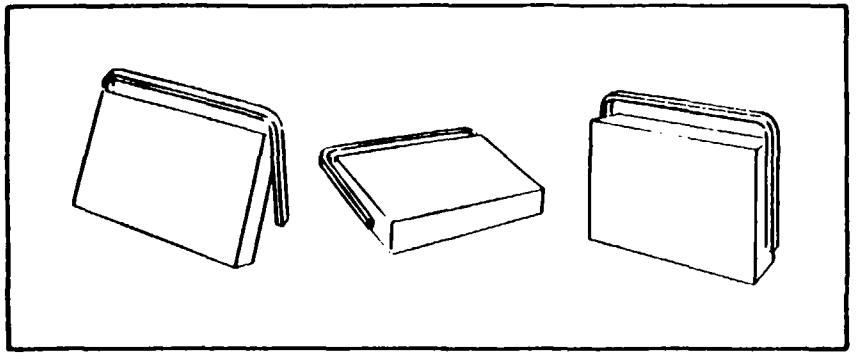


FIGURE 7

III. Calibration

The operator has a choice of three calibration methods — Winkler Titration, Saturated Water, and Air Experience has shown that air calibration is quite reliable, yet far simpler than the other two methods The three methods are described in the following paragraphs

Winkler Titration

1. Draw a volume of water from a common source and carefully divide into four samples. Determine the oxygen in three samples using the Winkler Titration technique and average the three values. If one of the values differs from the other 2 by more than 0.5 mg/l, discard that value and average the remaining two.
2. Place the probe in the fourth sample and stir
3. Set the SALINITY control to zero or the appropriate salinity value of the sample
4. Switch to desired mg/l range and adjust the CALIBRATION control to the average value determined in Step 1 Allow the probe to remain in the sample for at least two minutes before setting the calibration value, and leave in the sample for an additional 2 minutes to verify stability Readjust if necessary

Saturated Water

1. Air saturate a volume of water (300-500cc) by aerating or stirring for at le 15 minutes at a relatively constant temperature
2. Place the probe in the sample and stir Switch to TEMPERATURE Refe Calibration Table I for the mg/l value corresponding to the temperature
3. Determine local altitude or the "true" atmospheric pressure (note that tr atmospheric pressure is as read on a mercury barometer Weather Bur reporting of atmospheric pressure is corrected to sea level) Using Tabl determine the correct factor for your pressure or altitude
4. Multiply the mg/l value from Table I by the correction factor from Table I determine the corrected calibration value for your conditions.

   EXAMPLE Assume temperature = 21°C and altitude = 1000 feet Fr Table I the calibration value for 21°C is 8 9 mg/l From Tabl the correction factor for 1000 feet is about 0 96 The correc calibration value is 8 9 mg/l X 0 96 = 8 54 mg/l.
5. Switch to an appropriate mg/l range, set the SALINITY knob to zero, and just the CALIBRATE knob while stirring until the meter reads the correc calibration value from Step 4 Leave the probe in the sample for two minu to verify calibration stability. Readjust if necessary.

Air Calibration

1. Place the probe in moist air BOD probes can be placed in partially filled (5 mL) BOD bottles Other probes can be placed in the YSI 5075A Calibrati Chamber (refer to the following section describing calibration chamber) the small storage bottle (the one with the hole in the bottom) along with few drops of water The probe can also be wrapped loosely in a damp clo taking care the cloth does not touch the membrane Wait approximately 1 minutes for temperature stabilization.
2. Switch to TEMPERATURE and read Refer to Table I — Solubility of Oxyg in Fresh Water, and determine calibration value
3. Determine altitude or atmospheric correction factor from Table II
4. Multiply the calibration value from Table I by the correction factor from Tab II

   EXAMPLE: Assume temperature = 21°C and altitude = 1000 feet Fr Table I the calibration value for 21°C is 8 9 mg/l From Table the correction factor for 1000 feet is about 0 96 Therefore corrected calibration value is 8 9 mg/l X 0 96 = 8 54 mg/l
5. Switch to the appropriate mg/l range, set the SALINITY knob to zero and a just the CALIBRATE knob until the meter reads the correct calibration val from Step 4 Wait two minutes to verify calibration stability Readjust necessary.

The probe is now calibrated and should hold this calibration value for ma measurements Calibration can be disturbed by physical shock, touching th membrane, or drying out of the electrolyte Check calibration after each series measurements and in time you will develop a realistic schedule for recalibrati For best results when not in use follow the storage procedures recommended f the various probes described under OXYGEN PROBES AND EQUIPMENT Th will reduce drying out and the need to change membranes

Calibration Chamber

The YSI 5075A Calibration Chamber is an accessory that helps obtain optimum calibration in the field and is also a useful tool for measuring at shallow depths (less than 4').

As shown in Figure (A), it consists of a 4-1/2 foot stainless steel tube (1) attached to the calibration chamber (2), the measuring ring (3), and two stoppers (4) and (5).

For calibration, insert the solid stopper (4) in the bottom of the calibration chamber (2). Push the oxygen probe (6) through the hollow stopper (5) as shown in Figure (B). Place the probe in the measuring ring, Figure (C), and immerse the probe in the sample to be measured for five minutes to thermally equilibrate the probe. Quickly transfer the probe to the calibration chamber (5) draining excess water from the chamber and shaking any excess droplets from the probe membrane. For maximum accuracy, wet the inside of the calibration chamber with fresh water. This creates a 100% relative humidity environment for calibration. Place the chamber in the sample for an additional five minutes for final thermal equilibrium. Calibrate the probe as described in the air-calibration procedure. Keep the handle above water at all times.

After calibration, return the probe to the measurement ring for shallow measurements. Move the probe up and down, or horizontally, approximately one foot a second while measuring. In rapidly flowing streams (greater than 5'/second) install the probe in the measuring ring with the pressure compensating diaphragm towards the chamber.

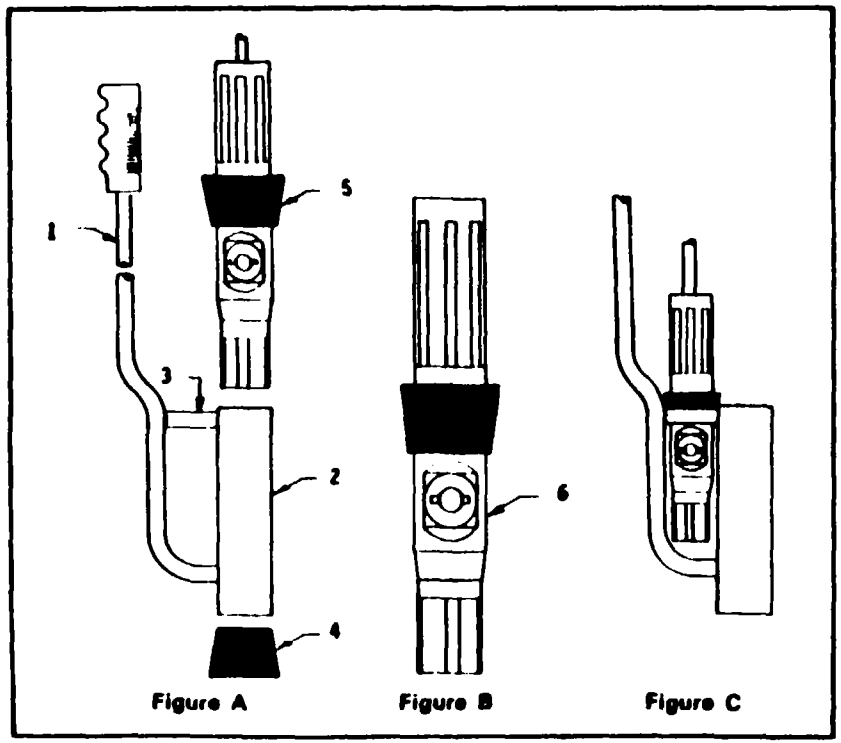


Figure A Figure B Figure C

FIGURE 8

IV. Dissolved Oxygen Measurement

With the instrument prepared for use and the probe calibrated, place the probe in the sample to be measured and provide stirring.

1. Stirring for the 5739 Probe can best be accomplished with a YSI submersible stirrer. Turn the STIRRER knob ON. If the submersible stirrer is not used, provide manual stirring by raising and lowering the probe about 1 ft. per second. If the 5075A Calibration Chamber is used, the entire chamber may be moved up and down in the water at about 1 ft. per second.
2. The YSI 5720A has a built in power driven stirrer.
3. With the YSI 5750 sample stirring must be accomplished by other means such as with the use of a magnetic stirring bar.
4. Adjust the SALINITY knob to the salinity of the sample.
5. Allow sufficient time for probe to stabilize to sample temperature and dissolved oxygen. Read dissolved oxygen.

V. Calibration Tables

Table I shows the amount of oxygen in mg/l that is dissolved in air saturated fresh water at sea level (760 mmHg atmospheric pressure) as temperature varies from 0° to 45°C.

Table I — Solubility of Oxygen in Fresh Water

Temperature °C	mg/l Dissolved Oxygen	Temperature °C	mg/l Dissolved Oxygen
0	14.60	23	8.56
1	14.19	24	8.40
2	13.81	25	8.24
3	13.44	26	8.09
4	13.09	27	7.95
5	12.75	28	7.81
6	12.43	29	7.67
7	12.12	30	7.54
8	11.83	31	7.41
9	11.55	32	7.28
10	11.27	33	7.16
11	11.01	34	7.05
12	10.76	35	6.93
13	10.52	36	6.82
14	10.29	37	6.71
15	10.07	38	6.61
16	9.85	39	6.51
17	9.65	40	6.41
18	9.45	41	6.31
19	9.26	42	6.22
20	9.07	43	6.13
21	8.90	44	6.04
22	8.72	45	5.95

Source: Derived from 15th Edition "Standard Methods for the Examination of Water and Wastewater."

Table II shows the correction factor that should be used to correct the calibration value for the effects of atmospheric pressure or altitude. Find true atmospheric pressure in the left hand column and read across to the right hand column to determine the correction factor. (Note that "true" atmospheric pressure is as read on a barometer. Weather Bureau reporting of atmospheric pressure is corrected to seal level.) If atmospheric pressure is unknown, the local altitude may be substituted. Select the altitude in the center column and read across to the right hand column for the correction factor.

Table II — Altitude Correction Factor

Atmospheric Pressure mmHg	or	Equivalent Altitude Ft.	=	Correction Factor
775		540		1.02
760		0		1.00
745		542		.98
730		1094		.96
714		1688		.94
699		2274		.92
684		2864		.90
669		3466		.88
654		4082		.86
638		4756		.84
623		5403		.82
608		6065		.80
593		6744		.78
578		7440		.76
562		8204		.74
547		8939		.72
532		9694		.70
517		10472		.68
502		11273		.66

Source: Derived from 15th Edition "Standard Materials for the Examination of Water and Wastewater."

VI. HIGH SENSITIVITY MEMBRANE

Use of high sensitivity .0005" membranes (YSI 5776) in place of standard .001" membranes (YSI 5775) when measurements are to be made consistently at low temperatures (less than 15°C). Calibration and readings will be made just as if the standard YSI 5775 membrane was being used.

The YSI 5776 High Sensitivity Membrane can also be used in certain situations to increase sensitivity at temperatures above 15°C. The ranges thus become 0-2.5, 0-5 and 0-10 mg/l. When calibration with high sensitivity membranes is attempted at temperatures greater than 15°C the selector switch must be set to 0-20 mg/l. Multiply the calculated calibration value by 2. For example at 21°C and 1000 ft. altitude the calibration value would be 8.6 x 2 or 17.2. Remember the 0-5, 0-10 and 0-20 mg/l ranges are now 0-2.5, 0-5 and 0-10 mg/l, and all mg/l readings must be divided by 2 for a final reading. When operating in this manner accuracy will be degraded slightly.

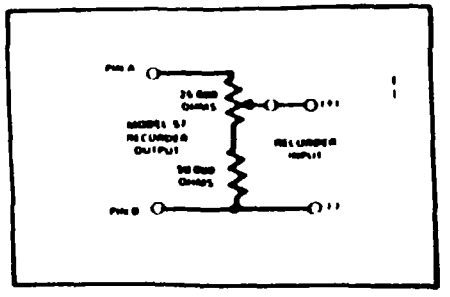
VII. RECORDER OUTPUT

Output at full scale is 114 to 136 mV.

Use a 50K or higher input impedance recorder and operate it with the ter minals ungrounded.

Many recorders have an adjustable full scale sensitivity feature. When using this type, use the 100 mV range and adjust the full scale (span, range control sensitivity, etc.) control to give full scale chart deflection with full scale oxyger meter deflection. Refer to the recorder instructions. For recorders without this feature, a simple driver network as shown below can be constructed. This is adequate to adjust the signal for full scale chart and meter deflection on the 100 mV fixed range recorders.

FIGURE 9



Recorder Output Plug

The YSI Model 57 is supplied with the necessary parts to construct a water proof recorder plug for the YSI Model 57 Dissolved Oxygen Meter. The cable and potting materials are not included. (See Figure 10)

General purpose epoxy potting materials of medium viscosity and moderate cure rate are recommended. The two tube kits available in hardware stores are satisfactory.

1. Prepare the cable end by stripping back 3/16" (5MM) of insulation. Tin the ends with rosin core solder. If polarity is important pin "A" is the (+) termina
2. Disassemble the connector pieces and slide the mold, ring, extension, and coupling nut over the cable. Solder the leads to the appropriate connecto pins with rosin core solder.
3. Check all connections. The two leads should show electrical continuity to the pins and should not contact the body or each other.
4. Re-assemble the pieces and hold the connector upright. Pour the epoxy mi into the plastic mold until full. Refill as the epoxy settles.
5. After the epoxy cures the plastic mold may be removed with pliers or knife

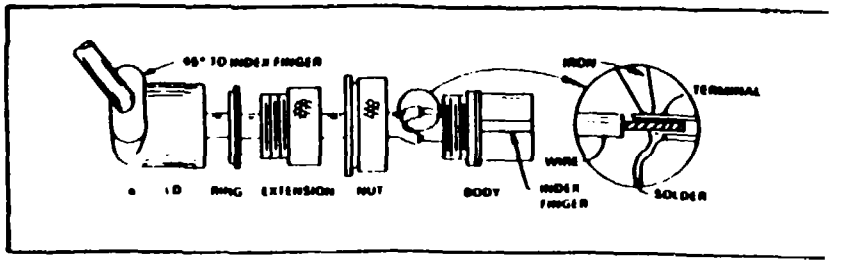


FIGURE 10

DISCUSSION OF MEASUREMENT ERRORS

There are three basic types of errors which can occur Type I errors are related to limitations of the instrument design and tolerances of the instrument components. These are chiefly the meter linearity and resistor tolerances Type II errors are due to basic probe accuracy tolerances, chiefly background signal, probe linearity, and variations in membrane temperature coefficient Type III errors are related to the operator's ability to determine the conditions at the time of calibration. If calibration is performed against more accurately known conditions, Type III errors are appropriately reduced.

Individual Sources of Error

This description of sources of error can be used to attach a confidence to any particular reading of dissolved oxygen. The particular example given is for a near extreme set of conditions. As a generality, overall error is diminished when the probe and instrument are calibrated under conditions of temperature and dissolved oxygen which closely match the sample temperature and dissolved oxygen.

Type I

A. Is the error due to the meter linearity.
   Error = ±1% of full scale of the measurement range.
B. Is the error due to tolerances in the instrument when transferring a reading from one range to another.
   Error = ±1% of the meter reading if the reading is taken on a range one range away from the calibration range.
   Error = ±2% of the meter reading if the reading is taken on a range two ranges away from the calibration range.
C. Is the error due to the design and components of the instrument salinity compensation circuit.
   Error = ±2.5% of the meter reading X $\frac{\text{sample salinity ppt}}{\text{40 ppt salinity}}$

Type II

A. errors are due to probe background current
   Error = $0.5\% \left(\frac{\text{meter reading mg/l}}{\text{1-Calib value}} \right)$ X calib. value, mg/l
B. errors are due to the probe non-linearity
   Error = 0.3% of reading
C. error is caused by variability in the probe membrane temperature coefficient.
   Error = zero if readings are taken at the calibration temperature.
   Error = ± 1% of meter reading if readings are taken with 5°C of the calibration temperature.
   Error = ±3% of meter reading all other conditions.

Type III

A. errors are due to the accuracy of the instrument thermometer when used to measure the exact probe temperature during calibration
   Error = ±1 5% of reading.
B. errors are due to the assumption of mean, barometric pressure.
   Daily variation is usually less than 1 7%
   Error = ±1 7% of reading

C. errors assume an ability to estimate altitude to within ±500 ft when computing the altitude correction factor.
   Error = 1 8% of reading
D. errors consider the possibility of only 50% relative humidity when calibrating the probe If the actual relative humidity is 50% instead of 100% the errors will be as follows

Calibration Temperature ± C	Error in Percent of Reading
0	(-) 0 3
10	(-) 0 6
20	(-) 1 15
30	(-) 2 11
40	(-) 3 60

Example of a Typical Error Calculation

The example given presumes the air calibration technique If calibration is done with air saturated water, the relative humidity consideration (III D) is eliminated If the Winkler calibration method is used Type III errors are deleted and replaced by the uncertainty attributable to the overall Winkler determination

Data. Instrument calibrated at 25°C, elevation estimated at 2000 feet ±500 feet, normal barometric pressure presumed, calibrated on 0-10 mg/l scale at 7 8 mg/l. Readings taken on 0-5 mg/l range at 4 5 mg/l, temperature 20°C. Salinity of 20 ppt.

Type	Description	Calculations	Error mg/l
IA	Linearity	= .01 x 4 5 mg/l	.045
IB	Range Change	= .01 x 4 5 mg/l	.045
IC	Salinity	= $025 \times 4\ 5\ \text{mg/l} \times \frac{20\ \text{ppt}}{40\ \text{ppt}}$	.056
IIA	Probe Background	= $005 \times \left(1 - \frac{4\ 5\ \text{mg/l}}{7\ 8\ \text{mg/l}}\right) \times 7\ 8\ \text{mg/l}$	.016
IIB	Probe Linearity	= 003 x 4 5 mg/l	014
IIC	Temp. Compensation	= 01 x 4 5 mg/l	.045
IIIA	Temp. Measurement	= 015 x 4 5 mg/l	.068
IIIB	Pressure	= 017 x 4 5 mg/l	076
IIIC	Altitude	= 018 x 4 5 mg/l	081
IIID	R H.	= 016 x 4 5 mg/l	072
		Maximum Possible Error =	.518 mg/l
		Probable Error	± 259

Considering a statistical treatment of the probable error at any time for any instrument, it is likely that the actual error in any measurement will be about 1/2 of the possible error In this case the probable error is about ± 26 mg/l out of a reading of 4.5 mg/l or 5 8% of the reading

INSTRUMENT CASE

The instrument case is water resistant when properly closed As a precaution against damaged gaskets or loose fittings, the instrument case should be opened and inspected for moisture whenever the instrument has been subjected to immersion or heavy spray The instrument case is opened by removing the screws on the rear cover and lifting the cover off

INSTRUMENT BATTERIES

The instrument batteries are two "C" size carbon-zinc cells located inside the instrument on the meter end. These should be replaced when the RED LINE knob is at its extreme adjustment or at least annually. The amount of remaining adjustment is an indication of the battery condition. The batteries are replaced by removing the screws on the rear cover of the instrument and removing the two batteries at the end of the instrument near the meter. When installing the new batteries the plus (+) end fits into the red washer on the battery holder. (See Figure 11.)

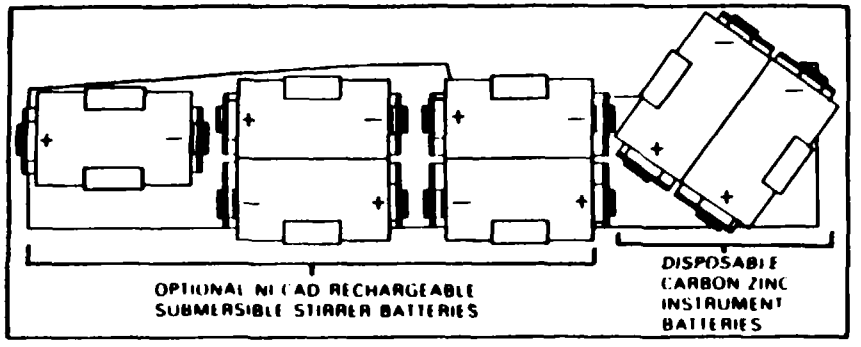


FIGURE 11

WARRANTY AND REPAIR

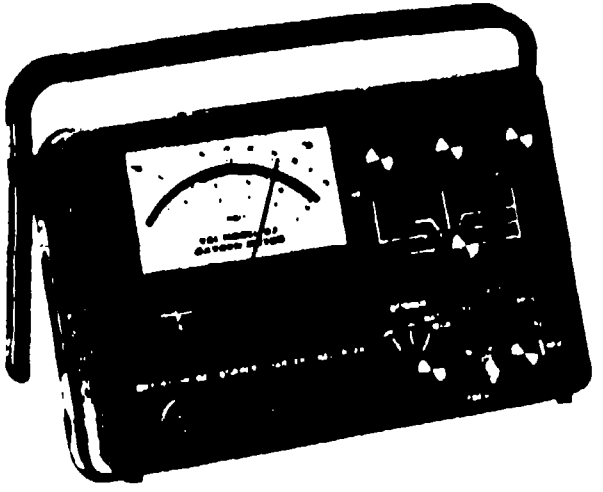
All YSI products carry a one-year warranty on workmanship and parts, exclusive of batteries. Damage through accident, misuse, or tampering will be repaired at a nominal charge, if possible, when the item is returned to the factory or to an authorized YSI dealer.

If you are experiencing difficulty with any YSI product, it may be returned for repair, even if the warranty has expired. YSI maintains complete facilities for prompt servicing for all YSI products.

SERVICE DEPARTMENT
YELLOW SPRINGS INSTRUMENT CO., INC.
P.O. BOX 279
YELLOW SPRINGS, OHIO 45387, U.S.A.
PHONE (513) 767-7241
TELEX 20-5437

ITEM 056003 P/N A057168 EP 9/87

INSTRUCTION MANUAL
YSI MODEL 57
DISSOLVED OXYGEN METER



Scientific Division
Yellow Springs Instrument Co., Inc.
Yellow Springs, Ohio 45387 • Phone 513-767-7241 • Telex 20-5437

PRICE INCLUDING HANDLING $5.00

PACKING LIST

MODEL 5739

OXYGEN TEMPERATURE PROBE

QUANTITY	ITEM DESCRIPTION
1 ea.	5739 Oxygen Probe
1 ea.	5775 Membrane KCL Kit
1 ea.	Air Sampler (Bottle)
1 ea.	Label, Caution
1 ea.	Pressure Diaphragm
1 ea.	O-ring Pack

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

YSI MODEL 57 RECORDER OUTPUT PLUG INSTRUCTIONS

DESCRIPTION

This kit contains the necessary parts to construct a waterproof recorder plug for the YSI Model 57 Dissolved Oxygen Meter. The cable and potting materials are not included.

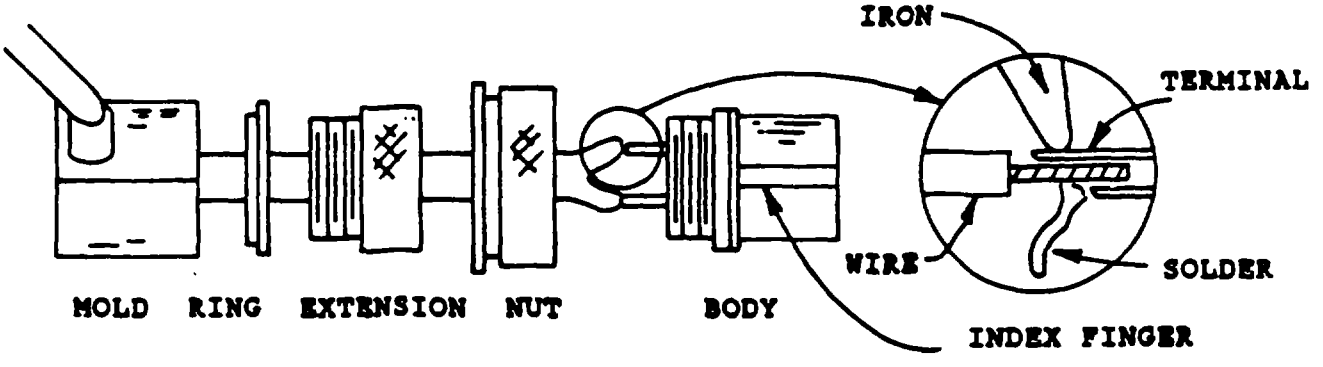
POTTING MATERIALS

General purpose epoxy potting materials of medium viscosity and moderate cure rate are recommended. The two-tube kits available in hardware stores are satisfactory.

ASSEMBLY

1. Prepare the cable end by stripping back 3/16" (5 mm) of insulation. Tin the ends with rosin core solder. If polarity is important, pin A is the positive (+) terminal.

2. Disassemble the connector pieces and slide the mold, ring, extension and coupling nut over the cable. Solder the leads to the appropriate connector pins with rosin core solder.



3. Check all connections. The two leads should show electrical continuity to the pins and should not contact the body or each other.

4. Assemble the pieces, screwing all parts tight. Force the plastic mold onto the ring. Align the mold with the cable so that the cable exits as shown in the sketch. Use adhesive tape to hold the mold firmly in place.

5. Pour eposy mix into the mold through the cable opening. Refill as the epoxy settles. For viscous epoxies, the cable opening can be enlarged by cutting.

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Yellow Springs Instrument Co., Inc.
Yellow Springs, Ohio 45387 USA • Phone 513 767-7241 • Telex 208437

Item 000911 Part A57700 A May 1987 EP

YSI 5700 SERIES DISSOLVED OXYGEN PROBES

The probes described in these instructions are designed for direct use with YSI Models 51B, 54APB, 54ARC, 56, 57 and 58 Dissolved Oxygen Meters. The probes can also be used with discontinued YSI Models 51A, 54BP and 54RC Dissolved Oxygen Meters when the YSI 5735 Cable Adaptor is employed.

PRINCIPLES OF OPERATION

YSI 5700 Series Probes are polarographic sensors. A thin permeable membrane stretched over the sensor isolates the electrodes from the environment, but allows oxygen and certain other gasses to enter. When a polarizing voltage is applied across the sensor, oxygen that has passed through the membrane reacts at the cathode, causing a current to flow.

The membrane passes oxygen at a rate proportional to the difference across it in partial pressure of oxygen. Since oxygen is rapidly consumed at the cathode, it can be assumed that the oxygen pressure under the membrane is zero. Hence, the force causing the oxygen to diffuse through the membrane is proportional to the partial pressure of oxygen outside the membrane. As the oxygen partial pressure varies, both the oxygen diffusion through the membrane and the probe current will change proportionally.

SPECIFICATIONS

Cathode: Gold
Anode: Silver
Membrane: .001" FEP Teflon
Electrolyte: Half saturated KCl
Temperature Range: -5º to 45ºC
15º to 35º C for the 5760 probe
Thermistor Accuracy: ±0.1ºC
±0.2ºC for the 5760 probe
Temperature Compensation: (see instrument specifications)
Polarizing Voltage: 0.8 Volts (nominal)
Probe Current in Air at 30ºC: 19 microamps (nominal)
in Nitrogen at 30ºC: 0.15 microamps or less
Response Time: Typical response for dissolved oxygen, using standard membranes, is 90% in 10 seconds at a constant temperature of 30ºC. Response at low dissolved oxygen levels is typically 90% in 30 seconds.

ACCESSORIES AND REPLACEMENT PARTS

YSI 5492A Battery Pack for Models 51B and 54A (Powers the submersible stirrers, and can power the 5760 when used with the 5761 Adaptor Cable)

YSI 5735 Cable Adaptor (Mates 5700 Series probes with discontinued YSI Models 51A, 54BP and 54RC Dissolved Oxygen Meters)

Accessories for the 5720A, 5739 and 5750

YSI 5680 Probe Reconditioning Kit. Includes a sanding tool and ten adhesive disks.

YSI 5775 Membrane and KCl Kit, Standard. Includes two 15-membrane packets (.001" thick standard FEP membranes) and a 30 ml bottle of KCl with Kodak Photo Flo.

YSI 5776 Membrane and KCl Kit, High Sensitivity. Includes two 15-membrane packets (.0005" thick FEP Teflon membranes) and a 30 ml bottle of KCl with Kodak Photo Flo. Used for measurements below 15ºC and/or for low oxygen levels

YSI 5945 O-ring pack (Contains replacement sensor O-rings)

Accessories for the 5720A Only

YSI 5486 Stirrer Boot Assembly

Accessories for the 5739 Only

YSI 5075A Calibration Chamber
YSI 5986 Diaphragm Kit

YSI 5740-10 detachable 10' cable
YSI 5740-25 detachable 25' cable
YSI 5740-50 detachable 50' cable
YSI 5740-100 detachable 100' cable
YSI 5740-150 detachable 150' cable
YSI 5740-200 detachable 200' cable

YSI 5795A Submersible Stirrer with 50' combined probe and stirrer cable

Accessories for the 5760 Only

YSI 5761 Battery Adaptor Cable (Used with YSI Models 57 and 58 only.) When used in conjunction with the YSI 5492A, it is also applicable to YSI Models 51B and 54A.

YSI 5764 Membrane Assemblies and KCl Kit, plus replacement sensor body O-ring.

YSI 5720A B.O.D. BOTTLE PROBE

The 5720A bottle probe (Figure 1) is used for measuring dissolved oxygen in standard B.O.D. bottles. It is provided with a stirrer powered by a DC supply available for 115 or 230 VAC input.

To use the 5720A, plug the stirrer power supply into line power and the probe plug in the instrument. With the stirrer off, place the tapered probe end into the B.O.D. bottle and turn on the stirrer. The probe should be operated with a minimum of trapped air in the bottle. A slight amount of air in the unstirred region at the top may be neglected, but no bubble should be permitted around the sensor. CAUTION: The motor housing is not waterproof; do not submerge this probe beyond the part that is inserted into a B.O.D. bottle.

STIRRER BOOT (YSI 5486)

The 5720A uses a flexible stirring boot to transmit motion from the motor housing to the sample. If the boot shows signs of cracking or other damage liable to allow leakage into the motor housing, it must be replaced. Boot life may be shortened by exposure to hydrocarbons, moderate to strong acids or bases, ozone, or direct sunlight. For maximum life, rinse the boot after each use. Boots are replaced as follows:

1. Pull off the old assembly and clean the stir rod housing.

2. Slide on the new assembly, making sure the back spring is over the grooved area of the stir rod housing. A drop of alcohol will aid installation by providing lubrication.

3. Do not permit the stir rod to press against the end of the stirrer boot tip or it will bind.

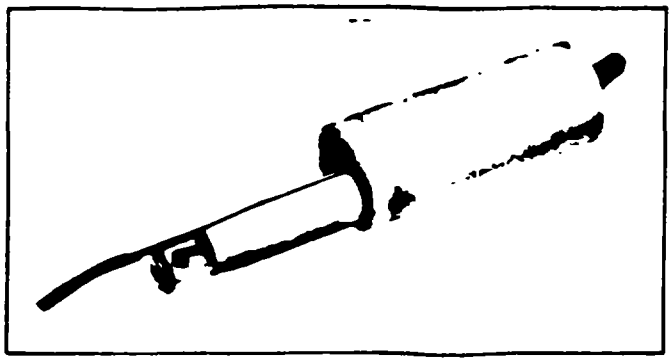

Figure 1. The YSI 5720A Probe

YSI 5739 DISSOLVED OXYGEN PROBE

The 5739 probe system consists of the probe body plus a detachable cable (see Figure 2). The detachable cable is a convenience feature that facilitates changing cable lengths and replacing damaged cables or probes. The probe and cable assembly is held together with a threaded retainer. The assembly is not intended for casual disconnection; cable and probe should be separated only when necessary.

To detach the cable, unscrew the retainer and slide it down the cable to expose the connector. Pull gently on the connector until it comes away from the probe body. If the O-ring is frayed or damaged, replace it: a replacement O-ring is supplied with each 5740 cable. Reassemble by pushing the connector into the probe body, rotating it until the two halves mate. A light coating of silicone grease on the O-ring will make reassembly easier. Be sure the connector is dry; otherwise, erratic readings may result. Screw on the retainer **finger-tight only.**

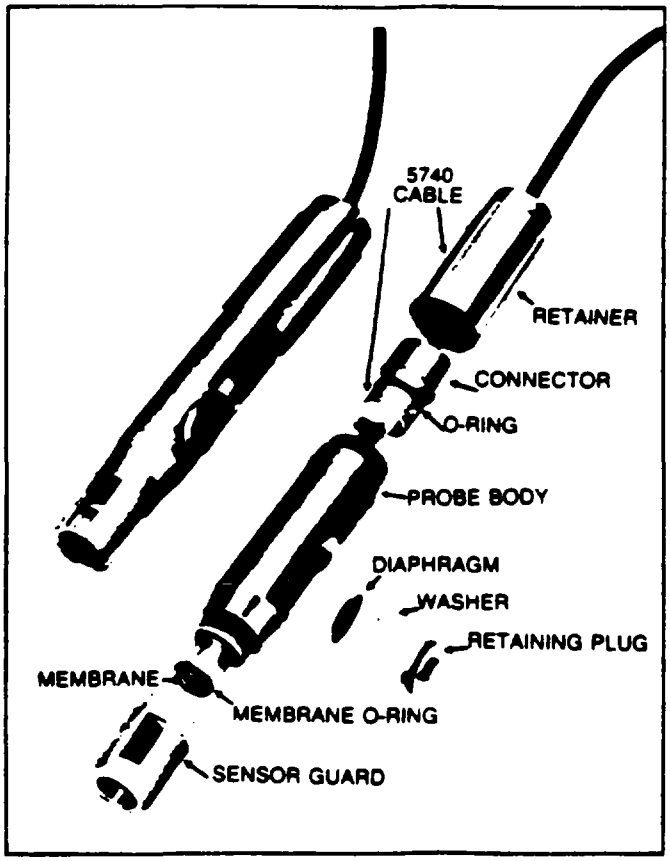

Figure 2. The YSI 5739 Probe

PRESSURE COMPENSATION

The 5739 probe has a unique pressure compensating system that helps assure accurate readings at great depths. Pressure compensation is effective to ½% of reading with pressures up to 100 psi (230 feet of water). The compensating system does not normally require service and should not be taken apart. However, if electrolyte is leaking through the diaphragm, or if there is an obvious puncture, the diaphragm must be replaced. A spare is supplied with the probe. Use a coin to unscrew the retaining plug and remove the washer and diaphragm. With distilled water, flush any salt crystals from the reservoir, install a new diaphragm if necessary (flat side out), replace the washer and securely screw in the retaining plug.

YSI 5750 B.O.D. BOTTLE PROBE

The 5750 (Figure 3) is similar to the 5720A except that it does not have a stirrer. Agitation of the sample must be provided by other means, such as a magnetic stirrer.

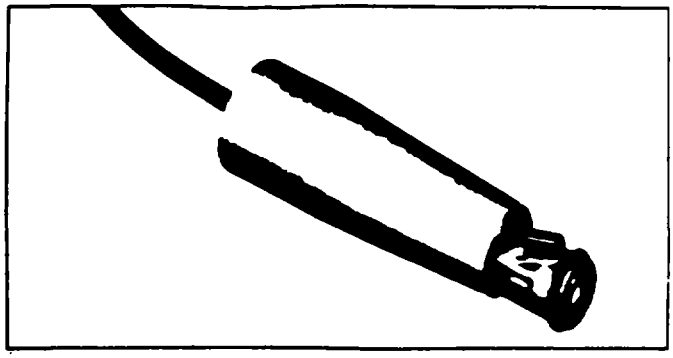

Figure 3. The YSI 5750 Probe

YSI 5760 B.O.D. BOTTLE PROBE

The 5760 probe (Figure 4) combines the stirrer and sensor in a single unit. The stirrer is powered by a constant voltage DC supply which is provided for either 115 or 230 VAC input as specified. Alternatively, the stirrer may be operated by instrument or by battery pack power when used with the 5761 Battery Adaptor Cable. The 5760 probe connector has a small integral jack into which the plug from the power source must be inserted. When using the 5761 Battery Adaptor Cable, the small plug is inserted into the jack on the probe connector, and the other end is connected to either the 5492A Battery Pack or to the STIRRER jack on the YSI Model 57 or 58.

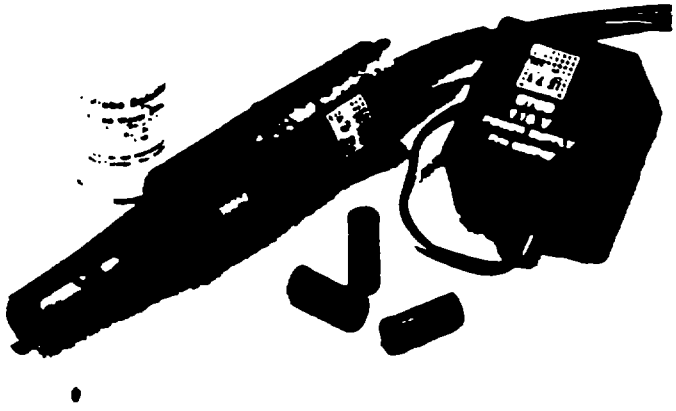

Figure 4. The YSI 5760 probe

PROBE PREPARATION

All probes are shipped dry. You must follow these instructions when preparing a new probe or when changing membranes. Prepare the electrolyte by dissolving the KCl crystals which are supplied in a dropper bottle that should be filled to the neck with distilled water. Then, proceed as follows:

Preparing the 5739, 5720A and 5750 Probes

1. Unscrew the sensor guard (5739 only). Remove the O-ring and membrane, then thoroughly rinse the sensor with distilled water.

2. To fill the probe with electrolyte and install a new membrane, follow these steps:
   a. Grasp the probe in your left hand. (See the sketches in Figure 5.) When preparing the 5739 probe, the pressure compensating port should be to the right. Successively fill the sensor body with electrolyte while pumping the diaphragm with the eraser end of a pencil or a similar soft, blunt tool. Continue filling and pumping until no more air bubbles appear. When preparing the 5720A or 5750 probes, simply fill the sensor body until no more air bubbles appear.
   b. Secure a membrane between your left thumb and the probe body. Add more electrolyte to the probe until a large meniscus completely covers the gold cathode. NOTE: Handle membrane material with care, touching it at the ends only.
   c. With the thumb and forefinger of your other hand, grasp the free end of the membrane.
   d. With a continuous motion, stretch it up, over and down the other side of the sensor. Stretching forms the membrane to the contour of the probe.
   e. Secure the end of the membrane under the forefinger of your left hand while holding the probe.
   f. Roll the O-ring over the end of the probe, being careful not to touch the membrane surface. There should be no wrinkles in the membrane or trapped air bubbles. Some wrinkles may be removed by lightly tugging on the edges of the membrane beyond the O-ring.
   g. Trim off excess membrane with scissors or sharp knife. Check that the stainless steel temperature sensor is not covered by excess membrane.

3. Shake off excess electrolyte. On the 5739, reinstall the sensor guard.

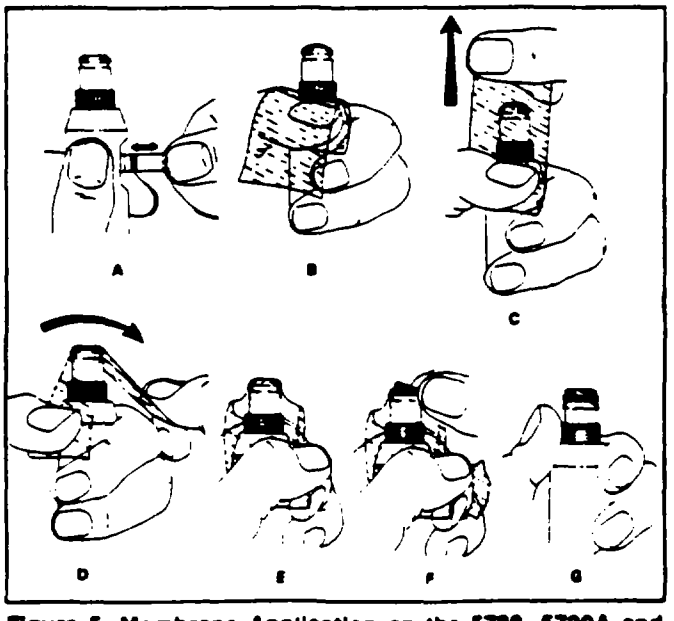

Figure 5. Membrane Application on the 5739, 5720A and 5750 Probes.

Preparing the 5760 Probe

1. Unscrew the sensor guard from the probe and remove the old membrane and ring. It is easier to grasp the membrane ring if you use a moist paper towel. (New probes have a "shipping membrane" in place which must be removed.) Thoroughly rinse the tip of the sensor with distilled water before membrane installation.

2. The membrane assembly consists of a membrane, a membrane ring and a disposable pusher tube. Installation steps are shown in Figure 6. Thoroughly rinse the membrane assembly with KCl solution; then, proceed as follows:
   a. Completely fill the membrane assembly with electrolyte. Be sure the end at which the ring is overlapped by Teflon is up.
   b. Hold the probe with the sensor end down and the vent hole facing you. Slowly push the sensor into the membrane assembly, stopping when the membrane ring is just below the vent hole. Tap the sensor with your finger several times to release any air bubbles.
   c. Continue slowly pushing the sensor down into the membrane assembly until the membrane ring rides over the O-ring on the sensor body. At that point the membrane ring will be seated against a shoulder stop.
   d. Remove the pusher tube by pulling it back over the installed membrane. Discard the used tube. Small air bubbles (1/8" diameter or less) will not affect probe performance and should be ignored. However, larger bubbles may necessitate changing the membrane.

3. Shake off excess electrolyte and reinstall the sensor guard.

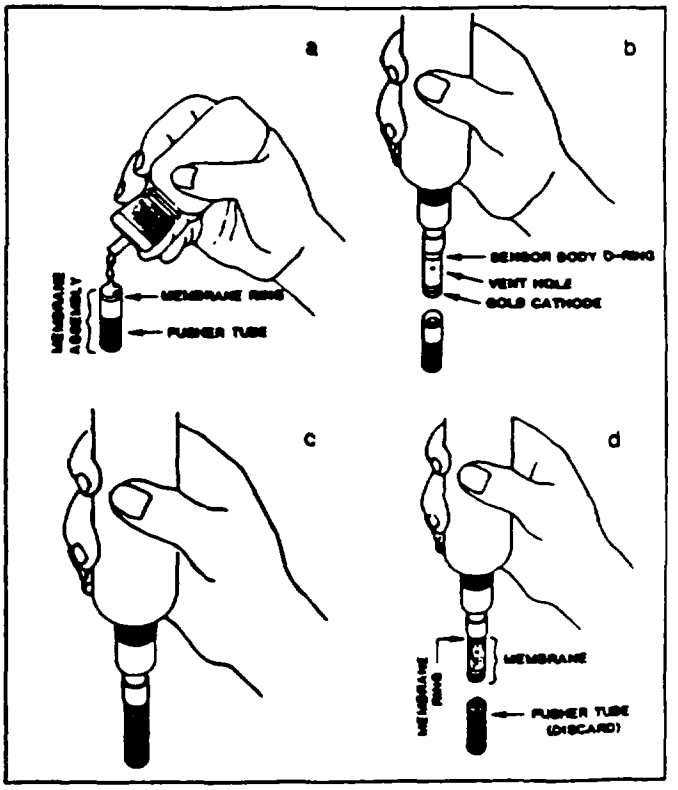

Figure 6. Membrane Installation on the 5760 Probe.

Probe Storage

A bottomless plastic bottle is provided with the YSI 5739 probe for convenient storage. Place a small piece of moist towel or sponge in the bottle and insert the probe into the open end. This keeps the electrolyte from drying out.

The 5720A, 5750 and 5760 probes can be stored in a B.O.D. bottle containing about 1" of water.

OPERATING PRECAUTIONS, ALL PROBES

1. Membrane life depends on use. Membranes will last a long time if installed properly and treated with care during use. Erratic readings result from loose, wrinkled or fouled membranes, or from large bubbles in the electrolyte reservoir. If erratic readings, or evidence of membrane damage occur, you should replace the membrane and KCl. The average replacement interval is two to four weeks. If the sensor body O-ring on the 5760 probe is worn or loose, replace it with the O-ring provided in the YSI 5764 membrane Kit. If the sensor O-ring on any of the other 5700 Series probes is worn or loose, replace it with the O-ring provided in the YSI 5945 O-ring Pack.

2. The gold cathode should always be bright and untarnished. If it is tarnished (which can result from contact with certain gasses) or plated with silver (which can result from extended use with a loose or wrinkled membrane), it needs to have its surface restored. The 5760 probe must be returned to the factory for this service. The other 5700 Series probes may either be returned to the factory, or cleaned with the YSI 5680 Probe Reconditioning Kit; never use chemicals or any abrasive not supplied with this kit.

3. It is also possible that the silver anode may become contaminated, which will prevent successful calibration. Try soaking the probe overnight in a 3% ammonia solution; rinse with deionized water, recharge with electrolyte, and install a new membrane. If still unable to calibrate after several hours, return the probe for service.

4. Hydrogen Sulfide, Sulfur Dioxide, Halogens, Neon, and Carbon Monoxide are interfering gasses. If you suspect erroneous readings, it may be necessary to determine if these are the cause.

These gasses have been tested for reponse:

100% Carbon Monoxide	less than 1%
100% Carbon Dioxide	around 1%
100% Hydrogen	less than 1%
100% Chlorine	2/3 O_2 response
100% Helium	none
100% Nitrous Oxide	1/3 O_2 response
100% Ethylene	none
100% Nitric Oxide	1/3 O_2 response

5. The correct liquid level in B.O.D. bottles is achieved by overfilling, then inserting a stopper and pouring off the excess. When using the YSI 5760 probe in a filled B.O.D. bottle, be careful to insert it slowly to avoid sample overflow.

6. When using the 5720A or the 5760 in samples containing heavy particulate solids, additional stirring may be needed.

CALIBRATION

Daily calibration is generally appropriate. Calibration can be disturbed by physical shock, touching the membrane, fouling of the membrane or drying out of the electrolyte. Check calibration after each series of measurements, and in time you will develop a realistic schedule for recalibration. When probes are not in use, store them as recommended in Probe Preparation.

Probes may be calibrated by Winkler Titration or by the Water Saturated Air method. Experience has shown that air calibration is quite reliable, yet far simpler than titration. Both methods are described here. Consult the manual for your particular instrument for more complete instructions.

Winkler Titration

1. Draw a volume of water from a single source and carefully divide it into four samples. Determine the oxygen in three of the samples using the Winkler Titration technique and average the three values. If one of the values differs from the other two by more than 0.5 mg/l, discard it and average the two values remaining.

2. Using the probe-meter system you are calibrating, place the probe into the fourth sample and stir.

3. Switch to the desired mg/l range and adjust the CALIBRATION control to the average value determined in step 1. Allow the probe to remain in the sample for at least 5 minutes before setting the calibration value, then leave it in the sample for an additional 2 minutes to verify stability. Readjust if necessary.

Air Calibration

1. Place the probe in a B.O.D. bottle containing about 1 inch of water. Wait approximately ten minutes for temperature stabilization.

The 5739 probe can be placed in the YSI 5075A Calibration Chamber or in the small calibration bottle supplied with the probe (the one with the hole in the bottom) along with a few drops of water.

2. Read the temperature and refer to the instrument Calibration Table to determine the calibration value. NOTE: To achieve the stated accuracy of measurement, the probe must be stabilized before calibrating. The calibration temperature should be within 5 degrees of the sample temperature.

3. Determine the atmospheric correction factor (see instrument instructions).

4. Multiply the calibration value by the correction factor.

5. Switch your instrument to an appropriate mg/l range and adjust the CALIBRATE control until the meter reads the corrected calibration value from step 4. Without changing the calibration setup, monitor the readings for an additional 3 minutes to verify calibration stability. Readjust if necessary.

WARRANTY AND REPAIR

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 possible, when the item is returned to the factory or to an authorized YSI dealer. Electrode cleaning is not covered by warranty.

If you are experiencing difficulty with any YSI product, it may be returned for repair, even if the warranty has expired. YSI maintains complete facilities for prompt servicing on all its products. This warranty is limited to repair or replacement (YSI's option) at no charge.

Scientific Division
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Item No 004483 PNA05730L

APPENDIX 4.5

SALINITY, CONDUCTIVITY, TEMPERATURE METER
YSI MODEL 33 AND 33M

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.

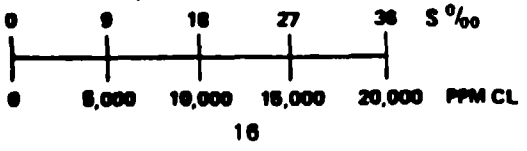
YSI MODEL 33 AND 33M USED WITH YSI 51A, 54 and 57 OXYGEN METERS

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

$$\text{PPM Chlorosity} = \frac{\text{Salinity } {}^{0}/_{00} - 0.03}{1.8} \times 10^3$$

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

$$\text{PPM Cl} = \frac{\text{SS } {}^{0}/_{00} \times 10^3}{1.8}$$



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

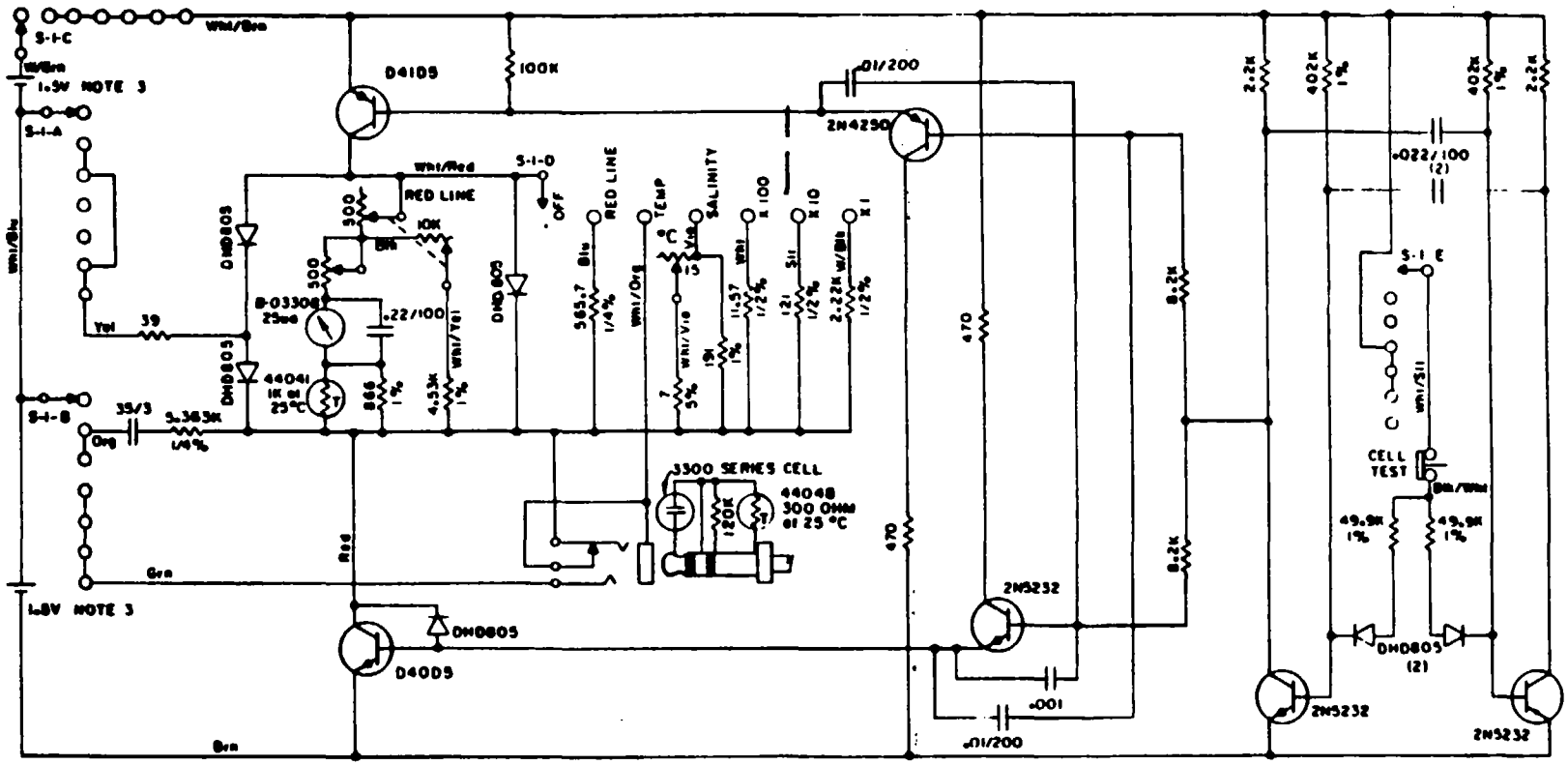
Model 33 and 33M salinity readings taken in conjunction with Model 54 dissolved oxygen readings can be used to correct the Model 54 for salinity and to make post-measurement salinity corrections to dissolved oxygen data. Correction tables are available from the factory.

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

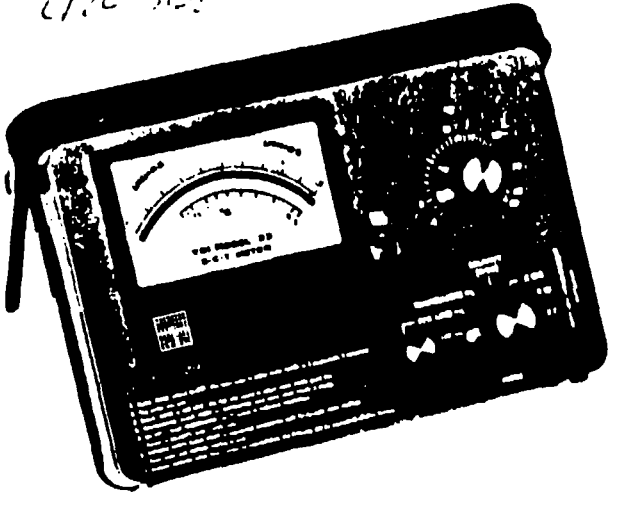


YSI MODEL 33 AND 33M B-03321-F

NOTE:

1. Resistance values in ohms, K=1,000; resistors are 1/4W, 10% unless otherwise specified.
2. The values shown on this 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.

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



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ITEM 021470 P/N A03309L APRIL 1983

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.

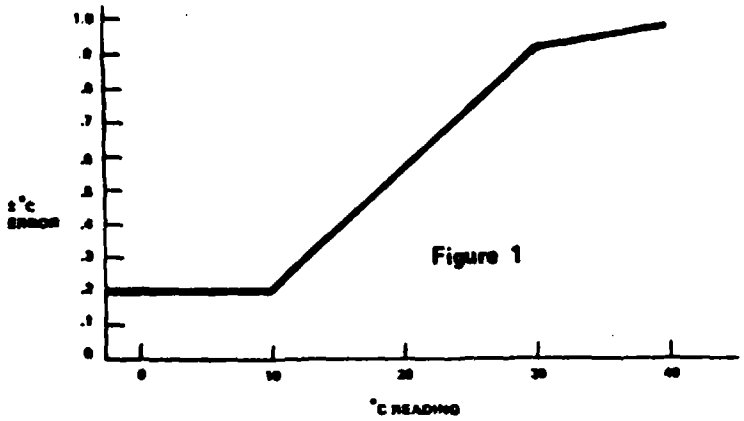


Figure 1

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

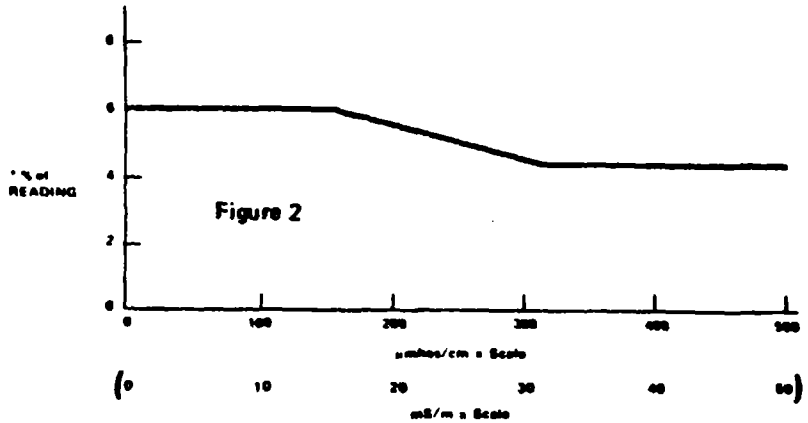


Figure 2

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) Salinity

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.

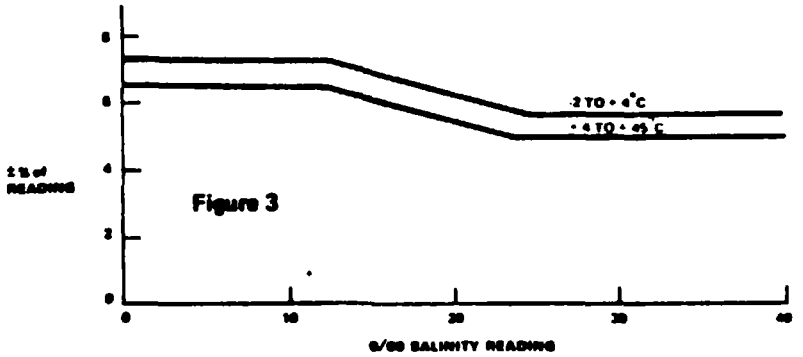


Figure 3

Example: Meter Reading: 10 0/00. @ 10°C

% of Reading Error: 6.5%

Accuracy: 10 ‰ ± 0.65 ‰ for all errors, combined worst case.

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.

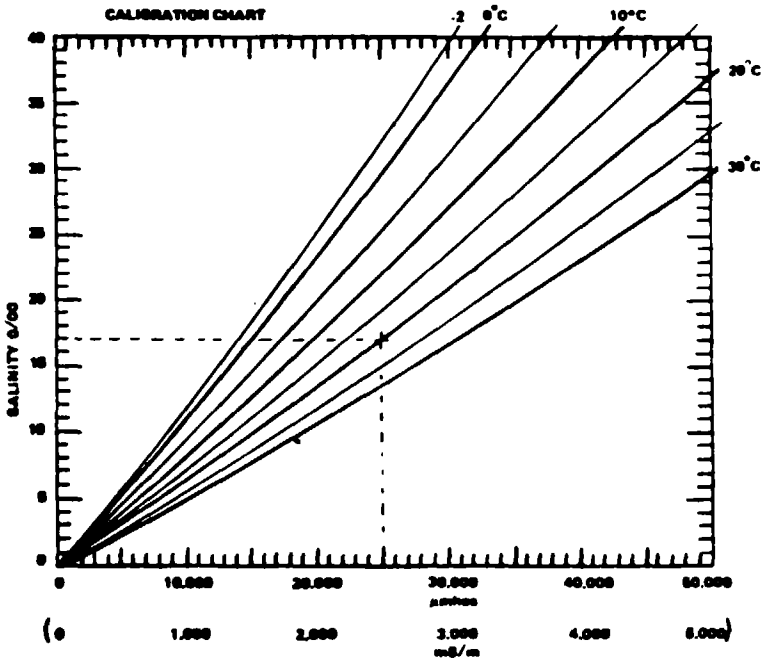
Replace batteries every six months to reduce the danger of corrosion due to leaky batteries. To replace batteries, remove the six screws from the rear plate. The battery holders are color coded. The Positive (+ button) end must go on red.

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.)



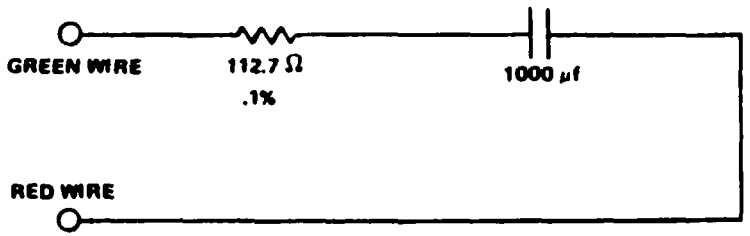
(b) Remove the °C knob, switch to SALINITY, and turn the control shaft until the meter needle indicates the salinity value determined in Step (a). In the example given, the value is 17.

(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.

Temperature °C	Conductivity 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

APPENDIX 4.6

PORTABLE GAS DETECTOR
ENMET MODEL CGS-100

ENMET CORPORATION

CGS-100
CGS-100SP

Gas and Vapor Detection Instruments for Industrial Health and Safety Applications
2308 S. Industrial Hwy., P.O. Box 979, Ann Arbor, MI 48106-0979 • Phone 313-761-1270, Telex 23-0501

ENMET CORPORATION
P.O. BOX 979
ANN ARBOR, MI 48106-0979

CGS-100
CGS-100SP

80007-006

2-21-88

INSTRUCTIONAL VIDEO TAPES AVAILABLE

Frequently, one of the best methods of learning how to operate new and unfamiliar equipment is to see it demonstrated and have its functions explained pictorially. By seeing just how the different components of an instrument are used, it is often quite simple to learn operating techniques and maintenance procedures. Watching someone use equipment in an actual application enhances our understanding of the overall function of the equipment and provides a familiar example to follow. After all, a picture is often worth a thousand words!

ENMET has recently produced a complete series of video tapes demonstrating operation and maintenance procedures for our entire series of Tritector portable gas detection instruments. One series of tapes covers instrument operation. These tapes discuss the overall purpose of the instruments, describe their capabilities, demonstrate the function and operation of each instrument component, and provide examples of actual applications. The other tape series demonstrates maintenance procedures, such as Field Testing, calibration and certain component replacement procedures.

ENMET Video Training Tapes can be purchased from your local ENMET distribution center. Both VHS and BETA tapes are available.

Instrument	Series	Part Number
CGS-100/100SP	Operation (VHS)	80023-004
CGS-100/100SP	Operation (BETA)	80023-005
CGS-100/100SP	Maintenance and Calibration (VHS)	80025-004
CGS-100/100SP	Maintenance and Calibration (BETA)	80025-005

TABLE OF CONTENTS

DRAWINGS, ILLUSTRATIONS

1.0 UNDERSTANDING THE CGS-100 AND CGS-100SP

1.1 Introduction

The ENMET model CGS-100 portable gas detector monitors three types of potential gas and vapor hazards: toxic gases and vapors, combustible gases and vapors, and oxygen deficiency. A unique liquid crystal display (LCD) indicates the approximate concentrations of all three hazards simultaneously. If the concentration of any or all of these gases exceed pre-set alarm points, the CGS-100 activates audio and visual alarm signals. With its sensor cable and detachable sensor module, the CGS-100 can be used to test ambient air at the user's location or a remote area (confined spaces). The CGS-100 (with Below Ground/Public Works calibration) operates continuously for 8 hours or more on an overnight charge. We recommend that the instrument be kept on and remain with a work party whenever such personnel enter or work in a confined space or other hazardous area.

The CGS-100SP is a slightly modified version of the CGS-100. This unit has a unit-specific detachable sample pump module which replaces both the sensor cable and detachable sensor module on the CGS-100. Utilizing flexible tubing, the pump draws air from a remote area to sensors inside the pump module. This sample is then tested for oxygen deficiency and toxic and combustible gases. Except for this variation in air sample delivery to the sensors, all of the features of the CGS-100 and the CGS-100SP are identical.

Read through this manual completely and thoroughly. Following all the instructions and precautions outlined in this manual will help maintain the accuracy and useful life of the instrument you own and use.

NOTE: The leather case is an integral part of this instrument. In addition to furnishing protection during use, the leather case affords a certain amount of protection during shipment. We suggest that the instrument be used and shipped only in its leather case to minimize the possibility of damage if it is dropped or struck.

1.2 Operating Principles Explained

The CGS-100 is a completely rechargeable solid state electronic gas detection instrument which uses three independent sensing elements: a gas-sensitive metallic oxide semiconductor element (MOS sensor) for combustible gas detection; another MOS sensor for toxic gas detection; and an electrochemical fuel cell (oxygen cell) for oxygen detection. The oxygen cell operates differently than the MOS sensors, and all three sensing elements have dif-

1.2 Operating Principles Explained (continued)

ferent response characteristics. The sensors are housed in the sensor module of the CGS-100 or the sample pump module of the CGS-100SP.

Inside the MOS sensor, a non-linear device, an oxidation reaction occurs on the electronically heated surface of the sensor element upon contact with a suitable gas changing the electrical resistance of the sensor. The resulting electrical signal is processed by instrument electronics, translating the signal into an approximate gas concentration. If the concentration exceeds a calibrated alarm point, alarm signals activate.

Even though conditioned electronically for response to a particular gas, the MOS sensor responds to a variety of gases and vapors (mainly hydrocarbons). However, MOS sensor response to gases other than those for which it is calibrated does not identify any specified concentrations of such gases. For example, a sensor calibrated to activate alarm signals for 20% LEL methane may also alarm in the presence of gasoline. In such a case, although the alarm signals would indicate the presence of a gas or vapor, the alarm signals and instrument meter response would not identify a particular concentration of gasoline.

The electrochemical fuel cell (oxygen cell) is a linear device specific to oxygen gas. Oxygen diffuses through a thin, selective, permeable membrane on the surface of the cell screen, inducing a chemical reaction within the cell. This reaction produces a small electrical current proportional to the partial pressure of oxygen in ambient air. The current signal is translated by instrument circuitry into an approximate oxygen concentration, which is shown on the oxygen display of the LCD. If this concentration falls below the pre-set oxygen deficiency alarm point, audio and visual alarm signals activate.

Two 4.4 volt batteries in series supply the power for the CGS-100 instrument. These batteries are completely rechargeable and power the instrument (with Below Ground/Public Works calibration) for 8 hours or more from an overnight charge. Low battery signals activate approximately 15 minutes before battery depletion affects instrument performance, providing ample time for a work party to exit a hazardous area. A special low-battery shut-off circuit automatically turns the instrument off if low battery warning signals are ignored. In addition, the batteries are fused; current limiting resistors in the battery connections render the equipment intrinsically safe.

1.3 Calibration Explained

1.3.1 Terminology

The terms "percent lower explosive limit" (%LEL), "parts per million" (ppm) and "percent oxygen by volume" are often used to indicate quantities or concentrations of gases and vapors. Such terminology is also used to indicate the calibrated alarm levels of ENMET instruments. These terms are described below.

Used to identify combustible gas concentrations, "LEL" refers to the Lower Explosive Limit of a gas. Often expressed as 100% LEL, the Lower Explosive Limit is the lowest concentration of gas in air that will explode if exposed to a sufficient ignition source (open spark or flame). Concentrations above 100% LEL (such as 110% LEL) are potentially combustible. Concentrations below 100% LEL (such as 80% LEL) are not combustible, but indicate the presence of the gas and its proximity to the LEL.

ENMET portable gas detection instruments are usually calibrated to alarm at 10-20% LEL of a combustible gas, non-combustible concentrations one-tenth to one-fifth the amount required for combustion.

Used to identify toxic gas concentrations, the term "parts per million" is expressed as "ppm". Expressing a gas concentration in parts per million identifies the quantity of the gas as a proportion of the total volume of a space. For example, the concentration 20 ppm carbon monoxide in an area indicates that if the atmosphere of the area were divided into one million cubes (volumetric units) of equal volume, and the carbon monoxide could be concentrated in one area, exactly 20 of the cubes would consist of carbon monoxide and the remaining 999,980 cubes would be comprised of clean air. (In reality, the carbon monoxide gas is not isolated from the the rest of the atmosphere; this gas, when present, is mixed in with the rest of the air).

Unlike "%LEL", gas accumulations expressed in ppm do not in themselves express safe or dangerous concentrations. Therefore, a safety standard is needed when evaluating gas concentrations expressed in terms of parts per million. The TLV-TWA (Threshold Limit Value-Time Weighted Average) is such a standard for toxic gas concentrations. As defined in the American Conference of Governmental Industrial Hygienists' (ACGIH) Handbook, a TLV-TWA is

> ...the time-weighted average concentration for a normal 8-hour workday and 40 hour workweek, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect.

1.3.1 Terminology (continued)

The TLV-TWA is not a strict boundary between "safe" and "dangerous" concentrations. Unlike the LEL for a combustible gas, it is very difficult to determine at just what concentration toxic gases become hazardous. The TLV-TWA is an average exposure limit; a worker can be exposed to concentrations slightly above the TLV-TWA for a short time as long as this is balanced by exposure to atmospheres sufficiently below the TLV for at least the same amount of time. However, a worker should never be exposed to concentrations equal to 5 times the TLV or above. If a worker is exposed to such dangerous levels of toxic gas, he is risking physical injury or even death.

The toxic alarm point of ENMET portable instruments is usually calibrated to identify TLV concentrations of toxic gases. For additional safety guidelines and actual TLV values, consult an ACGIH handbook.

The term most commonly used to identify oxygen levels is "% by volume". Similar to the expression "ppm", the term "% by volume" expresses a gas concentration as the proportion of the total volume of a space. In fact, "ppm" and "% by volume" can be used interchangeably; for example, 10,000 parts per million is equal to 1% by volume (10,000 is 1%, or 1/100th, of one million). Because "% by volume" conveys larger proportions more easily than "ppm", it is primarily used to express larger accumulations of gas.

Similar to "ppm", the term "% oxygen by volume" does not distinguish between safe and harmful concentrations. A safety standard is needed. The concentration 20.9% by volume is the normal concentration of oxygen in clean, fresh air, indicating that just over one-fifth (20.9%) of the volume of clean fresh air consists of oxygen (the balance is nitrogen and traces of other inert gases). The concentration 19.5% has been established by the federal Occupational Safety and Health Association (OSHA) as the minimum oxygen requirement for entry to a confined space. This provides a good safety margin between the OSHA limit (19.5%) and the point at which humans are first significantly affected by lack of oxygen, which is about 16.0% by volume. If the oxygen level falls below 16.0% by volume, the senses and perceptivity of exposed workers are affected. At 14% oxygen by volume, degradation of the senses is serious. At 10% oxygen by volume the worker quickly becomes unconscious, and his life is in serious danger. Atmospheres containing 5% or less oxygen by volume are instantly fatal.

IMPORTANT: Oxygen enrichment also presents a hazard to workers. When the oxygen content of an area rises above approximately 23-25% oxygen by volume, the risk of combustion or explosion increases with many substances. Although the CGS-100 does not ac-

1.3.1 Terminology (continued)

tivate alarm signals to indicate oxygen-enriched areas, the oxygen scale on the CGS-100 LCD does indicate when the oxygen concentration has reached or exceeded 23-25% by volume.

1.3.2 Below Ground/Public Works Calibration

Unless otherwise specified, the CGS-100 is calibrated to a Below Ground/Public Works calibration as follows:

	Alarm Point	Full Scale on LCD
TOXIC	10 ppm hydrogen sulfide/ 50 ppm carbon monoxide	50 ppm hydrogen sulfide/ 300 ppm carbon monoxide
COMB	20% LEL methane	50% LEL methane

	Digital Display Alarm Point
OXYGEN	19.5% oxygen by volume

This calibration indicates that audio and visual alarms have been set to activate within certain time limits when a fully charged and purged instrument is exposed to any or all of the following: 10 ppm hydrogen sulfide, 50 ppm carbon monoxide, 20% LEL methane or 19.5% oxygen by volume. Note that 10 ppm hydrogen sulfide and 50 ppm carbon monoxide are the TLV-TWA for these gases, 20% LEL methane is well below the Lower Explosive Limit for methane, and 19.5% oxygen by volume is the OSHA-recommended limit for oxygen deficiency in a workspace. The purpose of this calibration is to alert the user to potential hazards involving some of the most common confined space gas hazards: hydrogen sulfide, carbon monoxide, methane and oxygen deficiency. A CGS-100 with this calibration also alerts the user to the presence of many other gases (but not specified concentrations). Intended applications include general confined space entry testing. NOTE: Unmarked regions on the LEL and PPM scales of the LCD do not represent particular gas concentrations.

1.3.3 Petrochemical Calibration

The CGS-100 is also available with a Petrochemical Calibration. This calibration is different from the Below Ground/Public Works calibration and involves the following gas concentrations:

1.3.3 Petrochemical Calibration (continued)

	Alarm Point on LCD Scale	LCD Full Scale Reading
TOXIC	100 ppm methyl chloride	300 ppm methyl chloride
COMB	20% LEL propane	50% LEL propane

	Digital Display Alarm Point
OXYGEN	19.5% oxygen by volume

This calibration indicates that audio and visual alarms have been set to activate within certain time limits when a fully charged and purged instrument is exposed to any or all of the following: 100 ppm methyl chloride, 20% LEL propane, and 19.5% oxygen by volume. Note that 20% LEL propane is well below the Lower Explosive Limit for propane and 19.5% oxygen by volume is the OSHA-recommended limit for oxygen deficiency in a workspace. Note also that 100 ppm methyl chloride is not the TLV-TWA for this gas. The CGS-100 with Petrochemical calibration is calibrated to alarm at 100 ppm methyl chloride only because this adjusts the circuitry and toxic MOS sensor to respond to low levels of general hydrocarbons. The intended applications for this calibration primarily involve testing for both toxic and combustible levels of hydrocarbons and hydrocarbon-containing materials (organic solvents, petrochemical feedstocks, etc.) in areas where detection of hydrogen sulfide or carbon monoxide is not essential. The CGS-100 with Petrochemical calibration has been used for such purposes as detection of leaks at petrochemical plants. NOTE: Unmarked regions of the LEL and PPM scales of the LCD do not represent particular gas concentrations.

1.3.4 Special Calibrations

Some of our customers require the CGS-100 to be calibrated for particular substances; examples are jet fuels, gasoline, and ammonia. The intended applications for instruments with special calibrations are limited to the particular situations identified by the customer requesting the calibration.

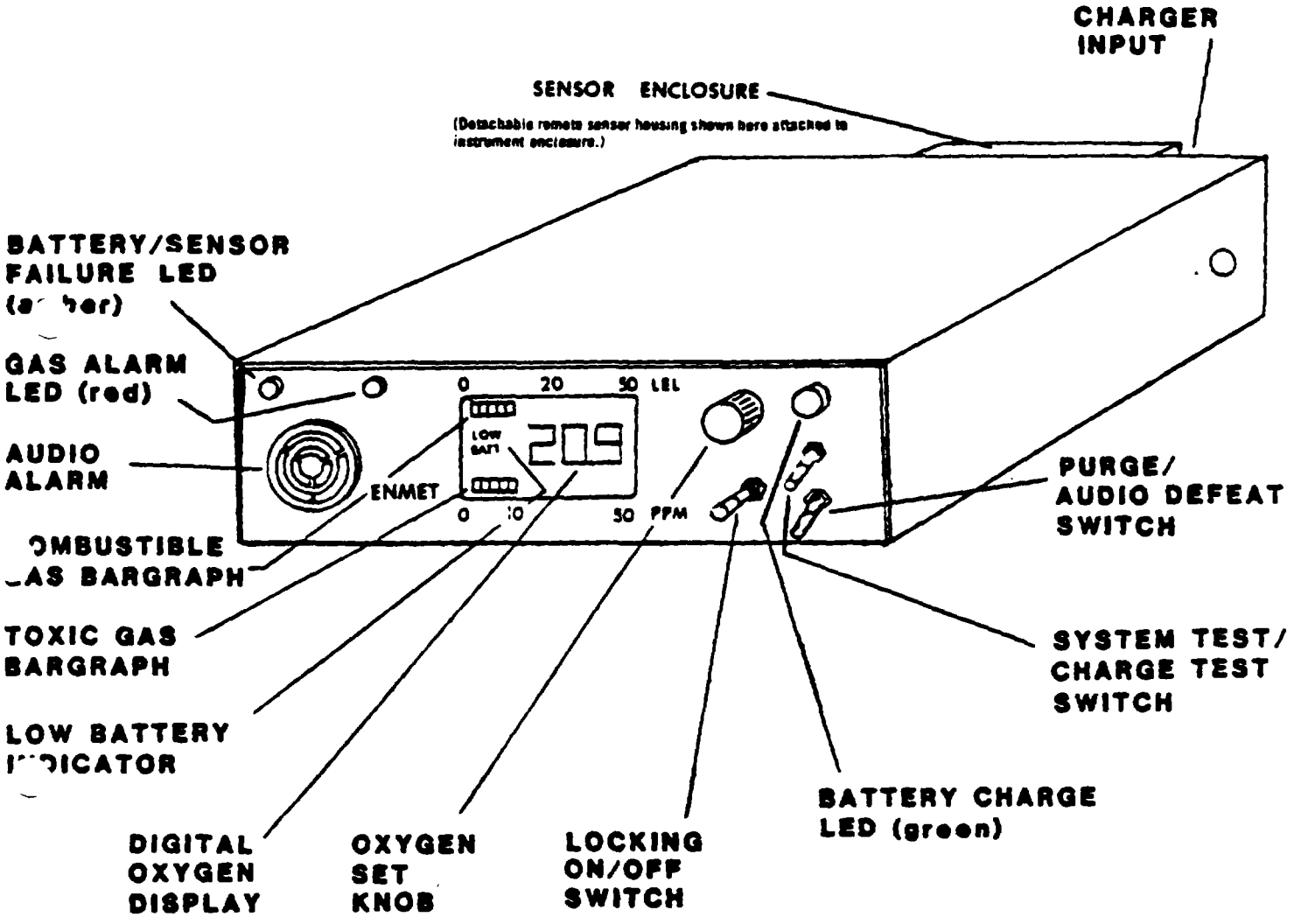


FIGURE 1: CGS-100 Instrument Outlined

2.0 USING THE CGS-100

2.1 Instrument Description (Refer to Fig. 1)

BATTERY/SENSOR FAILURE LED

This amber LED always indicates an instrument problem. It activates together with the audio alarm if the "LOW BATT" warning on the LCD (see Liquid Crystal Display below) is ignored. It also activates with the audio alarm if the there is a problem with the sensors. NOTE: On the CGS-100SP only, this amber LED also activates with the audio alarm when the air flow to the sample pump is interrupted (see Hydrophobic Filter and CAL/READ Switch below).

GAS ALARM LED

This red LED, together with the audio alarm, always indicates an oxygen deficiency or gas alarm. This LED stays on during an oxygen deficiency alarm, flashes during a gas alarm, and alternates between flashing and steady during the combination gas/oxygen alarm (see section 2.2 for description of alarm modes).

AUDIO ALARM

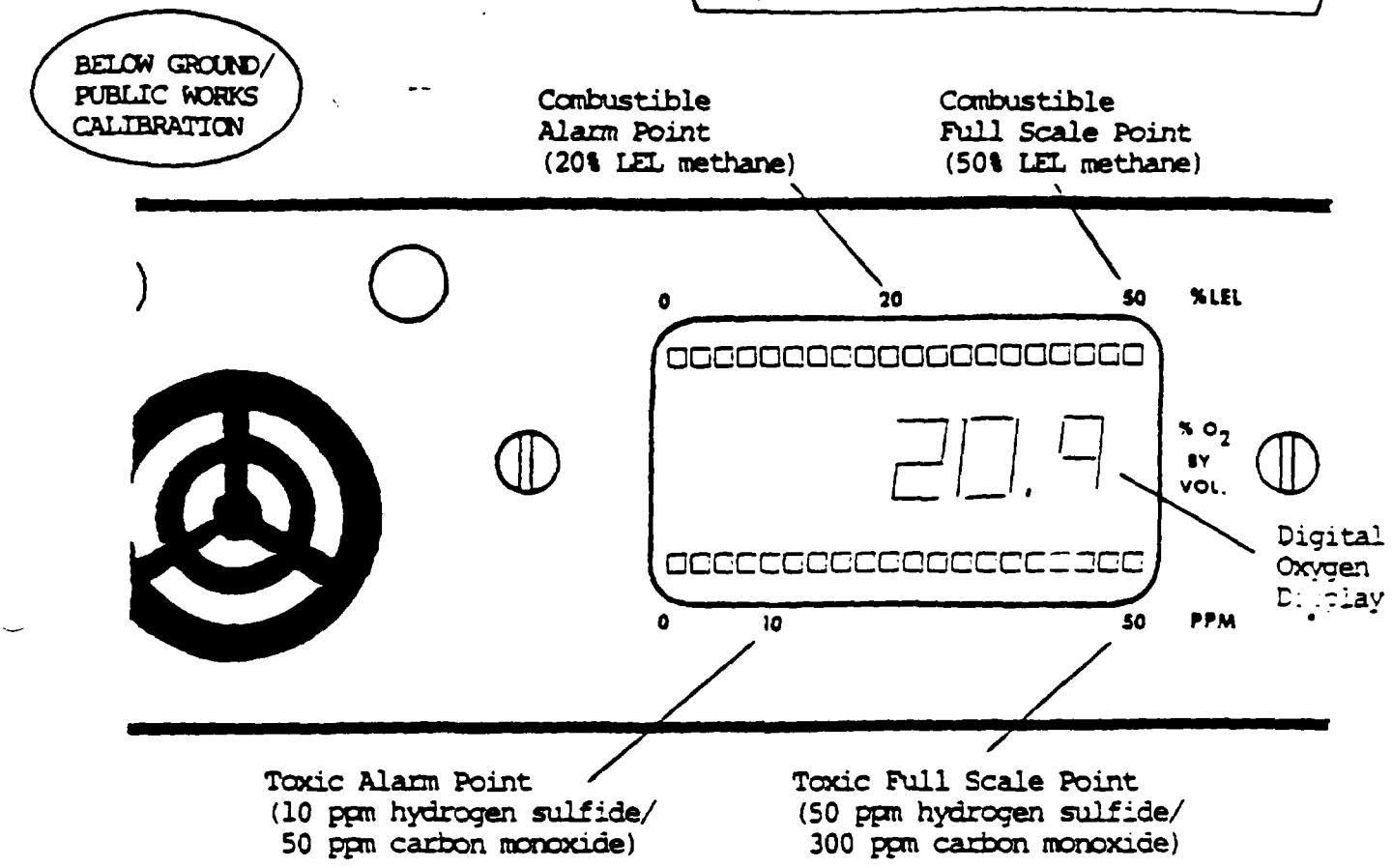
The audio alarm indicates a potential gas or vapor hazard or an instrument problem. The audio alarm emits a high-pitched, steady tone during oxygen deficiency alarm and Battery/Sensor Failure Alarm, a pulsed tone (approx. 1 pulse per second) during Gas Alarm, and alternating steady and pulsed tones during Combination Gas/Oxygen Deficiency Alarm.

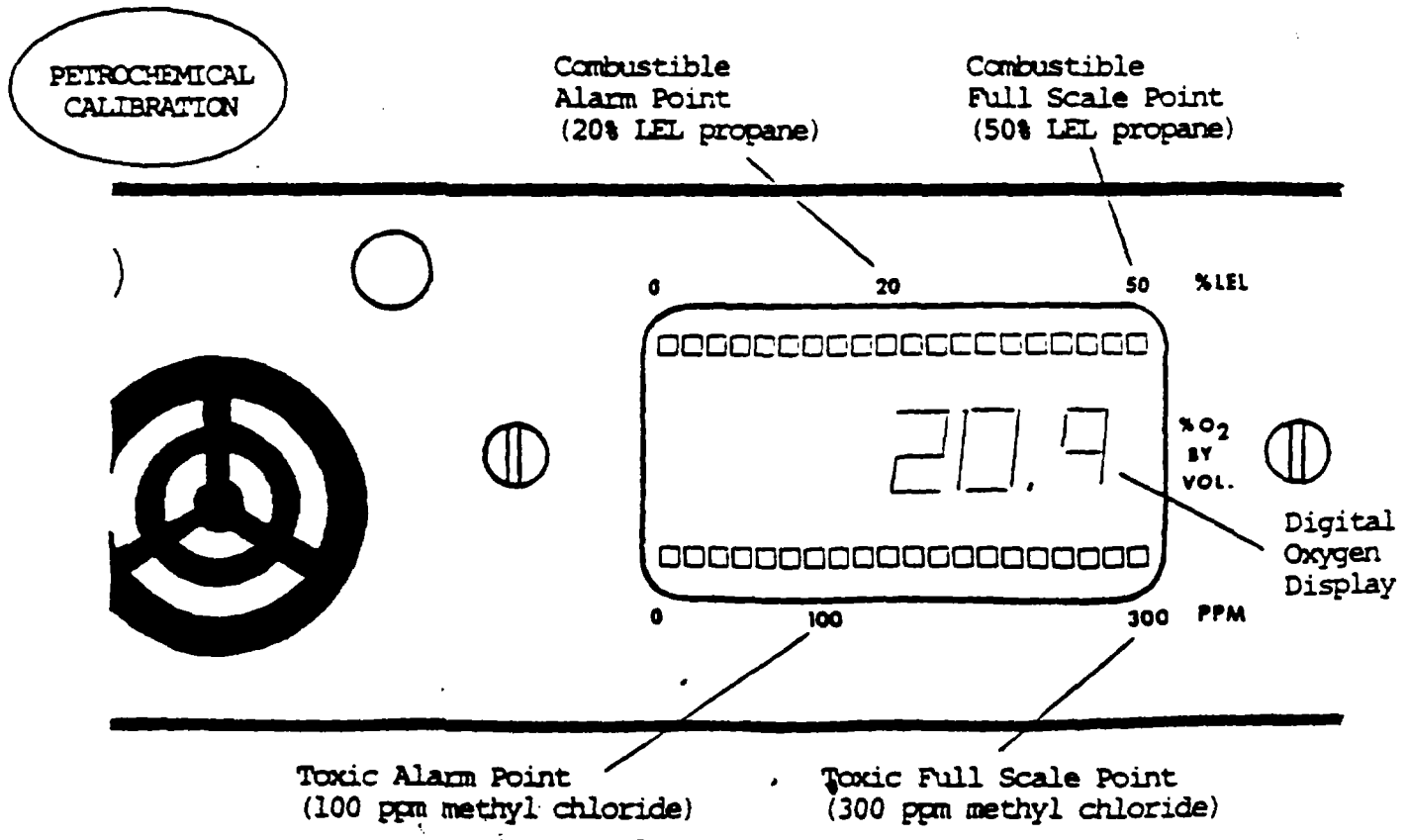
LIQUID CRYSTAL DISPLAY (refer to Fig. 2)

Bargraphs

Top bargraph (% LEL) indicates approximate combustible gas concentrations as a percent of the

FIGURE 2: CGS-100 LCD Display Outlined





2.1 Instrument Description (continued)

lower explosive limit. Bottom bargraph (PPM) indicates approximate toxic gas concentrations in parts per million.

Digital Display — Indicates % by volume oxygen in the monitored atmosphere.

Low Batt. Display — "LOW BATT" flashes on the LCD approximately 15 minutes before the instrument becomes inaccurate due to battery depletion, providing ample time for the user to take appropriate action.

OXYGEN SET KNOB — This knob is used to set the Digital Oxygen Display to a pre-set point, usually 20.9% while the instrument is in fresh air. To use, push in and turn.

ON/OFF SWITCH — This switch turns the CGS-100 on and off. To prevent accidental shut-off, the switch locks into position; it must be pulled away from its base to be set into the desired position.

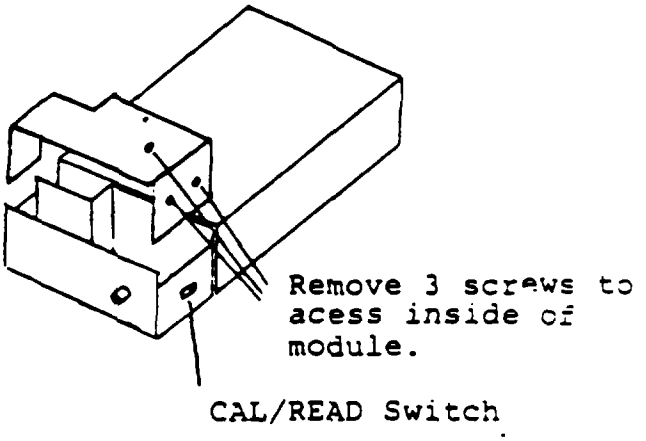
BATTERY CHARGE LED — When the Charge Test Switch (see below) is used to check the charge status of the batteries, this green LED flashes when the batteries are fully charged and remains steady when the batteries are at some point of discharge. LED does not activate unless the instrument is plugged into its charger.

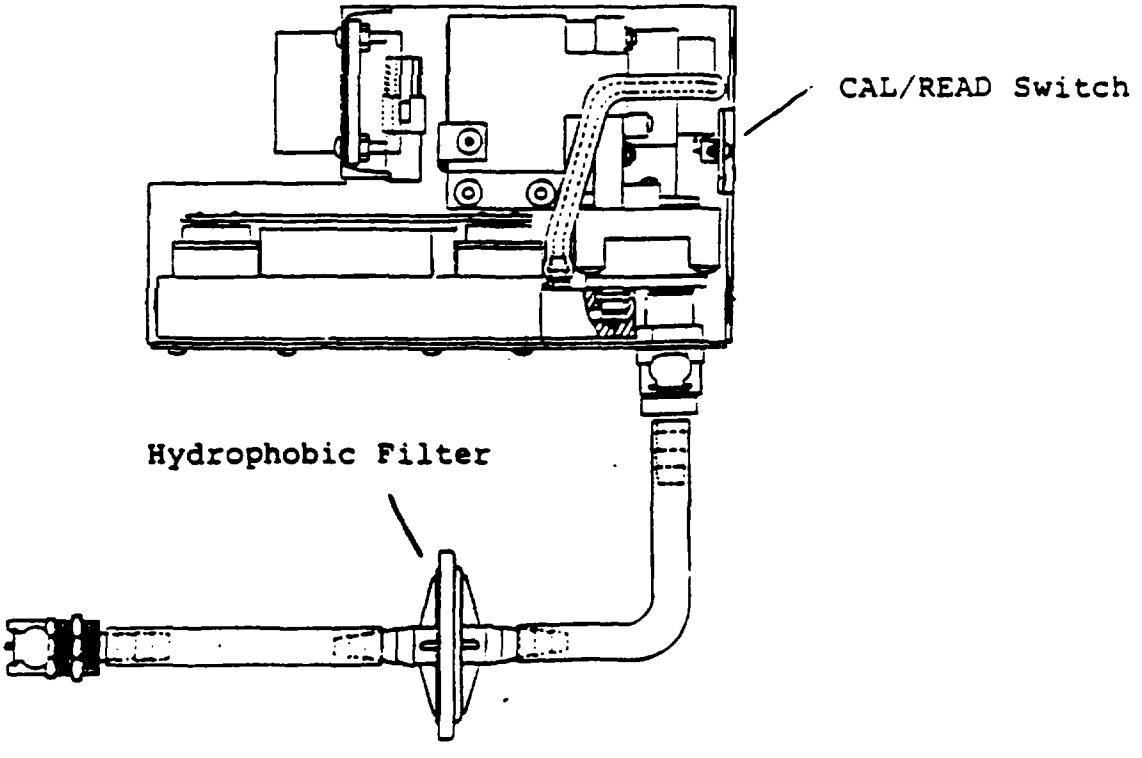
SYSTEM TEST/CHARGE TEST SWITCH

System Test — Checks displays, alarms and related electronics for proper operation. To use, pull out and hold in SYSTEM TEST position. This should cause both bargraphs on the LCD to read full scale, the digital display on

	the LCD to decrease, and the combination Gas/Oxygen Deficiency Alarm Signals to activate.
Charge Test	Checks the amount of charge in the batteries while the instrument is plugged into the charger. To use, pull switch out and hold in the CHARGE TEST position. The green LED marked "BATTERY CHARGE" will flash if the batteries are fully charged.
PURGE/AUDIO DEFEAT SWITCH	
Purge	Heats the toxic sensor electronically to clear it of contaminants. Pull the switch out and hold in the PURGE position to activate. In addition, purging automatically silences the audio alarm. NOTE: Due to a higher toxic sensor heater voltage on units with Petrochemical Calibration, PURGE is not operational on such instruments.
Audio Defeat	Silences the audio alarm. To use, pull switch away from base and hold in the AUDIO DEFEAT position.
CHARGER INPUT	Single-receptacle jack for instrument charger plug.
SENSOR MODULE (CGS-100)	On the CGS-100, the sensors are housed in the detachable sensor module at the back of the instrument. This module can be unscrewed from the unit at the MS (military specification) connector on the unit. Used with the CGS-100 sensor cable, the module can be used to check workspaces prior to entry (remote testing).
SAMPLE PUMP MODULE (CGS-100SP)	On the CGS-100SP, the sensors are located inside the sample pump module. By means of a length of

FIGURE 3 : Components Specific to CGS-100SP Sample Module





2.1 Instrument Description (continued)

flexible tubing, the CGS-100SP draws a continuous air sample from a remote location for testing.

2.1.1 Components Specific to the CGS-100SP (Refer to Fig. 3)

Hydrophobic Filter — The white plastic assembly in the sample tubing for the CGS-100SP is a hydrophobic filter. If water is drawn into the line, the filter prevents water from reaching the pump and sensors. If, as a result of this, the filter or sample tube becomes blocked, the Battery/Sensor Failure Alarm activates.

CAL/READ Switch — This switch is located inside the sample pump module. The switch must be in the READ position for the CGS-100SP to monitor correctly. When calibrating or Field Testing the instrument, this switch must be in the CAL position so that test gases can be applied. NOTE: In the CAL position, this switch shuts off the sample pump and activates the Battery/Sensor Failure Alarm.

2.2 Operating and Alarm Modes

Condition	Signals	Indicates
Normal operation (no alarms)	LCD Combustible and Toxic bargraphs read below alarm point. Digital Oxygen Display indicates between 19.5-23.0%	Safe gas and vapor concentration in the local test area.

This is the normal operating condition for the CGS-100. If the instrument is on, and these are the only signals given, then the gas concentrations for which the CGS-100 is calibrated are low enough to be safe, and the oxygen concentration is sufficient for the safety of workers. NOTE: Oxygen concentrations above 23-25% by volume do not initiate an instrument alarm, but present increased flammability risks.

2.2 Operating and Alarm Modes (continued)

Condition	Signals	Indicates
Oxygen Deficiency Alarm	Steady audio tone. Steady red Gas Alarm LED.	Potential hazard involving oxygen deficiency.

When the oxygen alarm activates, it indicates that there is 19.5% oxygen by volume or less in the atmosphere. The LCD digital display indicates the approximate oxygen concentration. Leave the hazardous area when this alarm activates. *CAUTION: IF THE DIGITAL OXYGEN DISPLAY INDICATES A CONCENTRATION OF LESS THAN 16.0% OXYGEN BY VOLUME, IT IS POSSIBLE THAT THE OXYGEN CONTENT OF THE AREA IS LOW ENOUGH TO CAUSE SERIOUS PHYSICAL INJURY OR EVEN QUICK DEATH; TAKE ACTION ACCORDINGLY.* Note also that if the oxygen concentration exceeds 23-25% oxygen by volume, the area is oxygen-enriched, so the risk of fire or explosion increases. If the oxygen is above this level, leave the hazardous area.

Condition	Signals	Indicates
Gas Alarm	Pulsed audio tone. Flashing red Gas Alarm LED.	Potential hazard involving toxic and/or combustible gas.

When the Gas Alarm activates, it indicates that there is a potential hazard involving at least one combustible or toxic gas/vapor. The LCD "PPM" and "%LEL" bargraphs indicate whether the hazard is toxic gas, combustible gas or both. Leave the hazardous area when the Gas Alarm activates. CAUTION: IF THE TOXIC OR COMBUSTIBLE GAS CONCENTRATION ON THE LCD IS ABOVE THE FULL SCALE READING, IT IS POSSIBLE THAT THE GAS CONCENTRATION IS HIGH ENOUGH TO CAUSE SERIOUS PHYSICAL INJURY OR EVEN QUICK DEATH; TAKE ACTION ACCORDINGLY.

Condition	Signals	Indicates
Combination Gas Alarm/Oxygen Deficiency Alarm	Steady audio tone, followed by 3-4 short audio pulses. Steady red Gas Alarm LED followed by 3-4 flashes.	Potential hazard involving toxic and/or combustible gas AND oxygen deficiency.

This alarm indicates that there is a potential hazard involving toxic gas and/or combustible gas AND oxygen deficiency. The LCD

2.2 Operating and Alarm Modes (continued)

indicates which gases are at alarm concentrations. Leave the hazardous area when this alarm activates. CAUTION: IF THE TOXIC OR COMBUSTIBLE CONCENTRATION ON THE LCD IS ABOVE THE FULL SCALE READING, IT IS POSSIBLE THAT THE CONCENTRATION OF GAS IS HIGH ENOUGH TO CAUSE SERIOUS PHYSICAL INJURY OR EVEN QUICK DEATH. SIMILARLY, IF THE DIGITAL OXYGEN DISPLAY INDICATES 16.0% OXYGEN OR LESS, THE CONCENTRATION OF OXYGEN MAY BE LOW ENOUGH TO CAUSE SERIOUS PHYSICAL INJURY OR EVEN QUICK DEATH. TAKE ACTION ACCORDINGLY.

Condition	Signals	Indicates
Battery/Sensor Failure Alarm	Steady audio tone. Steady amber Battery/ Sensor Failure LED.	Low batteries or problem with sensor(s). NOTE: On CGS-100SP, may indicate air flow to sensor manifold is interrupted.

When this alarm activates, it indicates either low batteries or a problem with the MOS sensors. LOW BATT flashes on the LCD if the problem is low batteries (see section 2.3 for recharging procedures). Otherwise, the problem involves the MOS sensors, and the sensor heater voltages must be checked to determine which sensor is failing (see section 4.2.1 or 4.2.2, step 4). Whenever the Battery/Sensor Failure Alarm activates, exit the hazardous area. NOTE: CGS-100SP only: If the Battery/Sensor Failure alarm activates, the problem may be with the air flow to the pump. To correct this, first make sure the pump is operating (low hum). Then check the sample tubing for obstructions or kinks. Finally, pull the tubing off the hydrophobic filter, shake out both filter and tube, and replace. If this does not correct the problem, see section 4.5 for pump replacement.

2.3 Charging the Batteries

When the CGS-100 batteries are low (see Battery/Sensor Failure Alarm in section 2.2 for a description of low battery signals), they must be recharged. The CGS-100 battery charger has one plug which inserts into the charge jack of the CGS-100 instrument. The battery charger automatically senses battery voltages and adjusts the charge rate for best performance. The Charge Test Switch on the CGS-100 is used to check the charge status of the batteries. A full recharge requires approximately 12-16 hours.

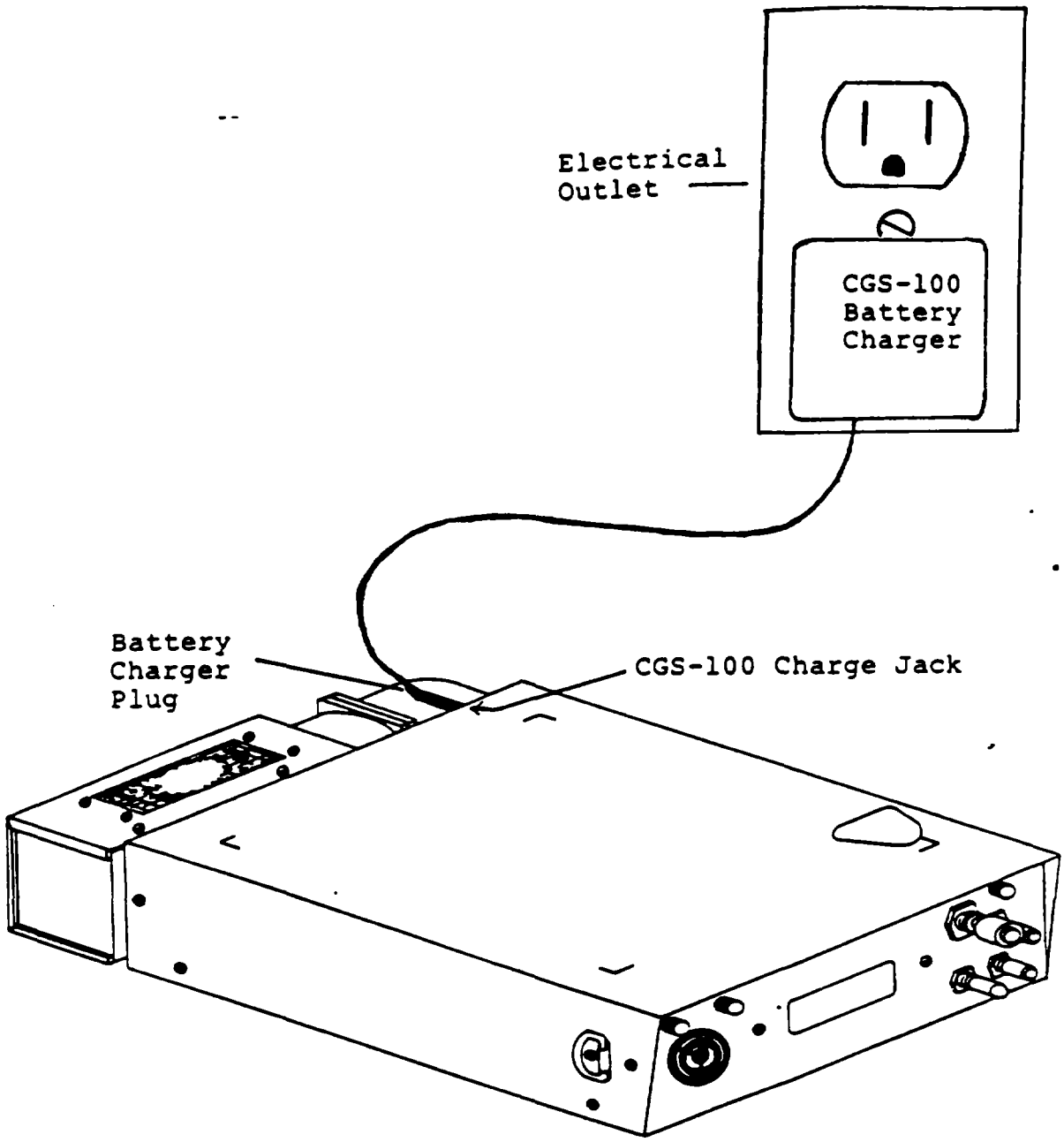


FIGURE 4 : Charging the CGS-100 Instrument

2.3 Charging the Batteries (continued)

Use only the charger provided with the CGS-100. Any other type may damage the battery pack or the electronics and void the warranty.

MATERIALS:

CGS-100 Battery Charger

CGS-100 or CGS-100SP instrument

110 Vac outlet (Note: If 220 Vac outlet is to be used, an appropriate charger must be ordered (see section 4.8)).

PROCEDURE:

1. Make sure the unit is off. Pull the locking toggle ON/OFF Switch away from its base and set it into the OFF position.

2. Plug the charger into a 110 vac wall outlet (if it is desired to use a 220 vac outlet, a special 220 Vac charger must be obtained from ENMET). Insert the charge plug of the charger into the charge jack on the back of the CGS-100 and allow the instrument to charge. A complete recharge requires approximately 12-16 hours.

3. To check the charge condition of the batteries, move the test switch to CHARGE TEST (make sure charger is still plugged into the instrument). If the green Battery Charge LED flashes on and off, the batteries are fully charged. NOTE: If the batteries do not power the instrument for a at least 8 hours (instruments with Below Ground/Public Works Calibration only), then the batteries should be replaced. See section 4.6.

2.4 A Note About Field Testing

The Field Test (section 3.0) is one of the most important precautionary measures the user can take before operating a CGS-100 with Below Ground/Public Works calibration. The Field Test is a quick check-out procedure to verify that an instrument is functional and not grossly out of calibration. To verify instrument accuracy, we recommend that a Field Test be performed upon receipt of the instrument and at least weekly thereafter. Note: Toxic and Combustible Field Tests in section 3.1 do not apply for units with Petrochemical or 'Special Calibration (Oxygen Field

2.4 A Note About Field Testing (continued)

Test in section 3.0 does apply); refer to section 4.2.2 or any addendums included with this manual for instructions on maintaining instrument accuracy for these units.

2.5 Operation

The CGS-100 simultaneously detects toxic gas, combustible gas and oxygen deficiency. The unit activates audio and visual alarms when any or all of these hazards reach the calibrated alarm points for the instrument. Keep unit in leather case during use.

Response Time: The CGS-100 uses two types of sensing elements (MOS sensor and oxygen cell), which have different response characteristics. In addition, the toxic, combustible, and oxygen calibrations involve different quantities of gases. Because the toxic sensor detects the smallest amount of gas, the toxic alarm has the slowest response time. Always allow at least 3 minutes of sampling time to fully test any atmosphere prior to entry. Allow up to 4 minutes when using CGS-100SP with a sampling line over 20 ft.

Gas Accumulations: Some gases and vapors are heavier than air, some are lighter. Methane, for example, is approximately half as dense as air, and can be found at the upper levels of an enclosed work area. When testing an atmosphere, always check both the high and low areas of the workspace. Also check any areas where gases can "pocket", such as below steel gratings or up between rafters.

IMPORTANT: The Digital Oxygen Display on the LCD indicates the percentage of oxygen in the air, unadjusted for changes in air pressure. The initial percentage, 20.9%, is set into the display while the instrument is in fresh ambient air at the user's worksite. At high altitudes, the pressure of the air is reduced. Because there is less air, there is less oxygen available even though the percentage of oxygen in the air remains the same as at sea level. The oxygen sensor in this instrument responds to the partial pressure of the oxygen in the air. Thus, an instrument initially set to 21% oxygen at sea level reads lower at several thousand feet elevation due to the lower partial pressure of oxygen. It is possible up to an altitude of around 5,000 feet (1524 meters) to readjust the meter to read 21% in fresh air, although there is not as much oxygen available because of the reduced air pressure at high altitudes.

At an altitude just above 5,000 ft., it becomes no longer possible to set the display to 20.9% oxygen in fresh air while using the controls and circuitry in the instrument. DO NOT CHANGE THE

CIRCUITRY OF THE INSTRUMENT TO MAKE HIGH ALTITUDE ADJUSTMENT OF THE DISPLAY TO 20.9% OXYGEN A POSSIBILITY. To do so voids the warranty on the instrument and initiates a situation of great potential danger to the user. At sea level, an alarm setting of 19.5% oxygen provides a safety factor for the user. At high altitudes, because of the decrease in available oxygen resulting from the decrease in air pressure, the safety factor is reduced until, at approximately 5,700 ft. (1750 m), the safety factor is eliminated for those not acclimated to work at high altitudes.

NOTE: Steps 1-5 of the operation procedure below must be performed in a clean, uncontaminated environment.

MATERIALS:

Fully charged CGS-100 (or CGS-100SP)

PROCEDURE:

1. Make sure the instrument has been fully charged (12-16 hours--see section 2.3). While the instrument is still plugged into the charger, use the Charge Test Switch to check the charge status of the batteries.

   CGS-100SP ONLY: The CAL/READ switch (see Fig. 3) must be in the READ position when the instrument is being used to monitor or test any atmosphere. If this switch is in the READ position there will be a low audible hum and slight vibration in the sample pump module. If there is no hum or vibration, then remove three screws in the sample pump module cover (see Fig. 3), lift off the cover and set this switch in the READ position. Replace cover. NOTE: If there is still no audible hum when the switch is in the READ position, there is a problem with pump operation. Try recharging the instrument. If this does not solve the problem, refer to section 4.5.

2. Turn the instrument on by pulling the ON/OFF Switch away from its base and setting it in the ON position. The MOS sensors activate alarm signals until they warm up. Push in the Push To Set Oxygen Knob and turn until the Digital Oxygen Display on the LCD reads 20.9%. If the display cannot be set to 20.9% while the instrument is in fresh air, replace the oxygen cell (see section 4.4.1 or 4.4.2).

   NOTE: For instruments with Petrochemical Calibration, allow unit to stabilize for six minutes, and then proceed to step 5, since PURGE is non-operational in such instruments.

2.5 Operation (continued)

3. A) If the unit is still in alarm, hold the Purge/Audio Defeat Switch in the Purge position until the red Gas Alarm LED deactivates. Continue to hold the switch in the Purge position for two minutes.

   B) If the unit is not in alarm, hold the Purge/Audio Defeat Switch in the Purge position for two minutes.

4. Wait 6 minutes for the sensors to stabilize. If the unit alarms during this time, the sensor may be very contaminated. Repeat step 3A to clear it. If the unit will not stay clear, recalibrate it (section 4.2).

5. Now hold the System Test/Charge Test Switch in the System Test position. If the LED bargraphs read full scale, the digital display decreases, and the combination gas/oxygen alarm activates, the unit is ready to operate.

CGS-100: Before entering a hazardous area, test the atmosphere for three minutes without entering the area yourself. For example, attach the sensor module to the sensor cable and lower the module into a confined space to test both the high and low areas of the entry space for three minutes. If no alarms activate (and Digital Oxygen Display indicates no more than 23% oxygen), it is safe to enter. After entering, keep the instrument on and the sensor module with you as long as you are in the area. Periodically test both the high and low points of the workspace for hazardous gases or vapors. Periodically check the LCD for gas concentrations. If any alarm activates, or if the oxygen content rises above 23-25% by volume, exit the hazardous area immediately.

CGS-100SP: Before entering a hazardous area, test both the high and low areas of the atmosphere for at least 3 minutes (4 minutes if using more than 20 ft. of sample tubing) without entering the area yourself. To do this, attach the sample tubing to the hydrophobic filter intake tubing (connectors on these components snap together; see Fig 3). Place the open end of the tubing in the high and low areas of the entry space for three minutes to draw air samples for testing. If no alarms activate, and the Digital Oxygen Display indicates no more than 23.0% oxygen by volume, it is safe to enter the area. After entering the area, either detach the tubing from the sample pump module, or keep the end of the tubing with you; you want to sample the air near you while you are in the area. Periodically test the high and low points of the area for hazardous gases.

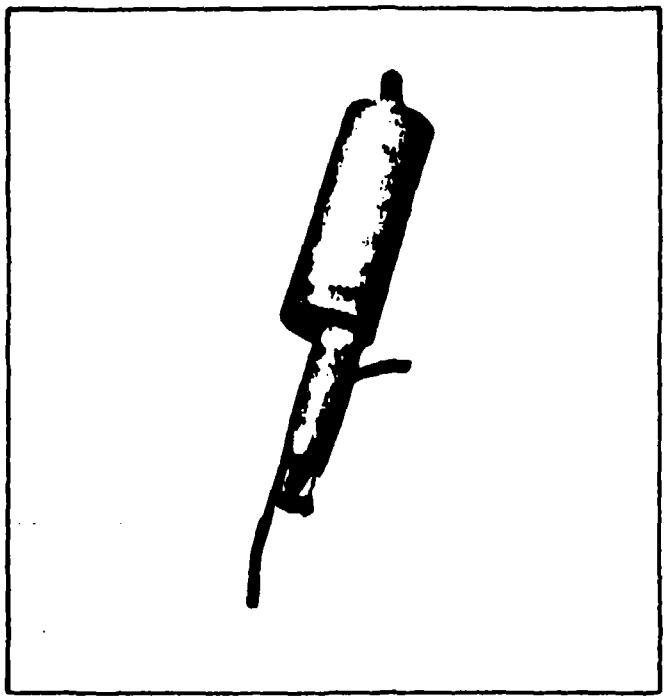


FIGURE 2

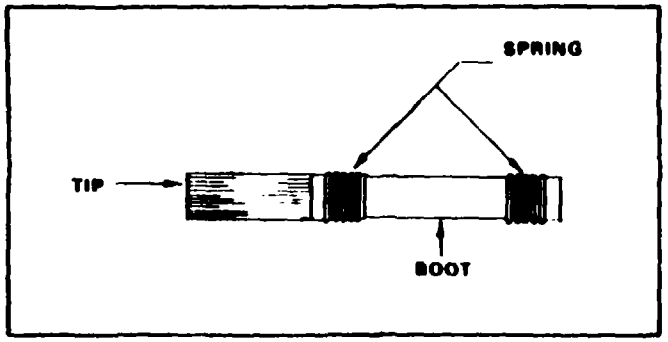


FIGURE 3

ozone, or direct sunlight. For maximum life rinse the boot after use in contaminated samples. (See Figure 3)

Boot replacement is as follows:

1. Pull off old assembly and clean shaft.
2. Slide on new assembly making sure the back spring is on the grooved area of the shaft. A small amount of rubber cement may be used.
3. Check that there is sufficient clearance between the tip and the end of the shaft to permit turning without binding.

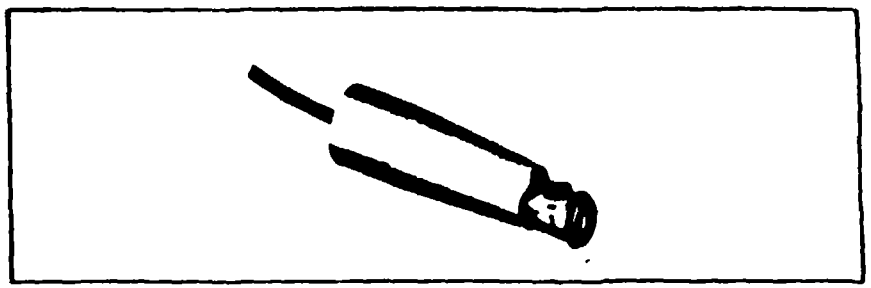


FIGURE 4

III. YSI 5750 B.O.D. Bottle Probe

The YSI 5750 B.O.D. Bottle Probe replaces the discontinued YSI 5450 B.O.D. Bottle Probe. It is similar to the YSI 5720A B.O.D. Bottle Probe, except that it does not have a stirrer. Agitation of the sample must be provided by other means, such as a magnetic stirrer. (See Figure 4)

IV. Cable Adaptors

All YSI 5700 Series Probes are designed for direct use with the YSI Model 57 Dissolved Oxygen Meter.

V. YSI 5791A and 5795A Submersible Stirrers

The YSI submersible stirrers are accessories that perform the function of stirring the sample being studied when making dissolved oxygen measurements in the field. The YSI 5791A stirrer can be used with the following dissolved oxygen probes: YSI 5418, 5419, 5718, 5719, and 5739. The YSI 5795A stirrer is only for use with the YSI 5739 Probe. (See Figure 5)

When a stirrer and probe are assembled, the stirrer agitates the sample directly in front of the sensor by means of a rotating eccentric weight which causes the spring-mounted hermetically sealed motor housing to vibrate. An impeller on the end of the motor housing flushes the media across the oxygen sensor. (See sales literature and instruction sheets for further information).

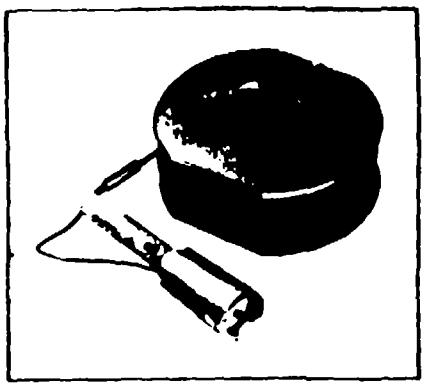


FIGURE 5

VI. YSI 5721 Battery Pack and Charger

The YSI 5721 Battery Pack and Charger is offered as an accessory to operate either the YSI 5791A or 5795A Submersible Stirrer when the stirrer is used in conjunction with the YSI Model 57 Oxygen Meter. The YSI 5721 can be purchased with the YSI Model 57 or installed at a later time (See sales literature and instruction sheet for further information).

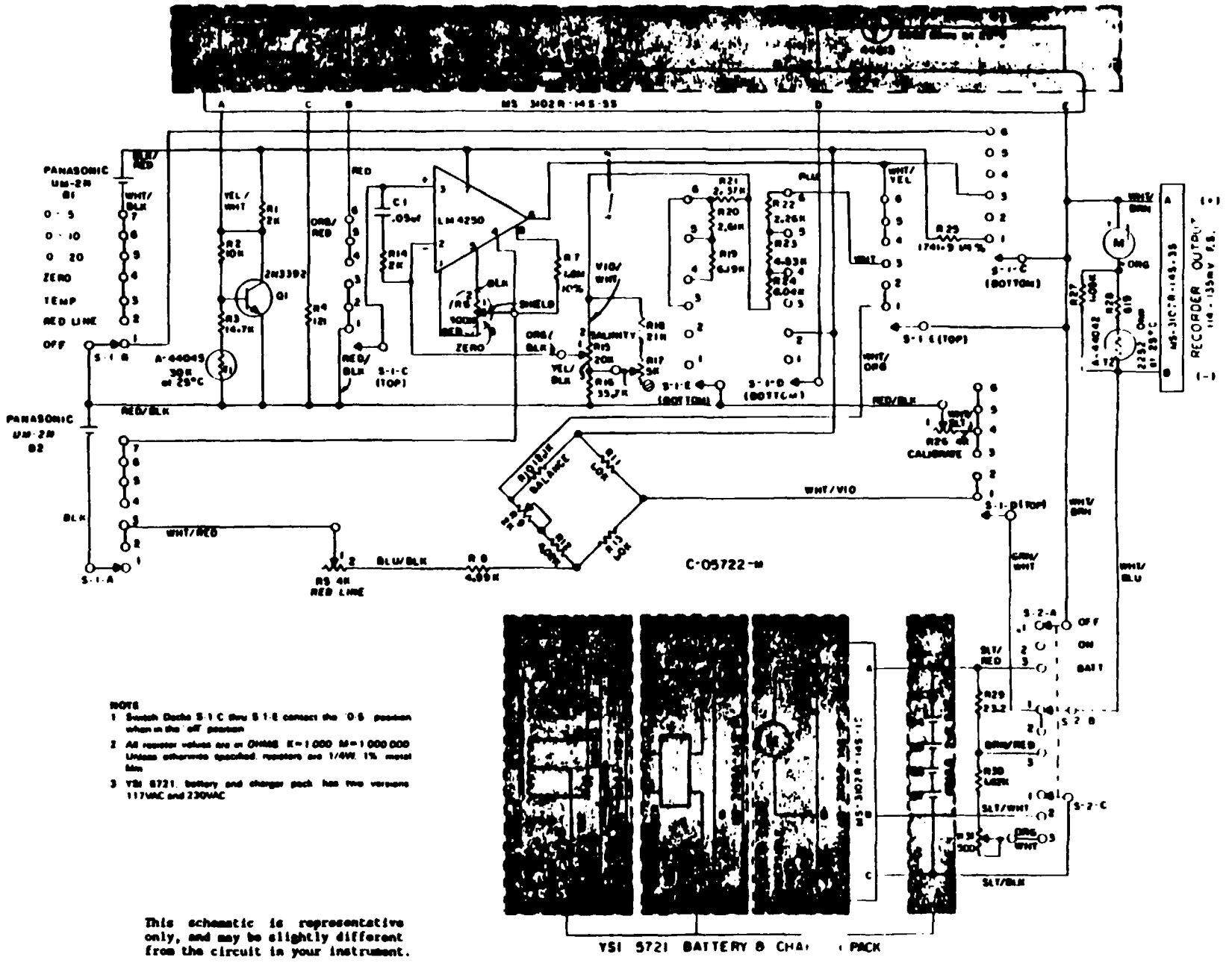
OPERATING PROCEDURES

I. Preparing the Probe

All YSI 5700 Series Probes have similar sensors and should be cared for in the same manner. They are precision devices relying on good treatment if high accuracy measurements are to be made. Prepare the probes as follows (See Figure 6)

ALL PROBES ARE SHIPPED DRY — YOU MUST FOLLOW THESE INSTRUCTIONS

1. Prepare the electrolyte by dissolving the KCl crystals in the dropper bottle with distilled water. Fill the bottle to the top.
2. Unscrew the sensor guard from the probe (YSI 5739 only) and then remove the "O" ring and membrane. Thoroughly rinse the sensor with KCl solution.
3. Fill the probe with electrolyte as follows:
   A. Grasp the probe in your left hand. When preparing the YSI 5739 probe the pressure compensating vent should be to the right. Successively fill the sensor body with electrolyte while pumping the diaphragm with the eraser end of a pencil or similar soft, blunt tool. Continue filling and pumping until no more air bubbles appear. (With practice you can hold the probe and pump with one hand while filling with the other.) When preparing the YSI 5720A and 5750 probes, simply fill the sensor body until no more air bubbles appear.
   B. Secure a membrane under your left thumb. Add more electrolyte to the probe until a large meniscus completely covers the gold cathode. NOTE: Handle membrane material with care, keeping it clean and dust free, touching it only at the ends.
   C. With the thumb and forefinger of your other hand, grasp the free end of the membrane.
   D. Using a continuous motion *stretch* the membrane *UP, OVER,* and *DOWN* the other side of the sensor. Stretching forms the membrane to the contour of the probe.
   E. Secure the end of the membrane under the forefinger of the hand holding the probe.
   F. Roll the "O" ring over the end of the probe. There should be no wrinkles in the membrane or trapped air bubbles. Some wrinkles may be removed by lightly tugging on the edges of the membrane beyond the "O" ring.
   G. Trim off excess membrane with scissors or sharp knife. Check that the stainless steel temperature sensor is not covered by excess membrane.
4. Shake off excess KCl and reinstall the sensor guard.
5. A bottomless plastic bottle is provided with the YSI 5739 probe for convenient storage. Place a small piece of moist towel or sponge in the bottle and insert the probe into the open end. This keeps the electrolyte from drying out. The YSI 5720A and 5750 probes can be stored in a B.O.D. bottle containing about 1" water.



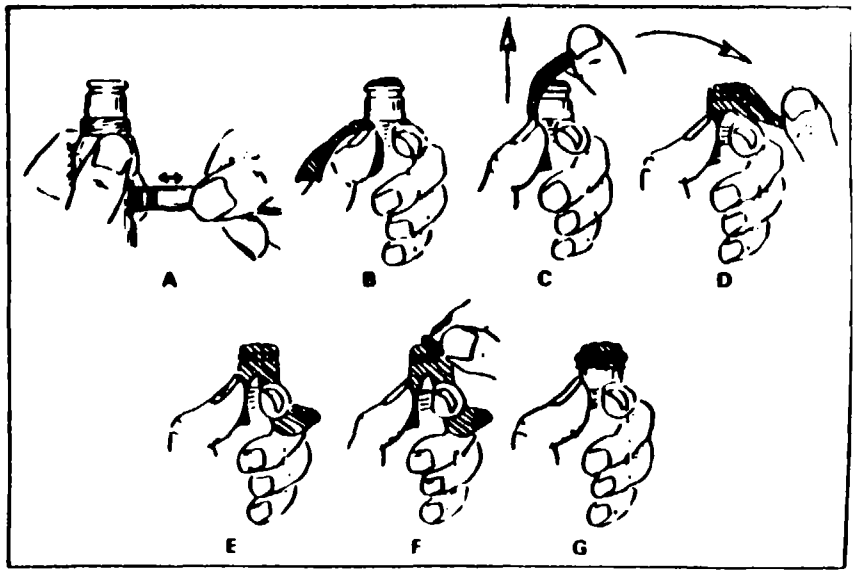
NOTES

1. Switch Decks S-1-C thru S-1-E connect the "0-5" position when in the "off" position.
2. All resistor values are in OHMS. K = 1,000 M = 1,000,000. Unless otherwise specified, resistors are 1/4W, 1% metal film.
3. YSI 5721 battery and charger pack has two versions: 117VAC and 230VAC.

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

6. Membranes will last indefinitely, depending on usage. Average replacement is 2-4 weeks. However, should the electrolyte be allowed to evaporate and an excessive amount of bubbles form under the membrane, or the membrane become damaged, thoroughly flush the reservoir with KCl and install a new membrane.
7. Also replace the membrane if erratic readings are observed or calibration is not stable.
8. "Home brew" electrolyte can be prepared by making a saturated solution of reagent grade KCl and distilled water, and then diluting the solution to half strength with distilled water. Adding two drops of Kodak Photo Flo per 100 ml of solution assures good wetting of the sensor, but is not absolutely essential.
9. The gold cathode should always be bright and untarnished. If it is tarnished (which can result from contact with certain gases) or plated with silver (which can result from extended use with a loose or wrinkled membrane), return it to the factory for service or else clean it with the YSI 5680 Probe Reconditioning Kit. Never use chemicals or any abrasive other than that supplied with this kit.
10. It is also possible that the silver anode may become contaminated, which will prevent successful calibration. Try soaking the probe overnight in a 3% ammonia solution; rinse with deionized water, recharge with electrolyte, and install a new membrane. If still unable to calibrate, return the probe for service.
11. H_2S, SO_2, Halogens, Neon, Nitrous Oxide and CO are interfering gases. If you suspect erroneous readings, it may be necessary to determine if these are the cause. These gases have been tested for response:

100% Carbon Monoxide-Less than 1%	100% Helium-none
100% Carbon Dioxide-Around 1%	100% Nitrous Oxide 1/3 O_2 response
100% Hydrogen-Less than 1%	100% Ethylene-none
100% Chlorine-2/3 O_2 response	100% Nitric Oxide 1/3 O_2 response



3.2 Oxygen Response Field Test (continued)

100 (see Fig. 6).

CGS-100SP: On the CGS-100SP, remove the sample tubing connector from the hydrophobic filter intake tubing connector (see Fig. 7). Then snap the calibration regulator assembly tubing connector on to the hydrophobic filter intake tubing connector.

7. On the CGS-100, the red Gas Alarm LED and a steady audio alarm should activate within 30 seconds. On the CGS-100SP, the same alarm signals should also activate within 30 seconds. The digital oxygen display on both instruments should read near 17.0%.

8. If this test fails to activate the alarm signals within the times indicated, repeat the procedure, reducing the gas flow slightly. If the test fails repeatedly, recalibrate the oxygen response for the instrument (see section 4.2.3).

9. Field Test for oxygen is complete. NOTE: On CGS-100SP, make sure the CAL-READ switch is in the READ position before using the instrument.

NOTE: For CGS-100 instruments (only) with 19.5% alarm points, a quick Field Test may be implemented. Hold your breath for 15 seconds, then exhale slowly all your breath over the screen in the far side of the sensor module. Oxygen alarm signals should activate when the Digital Oxygen Display reads below 19.5%.

If the Digital Oxygen Display does not respond with a reading below 19.5%, attempt the test again. Be sure to hold your breath for 15 seconds, and exhale slowly over the cell. If test fails repeatedly, recalibrate the oxygen alarm point (see section 4.2.3).

4.0 MAINTENANCE OF THE CGS-100 AND CGS-100SP

4.1 Maintenance Schedule

To maintain the accurate and reliable detection capabilities of the instrument, the user must periodically perform the maintenance procedures in this section. Listed below is a schedule for these maintenance procedures.

Maintenance	Frequency of Maintenance
Calibration (section 4.2)	At least once every six months for units with Below Ground/Public Works calibration; monthly for Petrochem or Special Calibrations. Also required if the unit fails a Field Test, if a sensor is replaced, or if the MOS sensor heater voltage is changed.
MOS sensor replacement (section 4.4)	Whenever the proper sensor heater voltage cannot be obtained (sensor heater voltage is checked during calibration procedures).
Oxygen cell replacement (section 4.4)	Whenever the digital oxygen display cannot be set to 20.9% when the unit is in fresh air.
Battery replacement (section 4.5)	Whenever the 2V or 9V battery does not last for its normal operating period after a complete recharge.
Fuse check or replacement (section 4.7)	Whenever the unit does not operate (even after a complete recharge).

4.2 Calibrating the CGS-100 and CGS-100SP Alarm Points

Each instrument is calibrated at the factory before shipping; however, over time and with continued use, the calibrated alarm points may drift. Recalibrating the alarm points involves gently exposing the MOS sensors (for toxic and combustible alarm point calibration) or oxygen cell (for oxygen alarm point calibration) of a completely charged and purged instrument to the correct calibration gas. Subsequently, potentiometers inside the instrument are used to adjust the alarm response of the instrument. NOTE: The procedure for toxic and combustible (MOS sensor) calibration outlined below does not apply to CGS-100 or CGS-100SP instruments with special calibration. For such instruments, consult the addendum included with this manual. The oxygen calibration procedure in this section does apply to CGS-100 or CGS-100SP instruments with special calibration.

When using a calibration gas to set the alarm levels for the toxic and combustible alarm modes, two important precautions are necessary. First, never calibrate the toxic or combustible alarm levels with compressed gases flowing directly from compressed gas cylinders, since such gases are extremely dry. Calibration procedures require gases with at least 10% relative humidity; ENMET calibration assemblies provide this humidity when used correctly. Secondly, do not use a calibration gas set in a background of pure inert gas (such as nitrogen or argon). The MOS sensor will pick up these background gases and render an inaccurate alarm response. Calibration gases must be set a background of hydrocarbon-free air. Appropriate calibration gases are available from ENMET.

An instrument with Below Ground/Public Works calibration should be calibrated at least once every six months. An instrument with Petrochemical calibration should be calibrated monthly. For instruments with special calibrations, see any addendums included with this manual. In addition, an instrument should be calibrated:

Whenever the unit fails a Field Test

Whenever a sensor is replaced

Whenever the sensor heater voltage is changed

PRECAUTIONS

Do not smoke while calibrating.

Calibration procedures must be performed in clean fresh air.

4.2.1 Below Ground/Public Works Calibration: Calibrating Toxic and Combustible Alarm Points

Follow the procedures below to calibrate the toxic and combustible alarm points of a CGS-100 or CGS-100SP with Below Ground/Public Works calibration. NOTE: Oxygen alarm point calibration for all instruments with 19.5% by volume oxygen alarm points (which includes Below Ground/Public Works and Petrochemical Calibrations) is described in section 4.2.3 of this manual.

MATERIALS:

- -- digital voltmeter (or a high quality volt-ohm meter). A digital voltmeter is available from ENMET; part #73800-001.
- -- cylinder of compressed air containing 20% LEL methane* (ENMET part #03220-020).
- -- cylinder of compressed air containing 50% LEL methane* (ENMET part #03220-050)
- -- cylinder of compressed air containing 50 ppm carbon monoxide* (CO) (ENMET part #03219-050). Note: 50 ppm CO is also a correlation gas for 10 ppm hydrogen sulfide (that is, 50 ppm CO causes the same instrument response as 10 ppm hydrogen sulfide).
- -- cylinder of compressed air containing 300 ppm carbon monoxide* (ENMET part #03219-300). Note: 300 ppm CO is a correlation gas for 50 ppm hydrogen sulfide.
- -- calibration regulator assembly* (CGS-100: ENMET part number 03700-003; CGS-100SP: ENMET part #03700-007) including humidifier, regulator and tubing
- -- clean water
- -- small screwdriver, flat heat
- -- medium screwdriver, phillips head
- -- fully charged CGS-100 (or CGS-100SP) with Below Ground/Public Works Calibration

* Items marked with an asterisk (*) are available as calibration kits for Below Ground/Public Works Calibration. The CGS-100 calibration kit is ENMET part #04800-124. The CGS-100SP calibration kit is ENMET part #04800-173.

4.2.1 Below Ground/Public Works Calibration: Calibrating Toxic and Combustible Alarm Points (continued)

PROCEDURE:

1. Lay the instrument flat on a stable surface. Remove the 8 cover-retaining screws (phillips head) from the yellow cover of the instrument. Pull the yellow cover off the body of the instrument.

2. Pull the ON/OFF Switch away from its base and set it to the ON position. Purge the instrument for 10 minutes. The Purge switch can be kept in the Purge position by doubling over the tubing from the calibration regulator assembly and setting it underneath the switch.

3. After purging, allow sensors to stabilize for 6 minutes.

4. Check the sensor heater voltages.

   CGS-100: Refer to Fig. 8.

   a) Remove the 4 screws of the sensor module cover. Pull the cover off. Insert the positive lead of the voltmeter into the Toxic Testpoint of the sensor circuitboard. Insert the negative lead of the voltmeter into the Ground Testpoint of the sensor circuitboard. The voltage should be 4.25 vdc + or - 0.05 vdc. If the voltage is not in this range, use the small screwdriver to adjust the screw in the Toxic Potentiometer on the sensor circuitboard until the correct reading is gained. Adjust this potentiometer clockwise to increase, counterclockwise to decrease the voltage.

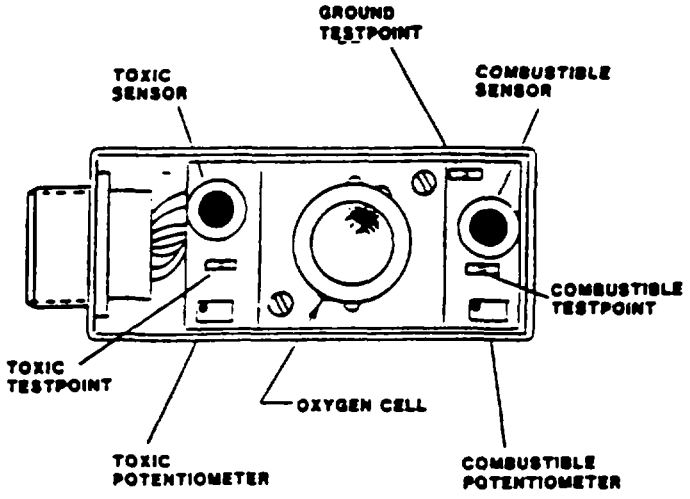
   b) Now insert the positive lead of the voltmeter into the Combustible Testpoint (leave the negative lead in the Ground Testpoint). The voltage should now read 5.0 vdc + or - 0.05 vdc. If the voltage is not in this range, adjusted the Combustible Potentiometer to gain the correct reading (adjust this potentiometer cw to increase, ccw to decrease the voltage).

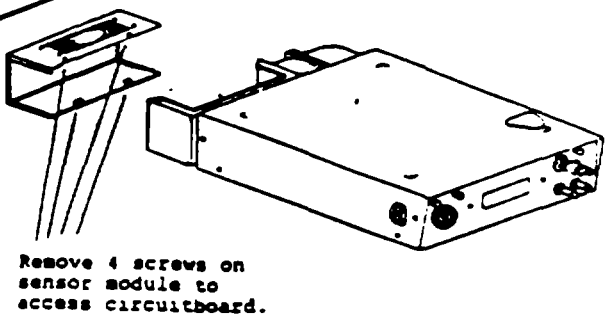
   NOTE: If the voltages cannot be adjusted to the correct values, replace the corresponding toxic or combustible MOS sensor(s). See section 4.4.1 or 4.4.2. to replace.

   CGS-100SP: Refer to Fig. 8.

   a) Remove the sample tubing connector from the hydrophobic filter intake tubing connector (see Fig. 10). Re-

FIGURE 8: Location of Test Points, Potentiometers for Sensor Heater Voltage Adjustment

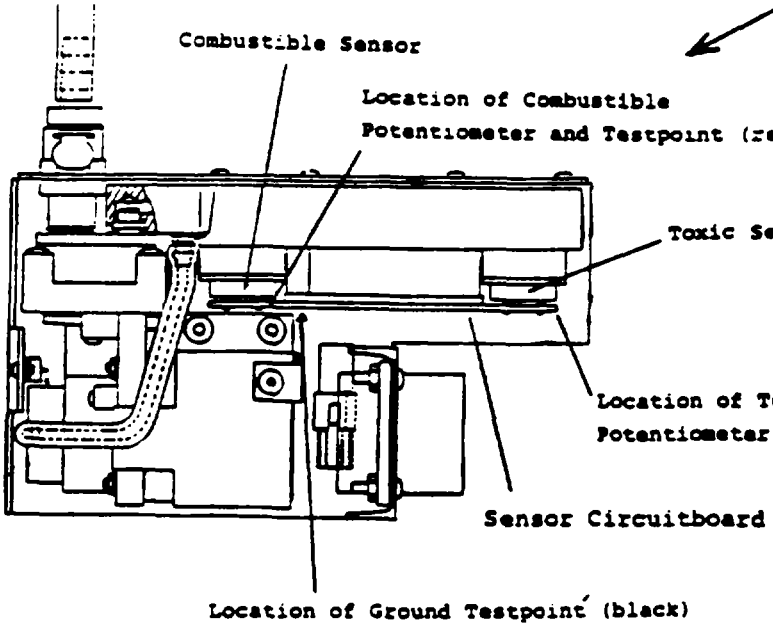


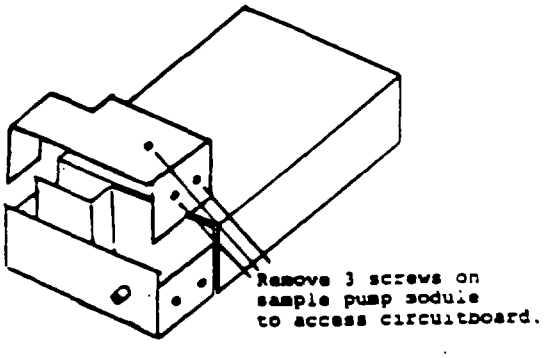


CGS-100 SENSOR MODULE (cover removed)

Potentiometer	To Increase Voltage, Turn Potentiometer:
TOXIC Sensor Heater	Clockwise
COMB Heater Voltage	Clockwise

CGS-100SP SAMPLE PUMP MODULE (cover removed)





4.2.1 Below Ground/Public Works Calibration: Calibrating Toxic and Combustible Alarm Points (continued)

move three screws on the sample pump module cover (see Fig. 8) to access the CAL/READ Switch (see Fig. 8). Set the CAL/READ switch in the CAL position.

b) Locate the sensor circuitboard (see Fig. 8). Insert the positive voltmeter lead into the Toxic Testpoint of the sensor circuitboard. Insert the negative voltmeter lead into the Ground Testpoint of the sensor circuitboard. The voltage on the voltmeter should be 4.25 vdc + or - 0.05 vdc. If the voltage is not in this range, use the small screwdriver to adjust the screw in the toxic potentiometer until the correct reading is gained (adjust this potentiometer clockwise to increase, counterclockwise to decrease the voltage).

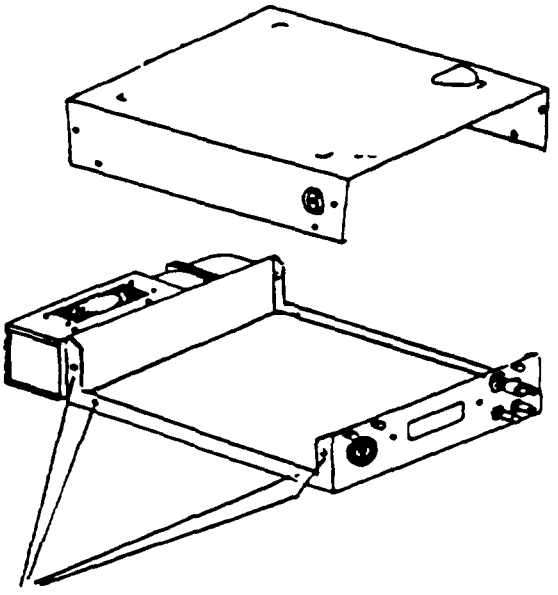
c) Now insert the positive lead of the voltmeter into the Combustible Testpoint (leave the negative lead in the ground testpoint). The voltage should now read 5.0 vdc + or - 0.05 vdc. If the voltage is not in this range, adjust the Combustible Potentiometer to gain the correct reading (adjust this potentiometer clockwise to increase, counterclockwise to decrease the voltage).

NOTE: If these voltages cannot be adjusted to the required values, replace the corresponding (toxic or combustible) MOS sensor(s). See section 4.4.1 or 4.4.2 to replace.

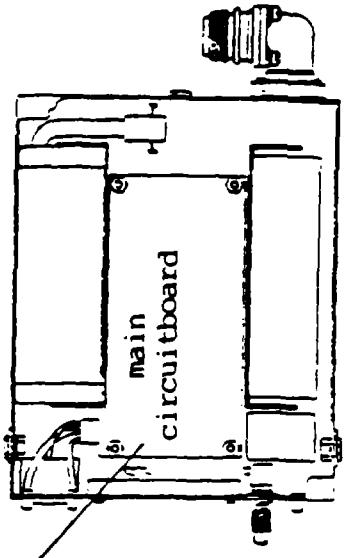
NOTE: If easier access to CGS-100SP sensor circuitboard testpoints and potentiometers is desired, it is possible to remove the sensor circuitboard. See section 4.4.2 (CGS-100SP Sensing Element Replacement Procedure) for sample pump module disassembly instructions.

5. In the body of the instrument, locate the calibration switch on the main circuitboard of the CGS-100 (or CGS-100SP). It is situated on the top circuitboard (see Figure 9), and is directly behind the LCD on the front of the instrument. Place the switch in the toxic calibration position (move it to the left). The red LED next to T1, T2 and T3 (see Fig. 9) should activate. This indicates that the instrument is ready for toxic calibration. Also, one of the yellow LEDs directly beneath the red LED should be on. NOTE: When the calibration switch is in the toxic or combustible position, the audio alarm is automatically silenced.

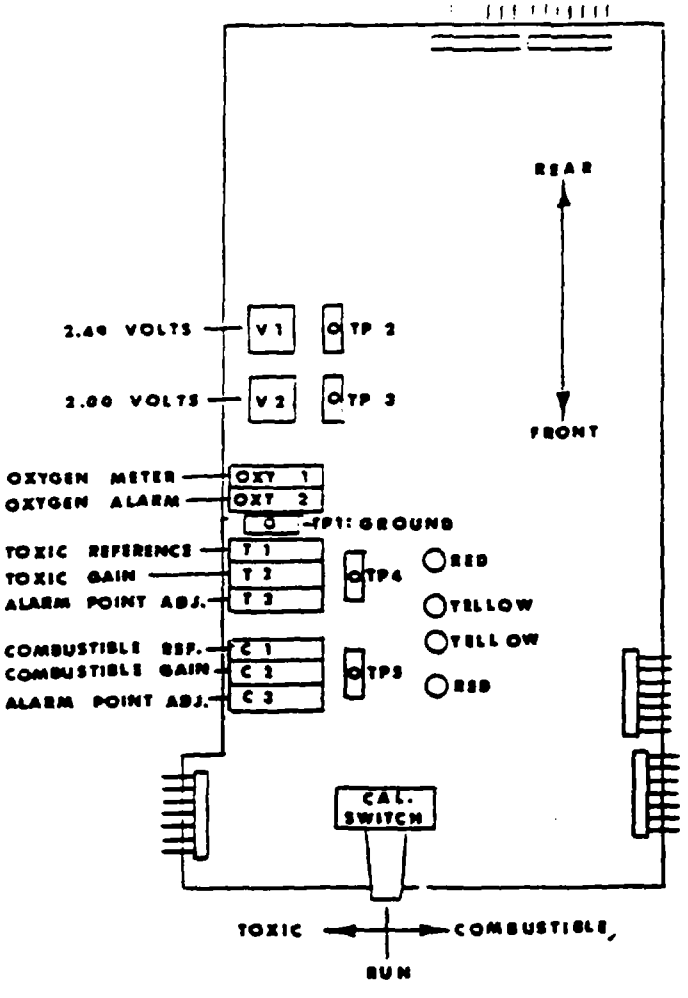
6. Insert the positive lead of of the voltmeter into TP4 on the main circuitboard. Insert the negative lead of the volt-



Remove 8 screws (4 this side, 4 other side) to remove body cover and access circuitboard.



Top View of CGS-100 Instrument Body, Cover Removed



CIRCUIT BOARD CONFIGURATION CGS-100 & CGS-100SP

Potentiometer	To Increase Voltage, Turn Potentiometer:
V1	Clockwise
V2	Clockwise
OXY 1	Clockwise
OXY 2	Counterclockwise
T1	Clockwise
T2	Clockwise
T3	Counterclockwise
C1	Clockwise
C2	Clockwise
C3	Counterclockwise

FIGURE 9: Main Circuit-board of Unit

4.2.1 Below Ground/Public Works Calibration: Calibrating Toxic and Combustible Alarm Points (continued)

meter into TP1. The voltage must be 4.75 vdc + or - 0.05 vdc. If necessary, adjust potentiometer T1 to gain the required reading (adjust this potentiometer clockwise to increase, counterclockwise to decrease the voltage).

7. Insert the positive lead of the voltmeter into TP5. Insert the negative lead of the voltmeter into TP1. The voltage must be 4.75 vdc + or - 0.05 vdc. If necessary, adjust potentiometer C1 (see Fig. 9) to gain the required reading (adjust this potentiometer clockwise to increase, counterclockwise to decrease the voltage).

8. Prepare the calibration regulator assembly by unscrewing the humidifier bottle of the assembly. Fill bottle halfway with water and replace onto assembly. Be careful not to tip the assembly; if water runs into the gas supply line, it could eventually reach the sensors during calibration and cause damage.

9. Make sure the regulator of the assembly is in the OFF position. Attach the calibration regulator assembly to the the gas cylinder containing 300 ppm CO. Set the humidifier/flowmeter upright on a level surface.

10. Open the regulator valve slowly in order to provide 0.9 - 1.1 scfh (standard cubic feet/hour) flow through the flowmeter on the assembly. Do not allow the gas to flow so fast as to force water into gas supply line leading to sensors.

11. CGS-100: Place the sensor cover of the calibration regulator assembly over the sensor module of the instrument (see Fig. 10).

    CGS-100: Insert the calibration regulator tubing connector into the hydrophobic filter intake tubing connector until the connectors snap into place (see Fig. 10).

12. Allow the gas to flow for 3 minutes. Then, slowly adjust potentiometer T2 (on the main circuitboard; see Fig. 9) clockwise until the second yellow LED on the main circuitboard (near T1, T2 and T3 -- see Fig. 9) just barely activates. This adjusts the full scale mark on the toxic bargraph of the LCD to the correct reading. NOTE: If the second yellow LED was already on before the potentiometer adjustment was made, adjust potentiometer T2 counterclockwise until the LED turns off, then readjust clockwise until the LED just barely comes on again. Be precise.

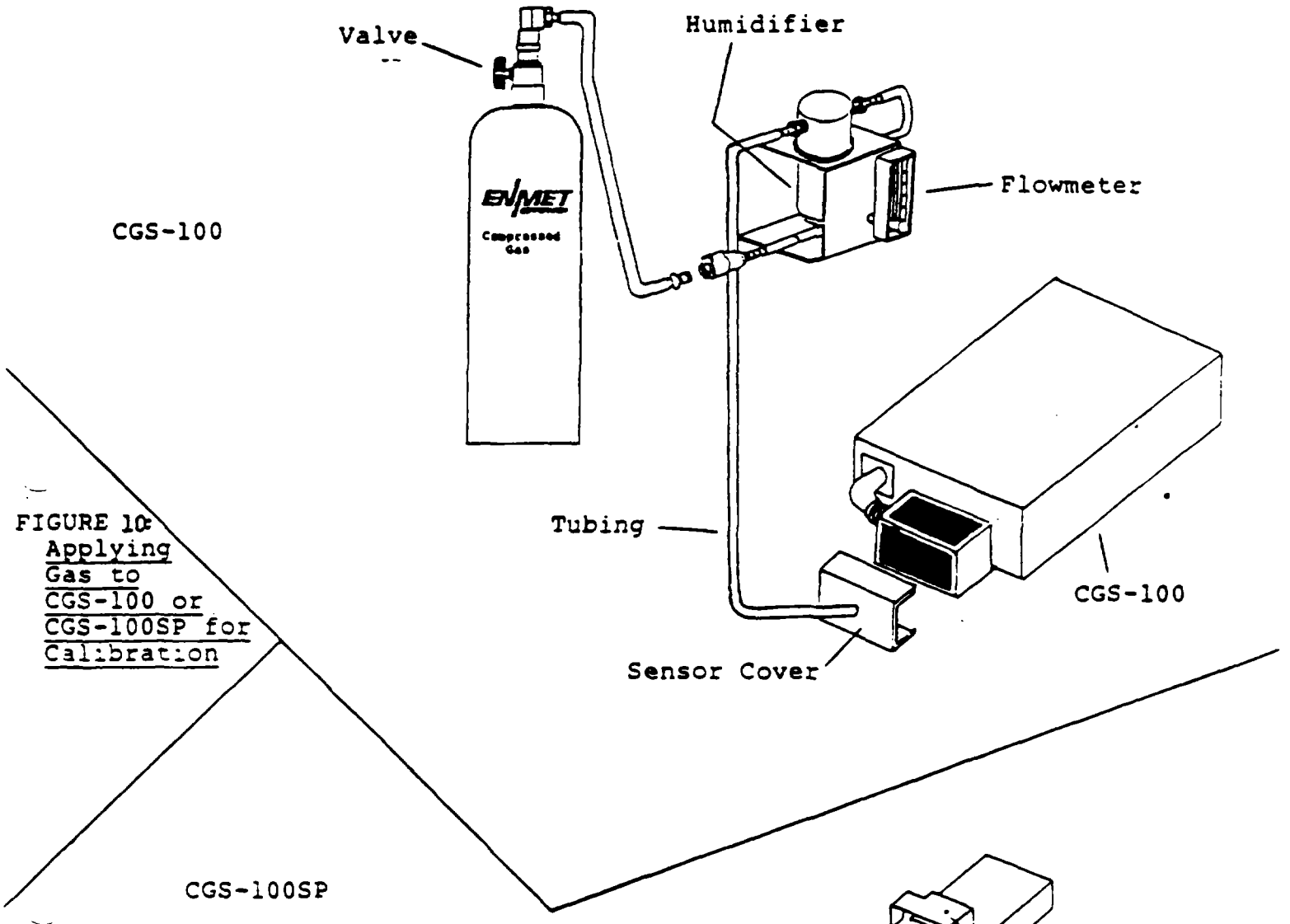
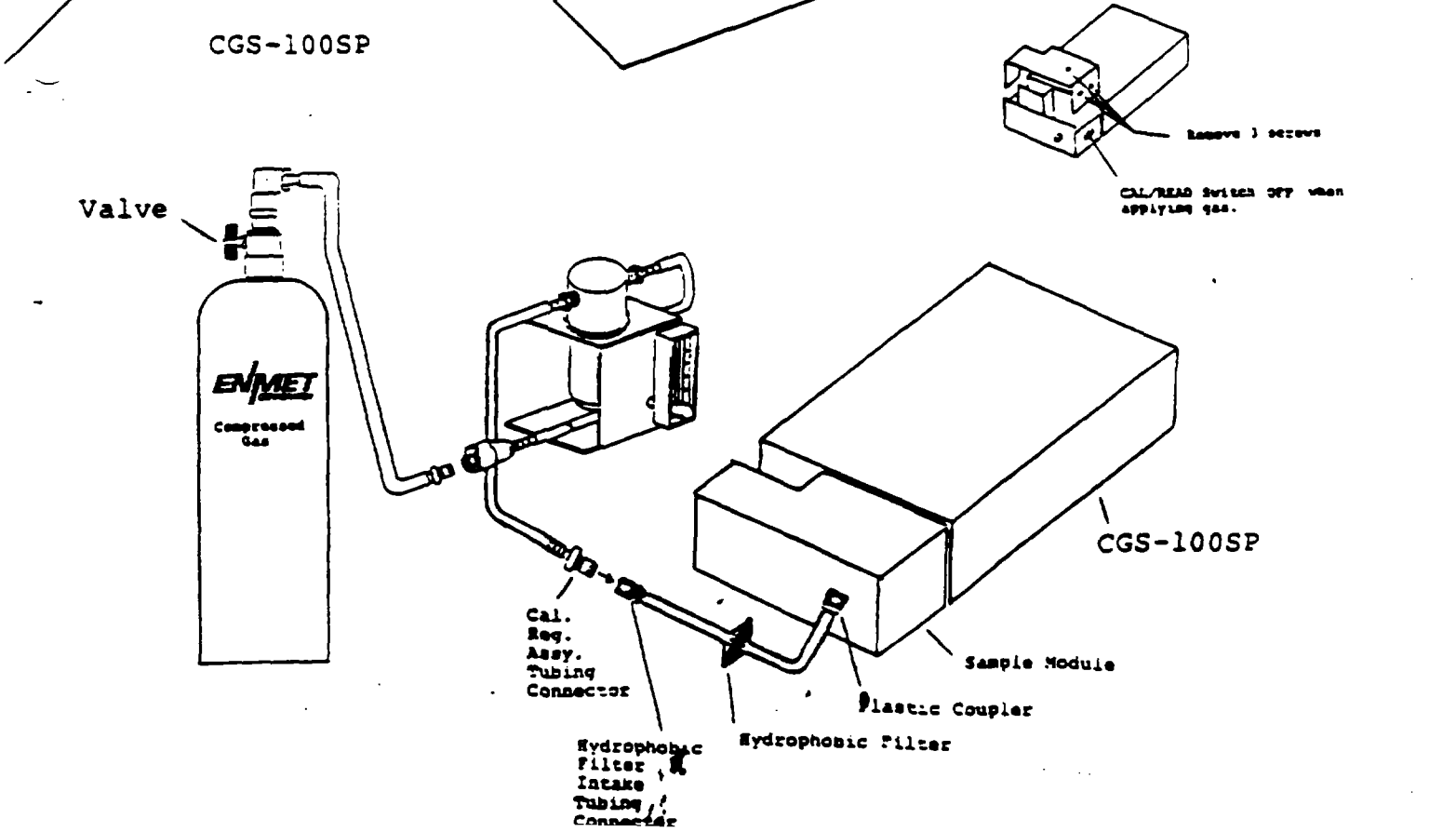


FIGURE 10: Applying Gas to CGS-100 or CGS-100SP for Calibration



4.2.1 Below Ground/Public Works Calibration: Calibrating Toxic and Combustible Alarm Points (continued)

13. CGS-100: Remove the calibration assembly sensor cover from the instrument. Turn off the gas.

    CGS-100SP: Disconnect the calibration assembly tubing connector from the hydrophobic filter intake tubing connector. Turn off the gas.

14. Allow the sensors to recover for 10 minutes. NOTE: On CGS-100SP, switch the CAL/READ Switch to the READ position. Allow the pump to operate for 10 minutes to clear the sensors, and then set switch back to CAL.

15. Being careful not to tilt the humidifier, remove the calibration regulator assembly from the cylinder of 300 ppm CO, and attach it to the cylinder of 50 ppm CO. Set the humidifier/flowmeter assembly upright on a level surface.

16. Repeat steps 9 and 10 in order.

17. Allow the gas to flow for 3 minutes. Then adjust potentiometer T3 (on the main circuitboard; see Fig. 9) until the toxic bargraph (PPM) on the LCD shows the proper concentration (10 ppm for Below Ground/Public Works calibration, since 50 ppm CO is a correlation gas for 10 ppm hydrogen sulfide). Adjust this potentiometer counterclockwise to increase, clockwise to decrease the meter reading. The red Gas Alarm LED on the display face of the instrument should activate when the meter is set to the alarm point.

18. Repeat step 13.

19. Now, move the calibration switch (referred to in step 5) to the combustible calibration position (to the right). The red LED next to C1, C2 and C3 on the main circuitboard (see Fig. 9) should activate. This indicates that the combustible sensor and circuitry are ready for calibration. One of the yellow LEDs on the main circuitboard should also be on.

20. Attach the calibration regulator assembly to the cylinder of 50% LEL methane. Set the humidifier/flowmeter assembly upright on a level surface.

21. Repeat steps 9-10 in order.

22. After 1 minute of gas flow, slowly adjust potentiometer C2 (see Fig. 9) clockwise until the second yellow LED on the main circuitboard just barely activates. NOTE: If the second yellow LED is already on before the potentiometer is

4.2.1 Below Ground/Public Works Calibration: Calibrating Toxic and Combustible Alarm Points (continued)

adjusted, adjust potentiometer C2 counterclockwise until the LED turns off, then readjust the potentiometer clockwise until the LED just barely activates. Be precise.

23. Repeat steps 12 and 13 in order.

24. Attach the calibration regulator assembly to the cylinder of 20% LEL methane (again, be careful not to tilt the humidifier). Set the humidifier/flowmeter upright on a level surface.

25. Repeat steps 9-10 in order.

26. Allow the gas to flow over the sensor for 1 minute. Then adjust potentiometer C3 on the main circuitboard (see Fig. 9) until the combustible gas bargraph on the LCD (%LEL) indicates the proper alarm point (20% LEL methane for Below Ground/Public Works calibration). Adjust this potentiometer counterclockwise to increase, clockwise to decrease the meter reading.

27. Repeat step 12.

28. Return the calibration switch (referred to in step 5; also see Fig. 9) to the RUN position (center position). Do not replace yellow instrument housing cover if oxygen calibration procedures are to be performed.

29. Toxic and combustible calibration is complete. NOTE: Set the CAL/READ Switch of the CGS-100SP to READ.

4.2.2 Petrochemical Calibration: Calibrating the Toxic and Combustible Alarm Points

As a result of the Petrochemical Calibration, the gases used to calibrate the instrument are different from those used in Below Ground/Public Works calibration; in addition, the sensor heater voltages for the MOS sensors are different from those used for Below Ground/Public Works calibration. Both the gases and sensor heater voltages used in the Petrochemical Calibration are specified below. No parts in the instrument have been changed.

Please note that Toxic and Combustible Field Tests (as described in section 3.0) have not been established for an instrument with Petrochemical Calibration (Oxygen Field Test in section 3.2 does apply). To maintain toxic and combustible detection accuracy of the CGS-100 or CGS-100SP with Petrochemical Calibration, these

4.2.2 Petrochemical Calibration: Calibrating the Toxic and Combustible Alarm Points (continued)

instrument responses must be calibrated periodically. For instruments used on a regular basis, checking calibration monthly is considered appropriate.

MATERIALS:

- -- digital voltmeter (or a high quality volt-ohm meter). A digital voltmeter is available from ENMET; part #73800-001.
- -- cylinder of compressed air containing 20% LEL propane* (ENMET part #03221-020).
- -- cylinder of compressed air containing 50% LEL propane* (ENMET part #03221-050).
- -- cylinder of compressed air containing 100 ppm methyl chloride* (ENMET part #03281-100).
- -- cylinder of compressed air containing 300 ppm methyl chloride* (ENMET part #03281-300).
- -- calibration regulator assembly* (CGS-100: ENMET part number 03700-003; CGS-100SP: ENMET part #03700-007) including humidifier, regulator and tubing.
- -- clean water
- -- small screwdriver, flat heat
- -- medium screwdriver, phillips head
- -- fully charged CGS-100 (or CGS-100SP) with Petrochemical Calibration

* Items marked with an asterisk (*) are available as a calibration kit for Below Ground/Public Works Calibration. For a CGS-100, the calibration kit is ENMET part #04800-128. For a CGS-100SP, the calibration kit is ENMET part #04800-175.

PROCEDURE:

1. Lay the instrument flat on a stable surface. Remove the 8 cover-retaining screws (phillips head) from the yellow cover of the instrument. Pull the yellow cover off the body of the instrument.

4.2.2 Petrochemical Calibration: Calibrating the Toxic and Combustible Alarm Points (continued)

2. Pull the ON/OFF Switch away from its base and set it to the ON position.

3. Allow sensors to stabilize for 6 minutes.

4. Check the sensor heater voltages.

CGS-100:

a) Remove the 4 screws of the sensor module cover. Lift the cover off.

b) Insert the positive lead of the voltmeter into the Toxic Testpoint of the sensor circuitboard. Insert the negative lead of the voltmeter into the Ground Testpoint of the sensor circuitboard. The voltage should be 5.00 vdc + or - 0.05 vdc. If the voltage is not in this range, use the small screwdriver to adjust the screw in the Toxic Potentiometer on the sensor circuitboard until the correct reading is gained (adjust this potentiometer clockwise to increase, counterclockwise to decrease the voltage).

c) Now insert the positive lead of the voltmeter into the Combustible Testpoint (leave the negative lead in the Ground Testpoint). The voltage should also read 5.0 vdc + or - 0.05 vdc. If the voltage is not in this range, adjust the Combustible Potentiometer to gain the correct reading (adjust this potentiometer clockwise to increase, counterclockwise to decrease the voltage).

NOTE: If the above voltages cannot be adjusted to the correct values, replace the corresponding toxic or combustible MOS sensor(s). See section 4.4 for sensor replacement.

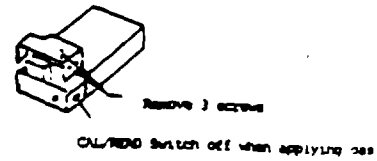
CGS-100SP:

a) Remove the sample tubing connector from the hydrophobic filter intake tubing connector (see Fig. 11). Remove three screws on the sample pump module cover to access the CAL/READ Switch (see Fig. 11). Set the CAL/READ switch in the CAL position.

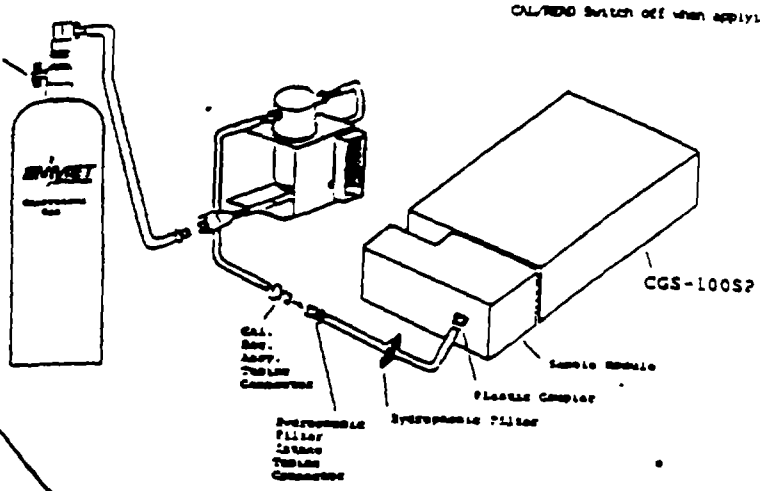
b) Locate the sensor circuitboard (see Fig. 11). Insert the positive voltmeter lead into the Toxic Testpoint of the sensor circuitboard. Insert the negative voltmeter lead into the Ground Testpoint of the sensor circuit-

FIGURE 11 : Checking Sensor Heater Voltage, Applying Gas to CGS-100 or CGS-100SP for Petrochemical Calibration

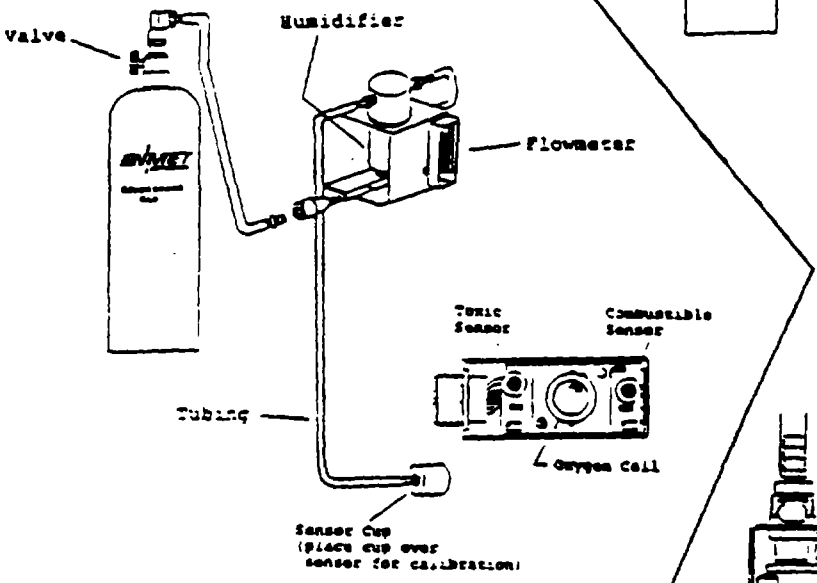
CGS-100SP

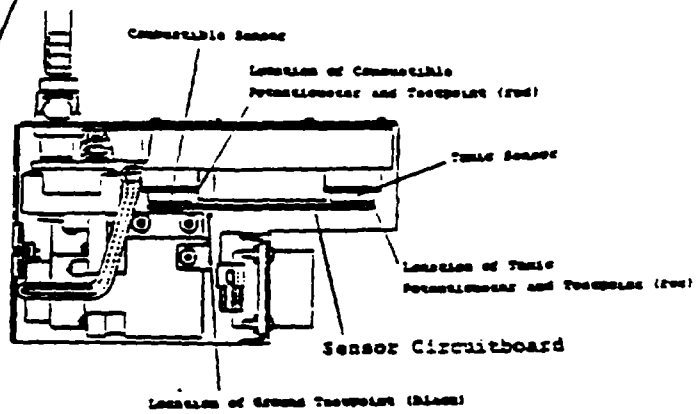


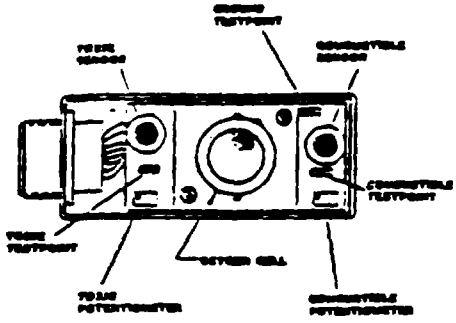
CAL/READ Switch off when applying gas



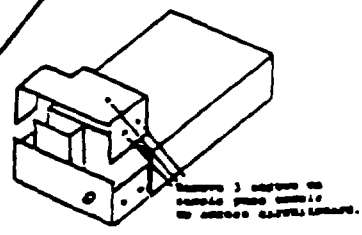
CGS-100

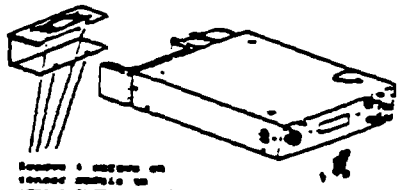






Potentiometer	To Increase Voltage, Turn Potentiometer:
TOXIC Sensor Heater	Clockwise
COMB Heater Voltage	Clockwise





4.2.2 Petrochemical Calibration: Calibrating the Toxic and Combustible Alarm Points (continued)

board. The voltage on the voltmeter should be 5.00 vdc + or - 0.05 vdc. If the voltage is not in this range, use the small screwdriver to adjust the screw in the Toxic Potentiometer until the correct reading is gained (adjust this potentiometer clockwise to increase, counterclockwise to decrease the voltage).

c) Now insert the positive lead of the voltmeter into the Combustible Testpoint (leave the negative lead in the ground testpoint). The voltage should now read 5.0 vdc + or - 0.05 vdc. If the voltage is not in this range, adjust the Combustible Potentiometer to gain the correct reading (adjust this potentiometer clockwise to increase, counterclockwise to decrease the voltage).

NOTE: If these voltages cannot be adjusted to the required values, replace the corresponding toxic or combustible MOS sensor(s).

NOTE: If easier access to CGS-100SP sensor circuitboard testpoints and potentiometers is desired, it is possible to remove the sensor circuitboard. See section 4.4.2 (CGS-100SP Sensing Element Replacement) for sample pump module disassembly instructions.

5. In the body of the instrument, locate the calibration switch on the main circuitboard of the CGS-100 (or CGS-100SP). It is situated on the top circuitboard (see Figure 9), and is located directly behind the LCD on the front of the instrument. Place the switch in the toxic calibration position (move it to the left). The red LED next to T1, T2 and T3 (see Fig. 9) should activate. This indicates that the instrument is ready for toxic calibration. Also, one of the yellow LEDs directly beneath the red LED should be on. NOTE: When the calibration switch is in the toxic or combustible position, the audio alarm is automatically silenced.

6. Insert the positive lead of of the voltmeter into TP4 on the main circuitboard. Insert the negative lead of the voltmeter into TP1. the voltage must be 4.75 vdc + or - 0.05 vdc. If necessary, adjust potentiometer T1 (see Fig. 9) to gain the required reading (adjust this potentiometer clockwise to increase, counterclockwise to decrease the voltage).

7. Insert the positive lead of the voltmeter into TP5. Insert the negative lead of the voltmeter into TP1. The voltage must be 4.75 vdc + or - 0.05 vdc. If necessary, adjust

4.2.2 Petrochemical Calibration: Calibrating the Toxic and Combustible Alarm Points (continued)

potentiometer C1 (see Fig. 9) to gain the required reading (adjust this potentiometer clockwise to increase, counterclockwise to decrease the voltage).

8. Prepare the calibration regulator assembly by unscrewing the humidifier bottle of the assembly. Fill bottle halfway with water and replace onto assembly. Be careful not to tip the assembly; if water runs into the gas supply line, it could eventually reach the sensors during calibration and cause damage. NOTE: For CGS-100, attach plastic sensor cup to calibration assembly to isolate sensor exposure to gas (see Fig. 11).

9. Make sure the regulator of the assembly is in the OFF position. Then attach the calibration regulator assembly to the cylinder containing the gas cylinder containing 300 ppm methyl chloride. Set the humidifier/flowmeter assembly upright on a level surface.

10. Open the regulator valve slowly in order to provide 0.5 scfh (standard cubic feet/hour) flow through the flowmeter on the assembly. Do not allow the gas to flow so fast as to force water into gas supply line leading to sensors.

11. CGS-100: Place the sensor cup of the calibration fixture over the appropriate sensor (see Fig. 11).

    CGS-100SP: Insert the calibration regulator assembly tubing connector into the hydrophobic filter intake tubing connector until the two connectors snap into place (see Fig. 11).

12. Allow the gas to flow for 3-5 minutes. Then, slowly adjust potentiometer T2 (see Fig. 9) clockwise until the second yellow LED on the main circuitboard (near T1, T2 and T3 -- see Fig. 9) just barely activates. This adjusts the full scale mark on the toxic bargraph of the LCD to the correct reading. NOTE: If the second yellow LED was already on before the potentiometer adjustment was made, adjust potentiometer T2 counterclockwise until the LED turns off, then readjust clockwise until the LED just barely comes on again. Be as precise as possible.

13. CGS-100: Remove the calibration assembly cup from the sensor. Turn off the gas.

    CGS-100SP: Remove the calibration assembly tubing connector from the hydrophobic filter tubing connector.

4.2.2 Petrochemical Calibration: Calibrating the Toxic and Combustible Alarm Points (continued)

14. Allow the sensors to recover for 10 minutes. NOTE: On CGS-100SP, switch the CAL/READ Switch to the READ position. Allow the pump to operate for 10 minutes to clear the sensors, and then set switch back to CAL.

15. Being careful not to tilt the humidifier, remove the calibration regulator assembly from the cylinder of 300 ppm methyl chloride, and attach it to the cylinder of 100 ppm methyl chloride. Set the humidifier/flowmeter assembly upright on a level surface.

16. Repeat steps 9 and 10 in order.

17. Allow the gas to flow for 3-5 minutes. Then adjust potentiometer T3 (see Fig. 9) until the toxic bargraph (PPM) on the LCD shows the proper concentration (it should read at "100" for Petrochemical Calibration). The red Gas Alarm LED on the display face of the instrument should activate. NOTE: Adjust this potentiometer counterclockwise to increase, clockwise to decrease the meter reading.

18. Repeat step 13.

19. Now, move the calibration switch (referred to in step 5) to the combustible calibration position (to the right). The red LED next to C1, C2 and C3 on the main circuitboard (see Fig. 9) should activate. This indicates that the combustible sensor and circuitry are ready for calibration. One of the yellow LEDs on the main circuitboard should also be on.

20. Attach the calibration regulator assembly to the cylinder containing 50% LEL propane. Set the flowmeter/humidifier assembly upright on a level surface.

21. Repeat steps 9-10 in order.

22. After 1.5 - 2.0 minutes of gas flow, slowly adjust potentiometer C2 (see Fig. 9) clockwise until the second yellow LED on the main circuitboard just barely activates. NOTE: If the second yellow LED was already on before the potentiometer was adjusted, adjust potentiometer C2 counterclockwise until the LED turns off, then readjust the potentiometer clockwise until the LED just barely activates. Be as precise as possible.

23. Repeat steps 12 and 13 in order.

4.2.2 Petrochemical Calibration: Calibrating the Toxic and Combustible Alarm Points (continued)

24. Attach the calibration regulator assembly to the cylinder of 20% LEL propane (be careful not to tilt the humidifier). Set the flowmeter/humidifier assembly upright on a level surface.

25. Repeat steps 9-10 in order.

26. Allow the gas to flow over the sensor for 1.5 - 2.0 minutes. Then adjust potentiometer C3 on the main circuitboard (see Fig. 9) until the combustible gas bargraph on the LCD (%LEL) indicates the correct alarm point (20% LEL propane for Petrochemical Calibration). Adjust potentiometer C3 counterclockwise to increase, clockwise to decrease the meter reading.

27. Repeat step 12.

28. Return the calibration switch (referred to in step 5; also see Fig. 9) to the :N position (center position). Do not replace yellow instrument housing cover if oxygen calibration procedures are to be performed.

29. Toxic and combustible calibration is complete. NOTE: CGS-100SP CAL/READ Switch must be returned to READ position.

4.2.3 Oxygen Alarm Point Calibration

This section describes oxygen alarm point calibration for instruments with a 19.5% by volume oxygen alarm point. The calibration procedure in this section applies to instruments with Below Ground/Public Works Calibration and Petrochemical Calibration. Note: This procedure must be performed in clean air.

Normally, the oxygen alarm point remains accurate for the life of the oxygen cell. Thus, the only time oxygen alarm point calibration is usually necessary is when the oxygen cell is replaced. However, if an instrument does not respond properly to the Oxygen Field Test, the oxygen alarm point should be recalibrated. In addition, if an oxygen circuit potentiometer is inadvertently adjusted, the oxygen alarm point should be calibrated for safety.

MATERIALS:

-- small screwdriver, flat head

-- medium screwdriver, phillips head

4.2.3 Oxygen Alarm Point Calibration (continued)

PROCEDURE:

Note: Instrument must operate for at least 15 minutes before oxygen calibration procedure is performed. If oxygen calibration is performed immediately following toxic and combustible calibration, this requirement has been fulfilled.

1. Remove yellow instrument body cover (8 screws) and set calibration switch (see Fig. 8) in the RUN position.

2. CGS-100SP only: Set the CAL/READ Switch to the READ position (see Fig. 8 to determine which screws on the sample pump module require removal for access to switch).

3. Locate the main circuitboard of the instrument (see Fig. 9). Insert the positive lead of the voltmeter into TP2. Insert the negative lead of the voltmeter into TP1. The voltage should be 2.49 vdc + or - 0.05 vdc. If necessary, adjust the small screw in potentiometer V1 to gain the required voltage.

4. Now insert the positive lead of the voltmeter into TP3 (leave the negative lead in TP1). The voltage should now be 2.00 vdc + or - 0.05 vdc. If necessary, adjust potentiometer V2 to gain the required voltage.

5. Push in the Push To Set Oxygen Knob and turn counterclockwise all the way, until the knob will not turn any farther.

6. On the main circuitboard, adjust potentiometer OXY 1 so the Digital Oxygen Display on the LCD reads 17.0.

7. Now, use the Push To Set Oxygen Knob to test the accuracy of the oxygen alarm point calibration. Push the knob in and turn until the Digital Oxygen Display on the LCD reads at 20. Then slowly dial the display down and verify that the oxygen alarm signals (steady audio tone, steady red Gas Alarm LED) activate when the display reads between 19.4 - 19.6. If the oxygen alarm signals do not activate within this range (19.4 - 19.6), adjust the Push To Set Oxygen Knob until the Digital Oxygen Display reads 19.5. Then adjust potentiometer OXY 2 (see Fig. 9) counterclockwise until the oxygen alarm signals just barely activate at this point. NOTE: If oxygen alarm signals are already on before the potentiometer adjustment is made, adjust OXY 2 clockwise until the alarm signals stop, then readjust OXY 2 counterclockwise until the alarm signals just barely activate.

4.2.3 Oxygen Alarm Point Calibration (continued)

8. Using the Push to Set Oxygen knob, set the Digital Oxygen Display to read 20.9. Oxygen calibration is complete.

9. Make sure the calibration switch (see Fig. 9) is in the RUN position. Replace the instrument housing cover (8 screws). The CGS-100 is ready for operation. NOTE: CGS-100SP -- Replace sample pump module cover (3 screws -- see Fig. 8 for location). Instrument is now ready for operation.

4.3 Weekly Exercise for Seldom-Used Instruments

If the CGS-100 or CGS-100SP is used once or twice a month (or less frequently), perform a weekly exercise to keep the sensor clean and the batteries in good condition. Although the batteries typically have 75% of capacity remaining when they have been stored for 30 days without being used or charged, a weekly operation exercise and recharging will keep the unit fully functional.

Perform the following once a week on infrequently used instruments:

1. Pull the ON/OFF Switch away from its base, and set it in the ON position.

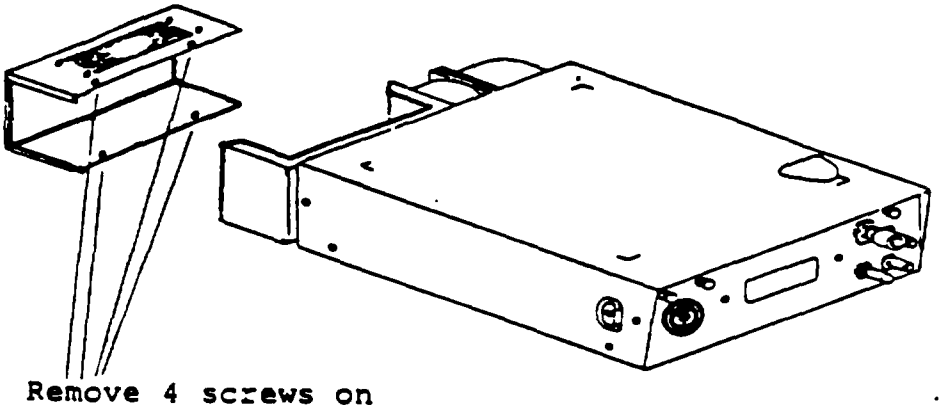
2. Allow the instrument to operate for 8 hours.

3. Turn the instrument off and recharge overnight (12-16 hours).

NOTE: Make sure the on-off switch is in the off position whenever recharging the instrument. Also, do not charge the instrument for more than 72 hours.

4.4 Sensing Element Replacement (continued)

Due to the configuration of the sensor module and sample pump module of the CGS-100 and CGS-100SP respectively, a separate procedure is required for sensing element replacement for each instrument. Be sure to consult the designated procedure for your instrument. IMPORTANT: Be sure to calibrate the instrument after replacing a sensing element.



Remove 4 screws on sensor module to access.

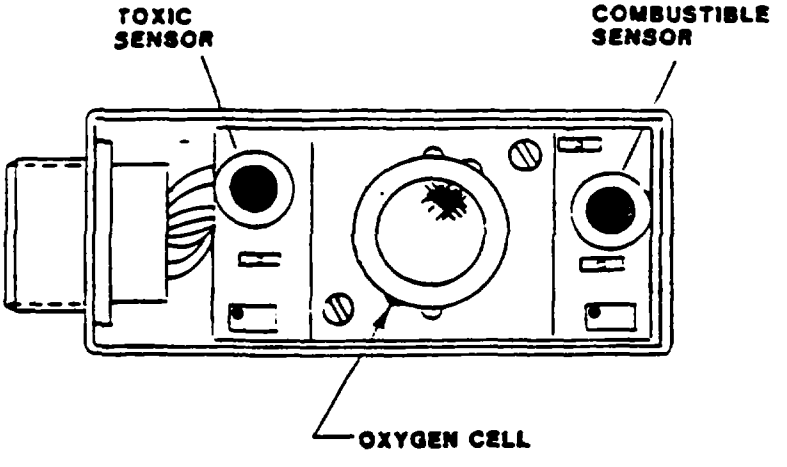


FIGURE 12: CGS-100 Sensing Element Replacement

4.4.1 CGS-100 Sensing Element Replacement

MOS Sensor: If the proper toxic or combustible sensor heater voltage for an MOS sensor cannot be obtained, the MOS sensor requires replacement. However, if an MOS sensor is replaced, the toxic and combustible responses of the instrument must be calibrated (see section 4.2 for calibration procedures).

Oxygen Cell: The oxygen cell should be replaced whenever the Digital Oxygen Display cannot be set to 20.9% in fresh air using the Push To Set Oxygen Knob. If the oxygen cell is replaced, the instrument should be recalibrated for oxygen response (see section 4.2.3).

IMPORTANT: If the oxygen cell is replaced, be careful to handle the cell only by its sides. A sensitive membrane covers the cell screen, and can be damaged easily if touched. In addition, to prevent depletion of the cell, keep the cell inside its airtight shipping package until it is ready to be used. The oxygen cell should be removed from its shipping package and allowed to adjust to ambient air for 4 hours before it is installed in the instrument.

MATERIALS:

-- small screwdriver (phillips head)

-- new sensing element (toxic MOS Sensor -- ENMET part number 03015-005; combustible MOS Sensor -- ENMET part number 03016-001; oxygen cell -- ENMET part number 67013-002).

PROCEDURE:

1. Make sure instrument is off. Remove the sensor module cover (4 screws) to access the MOS sensors and sensor circuitboard. Refer to Fig. 12.

2. Unplug the defective sensor or oxygen cell from the sensor circuitboard.

3. Plug in the new sensor or oxygen cell.

4. Proceed to section 4.2 of this manual to recalibrate the appropriate (toxic/combustible or oxygen) response. NOTE: Be sure to check ALL the MOS sensor heater voltages when calibrating.

4.4.2 CGS-100SP Sensing Element Replacement

Replacement of the sensing elements for this instrument requires the removal and disassembly of the sample pump module.

An MOS sensor should be replaced when the proper sensor heater voltage cannot be obtained. The oxygen cell must be replaced whenever the Digital Oxygen Display cannot be set to 20.9 in fresh air using the Push to Set Oxygen Knob. Whenever a sensor is replaced, the appropriate sensor circuitry should be recalibrated (see section 4.2).

When performing these procedures, it is helpful to situate the instrument and sample pump assembly so that the MS connector (Military Style connector -- large screw-on connection that attaches the sample pump assembly to the CGS-100) is in the far right hand corner as the instrument lays flat on the table and the display face of the instrument faces you. This procedure refers to right, left, bottom and top positions and are useful only if the instrument is situated properly. Refer to Fig. 13.

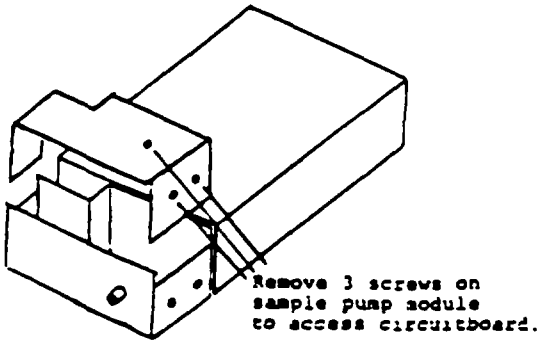
NOTE: When replacing an MOS sensor, make sure to check ALL the sensor heater voltages as described in the toxic and combustible alarm point calibration procedures (section 4.2.2 or 4.2.3.).

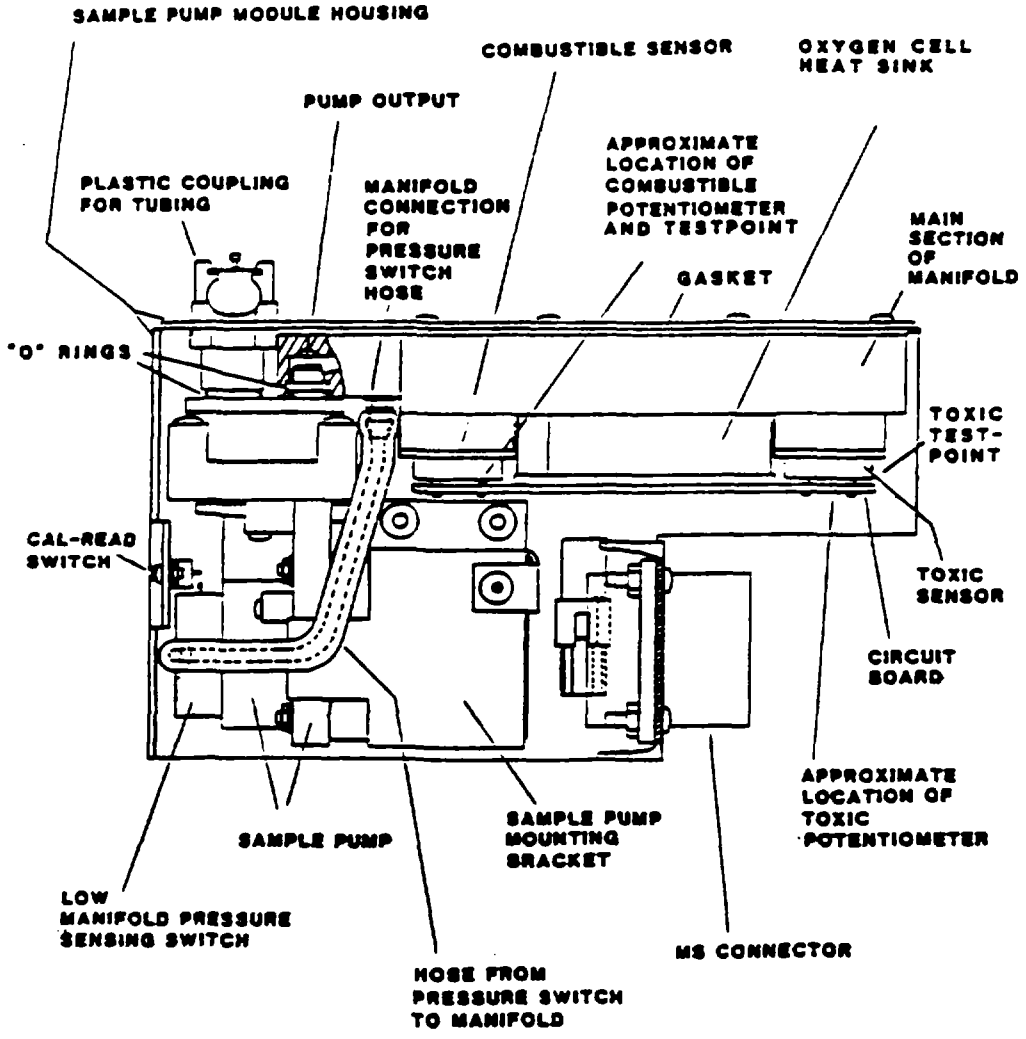
IMPORTANT: If the oxygen cell is replaced, be careful to handle the cell only by its sides. A sensitive membrane covers the cell screen, and can be damaged easily if touched. In addition, to prevent depletion of the cell, keep the cell inside its airtight shipping package until it is ready to be used. The oxygen cell should be removed from its shipping package and allowed to adjust to ambient air for 4 hours before it is installed in the instrument.

MATERIALS:

- -- small flat head screwdriver
- -- small phillips head screwdriver
- -- needle-nose pliers
- -- regular pliers
- -- new sensing elements (toxic MOS sensor -- ENMET part number 03015-005; combustible MOS sensor -- 03016-001; oxygen cell -- 67013-002)

FIGURE 13: CGS-100SP Sensing Element Replacement





4.4.2 CGS-100SP Sensing Element Replacement (cont.)

PROCEDURE:

1. Make sure the instrument is off (pull ON/OFF Switch away from its base and set into OFF position). Lay the instrument flat on a table so the display face of the unit is facing you.

2. Unscrew the MS connector (Military Style connector) to detach the sample pump module from the unit. Refer to Fig. 13.

3. Remove 3 screws on the yellow sample pump module housing (two on left side, one on top -- see Fig. 13).

4. Lift off the sample pump module cover. Refer to Fig. 14 for the rest of this procedure.

5. Remove the two screws for the pump bracket. These are next to each other on the bottom of the module.

6. Locate the short section of tubing leading from the pressure switch to the manifold. Pull off the end connected to the manifold.

7. Slowly pull the pump away from the plastic coupling and manifold until the pump intake and output ports are just free. DO NOT move the pump any farther, or the CAL/READ switch may be damaged. Instead, gently lift the pump out from the sample pump module.

8. Remove the MS connector from the sample pump module (4 bolts, 4 nuts, 4 lock washers).

9. Remove the 6 screws holding the manifold in place. These screws are on the outside of the sample pump module in the back (same side as plastic coupler for tubing).

10. Gently lift the manifold (2 pieces), gasket and sensor circuitboard out of the sample pump module.

11. Pull the manifold off of the circuitboard. Unplug the malfunctioning sensing element(s) and replace with new element(s). Note: The oxygen cell must be plugged in center pin to center hole for correct installation. Orientation of the MOS sensors does not matter as long as they are installed in the appropriate socket (toxic or combustible) of the circuitboard.

4.4.2 CGS-100SP Sensing Element Replacement (cont.)

12. Fit the circuitboard and sensing elements back into the manifold.

13. Place the manifold, gasket, circuitboard back into the sample pump module. Check to see if the gasket holes line up for the manifold screws, but do not replace the screws yet.

14. Put the MS connector back into place. Do not replace the bolts, nuts and washers yet.

15. Replace the screws for the manifold. Do not screw them down tightly; doing so may bend the sample pump module housing.

16. Replace the bolts, nuts and washers for the MS connector. It may be necessary to use the needle-nose pliers to get some of the nuts and washers into place.

17. Set the pump back into place so that it straddles the CAL/READ Switch. Make sure no wires are under pump or bracket. Then push it up into the receiving holes of the coupler and manifold. When the pump is in place, continue to push it up firmly while replacing the 2 screws for the pump bracket. This ensures a good seal for the pump intake and output ports.

18. Reattach the short hose from the pressure switch to the manifold; use the needle-nose pliers if necessary.

19. Set the CAL/READ Switch in the READ position.

20. Replace the sample pump module cover.

21. Reattach the sample pump module to the MS connector of the CGS-100 instrument.

22. Turn the CGS-100SP on (pull ON/OFF Switch away from its base and set it in the ON position). Place your finger over the plastic coupler (for sample tubing) on the sample pump module. If the connections inside the sample pump module are good, the sensor failure light on the CGS-100SP should go on. If the connections are loose, the pump will draw air through the loose connections, and the sensor failure light will not activate. If this happens, remove the sample pump module cover and check all the connections made during sensor replacement.

23. Proceed to section 4.2 and perform MOS Sensor and/or Oxygen Cell calibration procedures, depending upon which sensing element(s) was (were) replaced. NOTE: If performing MOS

4.4.2 CGS-100SP Sensing Element Replacement (cont.)

Sensor calibration procedures, make sure to calibrate both MOS sensors even if just one was replaced.

4.5 CGS-100SP Pump Diaphragm and Valve Replacement

The pump of the CGS-100SP utilizes a synthetic rubber diaphragm housed in a molded plastic assembly to draw air into the sample pump assembly of the CGS-100SP. Whenever the pump does not seem to be operating properly, this diaphragm should be checked. In addition, the molded plastic assembly which houses the pump diaphragm contains small flapper-type valves. These should be checked whenever the diaphragm is checked. If they are wearing out, the whole plastic assembly should be replaced. As routine maintenance, check the pump diaphragm and valves after 500 hours (approximately 3 months of daily use) of operation. To access the pump in the CGS-100SP, follow sensor replacement procedures for the CGS-100SP (section 4.4.2, steps 1-7). Pump diaphragm and valves are available from Brailsford & Co., Inc., 670-T Milton Rd., Rye, NY 10580 (phone 914-967-1820). Reference Brailsford Pump Model TD-3LL.

If for some reason the sample pump does not operate at all, the instrument must be checked out by qualified repair personnel at ENMET. NOTE: The sample pump is instrument-specific. The CGS-100SP must be recalibrated if the sample pump diaphragm, valves or module itself is replaced.

PROCEDURE:

1. Refer to Fig. 14. Make sure instrument is off. Unscrew two phillips head screws and remove plastic dust cover.

2. Unscrew four Binding Head screws and remove pump head.

3. Grasp connecting rod with fingers.

4. Unscrew the single Flat Head plastic screw and remove old diaphragm.

5. Again, grasp connecting rod with fingers and install new diaphragm. diaphragm itself MUST be properly centered by plastic retaining washer and the plastic screw must be tight. Use an appropriate size screwdriver to avoid damage to slot of screw.

6. Reinstall pump head with inlet port (marked "IN") at top. Ascertain that the rim of the diaphragm is correctly seated

INSTALLATION OF REPLACEMENT DIAPHRAGM AND/OR PUMP HEAD

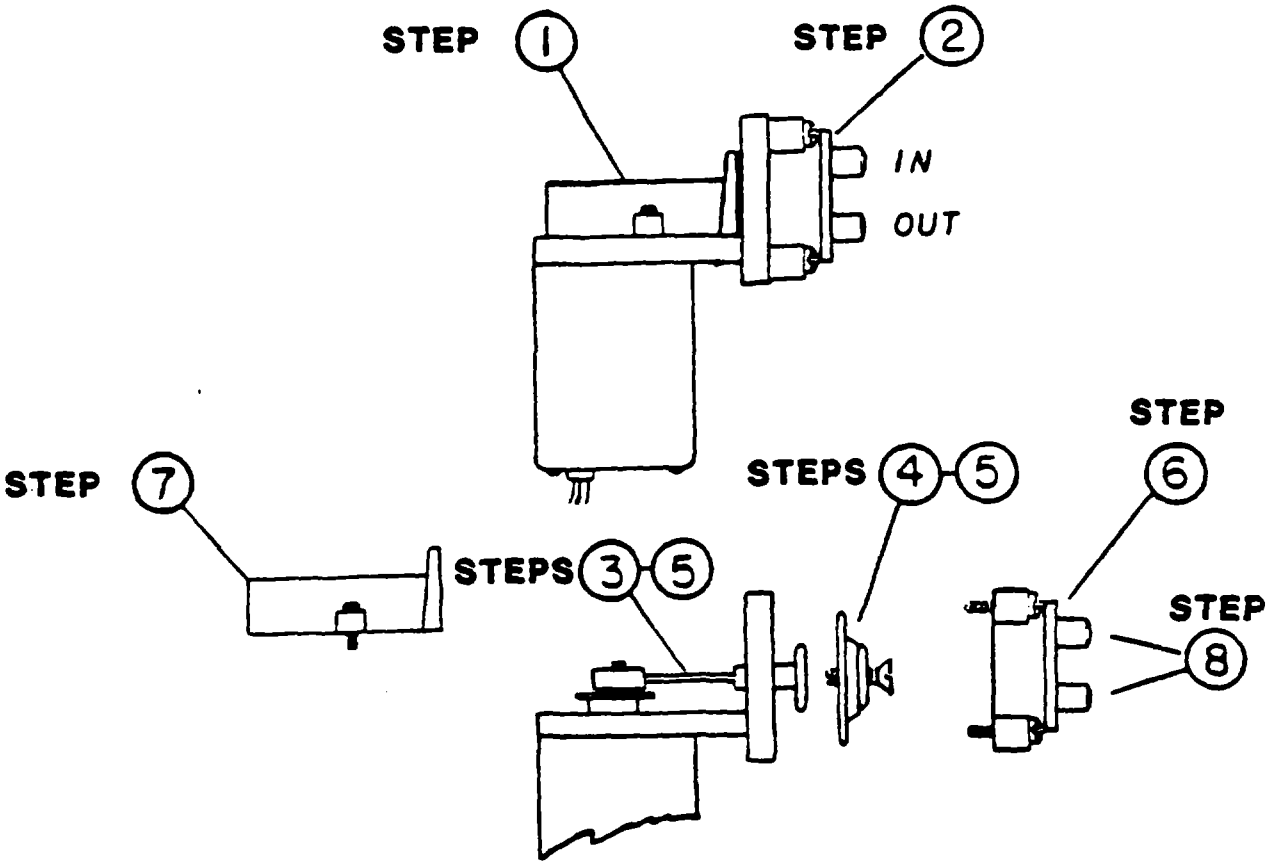


FIGURE 14: CGS-100SP Pump Diaphragm and Valve Replacement

4.5 CGS-100SP Pump Diaphragm and Valve Replacement (cont.)

in the matching groove on the underside of the pump head and DO NOT twist the diaphragm when tightening the four screws.

7. Reinstall dust cover.

8. Form new diaphragm with the pump running. Put CAL/READ Switch of sample pump module in READ position. Turn instrument on, and place finger over pump inlet port for one second.

9. Reinstall sample pump into sample pump module by following the sensing element replacement procedure for CGS-100SP (section 4.4.2), starting with step 17. Diaphragm and valve replacement is complete.

10. Proceed to section 4.2 and recalibrate the toxic, combustible and oxygen response of the CGS-100SP.

4.6 Battery Replacement Procedures

Replace the batteries if the instrument will not operate for a normal period. Instruments with Below Ground/Public Works calibration have a normal operating period of 8 hours or more. Other calibrations may have shorter operating periods.

'ATERIALS:

-- medium phillips head screwdriver

-- new battery packs (2); ENMET part # 67019-003

PROCEDURE:

1. Make sure the instrument is off. Open up the CGS-100 instrument by removing the 8 screws holding the yellow cover to the body of the instrument.

2. Unplug the plastic battery wiring connectors. DO NOT pull on the wires; pull only on the plastic connectors.

3. Connect the new batteries.

4. Replace the yellow cover onto the instrument, and recharge the instrument completely.

4.7 Fuse Replacement

If the instrument does not operate even if it is recharged, check the fuses in the wiring of the battery packs. Each fuse is located inside a piece of black shrink tubing in the battery pack wiring. Unsolder the fuse and check it for continuity. To check for continuity, obtain a voltmeter and set it to the lowest resistance setting. Place voltmeter leads on both sides of the fuse. If the fuse shows a very high resistance, it is blown and should be replaced (see section 4.8 for part number). If fuse shows little or no resistance, it is functional; problem with instrument operation involves some other component. Caution: Whenever replacing the fuse, make sure to provide a heat sink while soldering to protect the fuse, and be certain to replace the shrink tubing over the fuse.

4.8 Part Numbers for Replacement Parts, Accessories

Aspirator; 12' hose with squeeze bulb for sample draw (CGS-100 only)	04804-001
Aspirator; with 36" fiberglass probe, squeeze bulb for sample draw (CGS-100 only)	04804-002
Batteries; 8 volt, 5 amp hour battery packs	67019-003
Battery charger (110 Vac input)	67051-001
Battery charger (220 Vac input)	67051-016
Fuse	64008-001
Gases (24 liter cylinders, 300 psig)	
50 ppm Carbon Monoxide (CO)	03219-050
75 ppm CO	03219-075
300 ppm CO	03219-300
20% LEL methane	03220-020
25% LEL methane	03220-025
50% LEL methane	03220-050
Hydrophobic Filter (CGS-100SP only)	73089-051
Leather Case	04800-111
Sensors	
Toxic MOS Sensor (CGS-100 serial #443 and below)	03015-004
Toxic MOS Sensor (all CGS-100SP units, CGS-100 serial #444 and above)	03015-005
Combustible MOS Sensor (CGS-100 serial #443 and below)	03016-000
Combustible MOS Sensor (all CGS-100SP units, CGS-100 serial #444 and above)	03016-001
Oxygen Cell, C-3 (CGS-100 units serial #1150 and above, sensor modules serial #500 and above, sample pump modules	

4.8 Part Numbers for Replacement Parts, Accessories (cont.)

serial #150 and above	67013-002
Oxygen Cell, B-3 (CGS-100 units below serial #1150, sensor modules below serial #500, sample pump modules below serial #150	67013-000
Sensor Cables	
20 foot cable	04801-020
50 foot cable	04801-050
100 foot cable	04801-100
Test Kits	
CGS-100 Field Test Kit (for Below Ground/ Public Works calibration)	04800-123
CGS-100SP Field Test Kit (for Below Ground/Public Works calibration)	04800-172
Calibration Kits	
CGS-100 Calibration Kit (for Below Ground/ Public Works calibration)	04800-124
CGS-100 Calibration Kit (for Petrochemical calibration)	04800-128
CGS-100 Calibration Kit (for Special calibration)	04800-125
CGS-100SP Calibration Kit (for Below Ground/Public Works calibration)	04800-173
CGS-100SP Calibration Kit (for Petrochemical Calibration)	04800-175
CGS-100SP Calibration Kit (for Special Calibration)	04800-174
Service Kit for CGS-100 and CGS-100SP, includes calibration kit, voltmeter, operations video tape, maintenance video tape, miscellaneous parts and instruction manual	04800-171

5.0 SPECIFICATIONS

Mechanical

Enclosure: 16 gauge aluminum

Dimensions: 21 cm wide x 6 cm high x 33 cm deep

MS Connector: 14 pin military specification

Operating Temperature Range: 32 - 112 degrees F

Oxygen Cell

Expected Life: 9-12 months in air

ENMET Warranty: 6 months

Electrical

Audio Alarm: 68-80 dB at 2 ft.

Batteries: Fully rechargeable lead-acid; 8 volt, 5 amp hr.

MOS Sensors: Metallic oxide semiconductor elements

Oxygen Cell: Electrochemical Fuel Cell

6.0 WARRANTY

ENMET warrants new instruments to be free from defects in workmanship and material under normal use for a period of one year from date of shipment from ENMET. The warranty covers both parts and labor; however, oxygen cells are limited to a warranty period of six (6) months from date of shipment from ENMET. Equipment believed to be defective should be returned to ENMET within the warranty period (transportation prepaid) for inspection. If the evaluation by ENMET confirms that the product is defective, it will be repaired or replaced at no charge, within the stated limitations, and returned prepaid to any location in the United States. ENMET shall not be liable for any loss or damage caused by the improper use of the product. The purchaser indemnifies and saves harmless the company with respect to any loss or damages that may arise through the use by the purchaser or others of this equipment.

This warranty is expressly given in lieu of all other warranties, either expressed or implied, including that of merchantability, and all other obligations or liabilities of ENMET which may arise in connection with this equipment. ENMET neither assumes nor authorizes any representative or other person to assume for it any obligation or liability other than that which is set forth herein.

cut along this line

ENMET WARRANTY REGISTRATION

PLEASE FILL OUT COMPLETELY

*Name*_____ *Title* _____

Phone (_____)_____-_____

*Company*_____ *Dept.*_____

*Address*_____

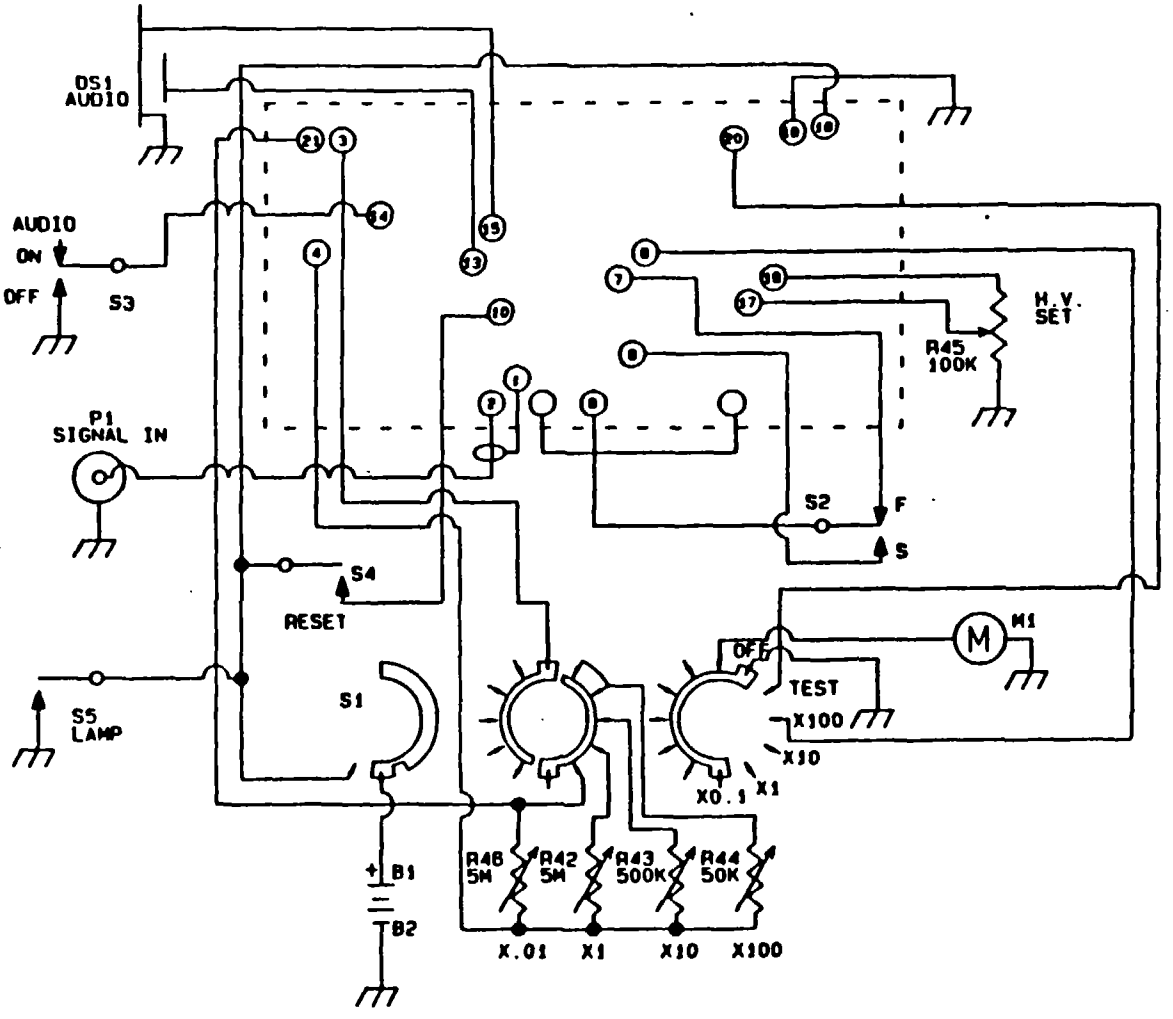
ENMET Instrument/System description and serial number:

*Model No.*_____ *Serial No.*_____

Cut out and mail promptly upon receipt of instrument to:
ENMET Corp., P.O. Box 979, Ann Arbor, MI, 48106-0979

6.1 Shipping Units to Service Center for Repair

The leather case is an integral part of this instrument. In addition to furnishing protection during use, the leather case affords a certain amount of protection during shipment. We suggest that instruments be shipped only in their leather cases, in order to avoid the possibility of switch shaft and display damage during shipment.



DESC: CHASSIS WIRING DIAGRAM	
MODEL: 3-5	
PART #: 82-135	
DWN: BKS	DATE: 8/28/83
DSGN:	DATE:

BS 8/28/84			
TOL:		SCALE:	
TITLE MODEL 3-5 WIRING DIAGRAM			
LUDLUM		82	84

APPENDIX 4.7

RADIATION SURVEY METER
LUDLUM MODEL 3-5

Instruction Manual

LUDLUM MODEL 3-5 SURVEY METER

LUDLUM MEASUREMENTS, INC.
801 OAK 915 - 235-5[illegible] P. O. BOX 248
SWEETWATER, TEXAS [illegible].A., 79556

DESIGNER AND MANUFACTURER
OF
Scientific and Industrial
INSTRUMENTS

WARRANTY CERTIFICATE

Ludlum Measurements, Inc. warrants the products covered in this Instruction Manual to be free of defects due to workmanship, materials, and design for a period of twelve months from the date of delivery, with the exception of photomultiplier tubes and geiger tubes, which are warranted defect free to 90 days.

In the event of instrument failure, notify Ludlum Measurements, Inc. for repair or replacement. Liability of this warranty is limited to the purchase price of the instrument.

RECEIVING CONDITION EXAMINATION

Be sure to verify that the shipping carton is received in perfectly good condition. For example, that no damage should be visible.

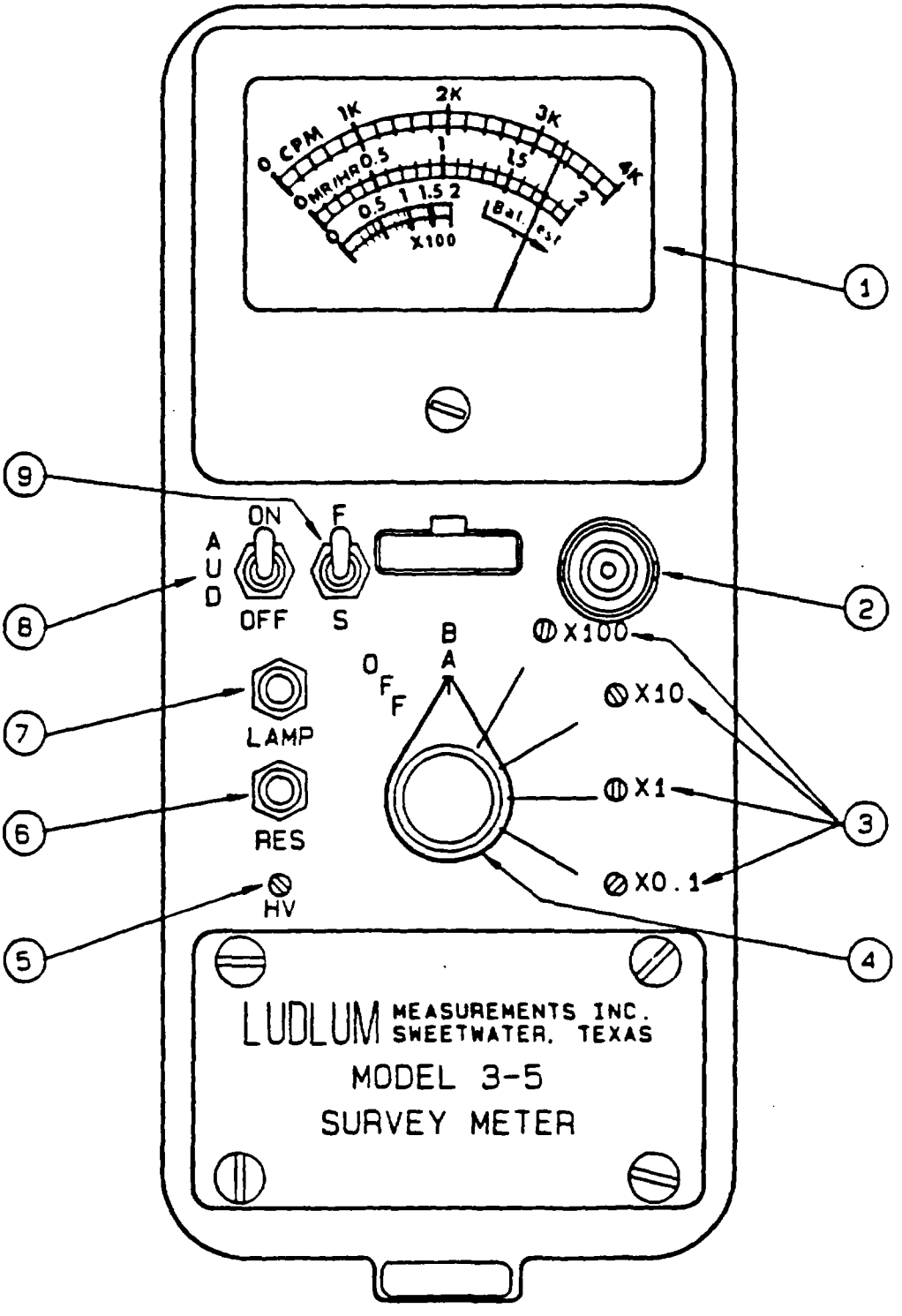
Should the instrument be received in a damaged condition, save the shipping container and the packing material and request an immediate inspection by the carrier.

Ludlum Measurements, Inc. is not responsible for the damage which occurs during shipment, but will make every effort to help obtain restitution from the carrier.

RETURN OF GOODS TO MANUFACTURER

If equipment needs to be returned to Ludlum Measurements, Inc. for repair, calibration, etc., please do so by the appropriate method of shipment. All shipments should include documentation containing shipping address, customer name and telephone number, and all other necessary information.

Your cooperation will expedite the return of your equipment.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2K
3K
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X100
Bal.
1
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ON
F
A
U
D
OFF
S
2
X100
8
B
A
OFF
X10
7
LAMP
X1
3
6
RES
X0.1
5
HV
4
LUDLUM MEASUREMENTS INC.
SWEETWATER, TEXAS
MODEL 3-5
SURVEY METER

LUDLUM MODEL 3-5 SURVEY METER

TABLE OF CONTENTS

AUGUST 1984

LUDLUM MODEL 3-5 SURVEY METER

1. GENERAL

The Model 3-5 is a waterproof, portable survey instrument that operates on two standard "D" cell flashlight batteries. The instrument features a regulated high-voltage, power supply adjustable from 400 to 1500 volts and provides a 4-linear range from 0-200 mR/Hr.

The unit body is made of cast aluminum, including the meter housing. The can is 1/16 aluminum. Other operating features of the instrument include a unimorph speaker mounted to the instrument can with an audio ON-OFF capability, fast-slow meter response, meter reset button, meter light pushbutton and a 6-position switch for selecting battery check or scale multiples of X0.1, X1, X10 and X100. Each range multiplier has its own calibration potentiometer.

Any G-M probe offered by the company will operate on this unit as well as many of the scintillator-type detectors. The instrument is set for 900-volt, G-M tube operation. For special requirements, it may be adjusted for operation with any G-M or scintillator tube between 400 and 1500 volts.

The unit is operated with two flashlight batteries for operation from 150° to approximately 32°F. For temperature operation to 0°F, either very fresh alkaline batteries or rechargeable NiCd batteries may be used. Battery drain averages 30 milliamperes.

2. SPECIFICATIONS

POWER: two standard "D" size batteries

FOUR LINEAR RANGES: from 0 to 200 mR/Hr; meter scale presentation - 0 to 2 mR/Hr with range multiples of X0.1, X1, X10, X100

SENSITIVITY: 40 millivolts, (+20mV, -16mV)

AUDIO: built-in unimorph speaker with an ON-OFF switch

HIGH VOLTAGE: externally adjustable from 400 to 1500 volts

RESPONSE: 5 or 25 seconds for 90% of final meter reading

LINEARITY: plus or minus 5% full scale

CALIBRATION STABILITY: less than 15% variance to battery end point

METER: 50 Micro-amp, 2 1/2-inch scale, with pivot-and-jewel suspension

CONNECTOR: Series "C", 706 U/G; BNC or MHV may also be provided

SIZE: 3.4 x 3.5 x 7.0 inches (H x W x L exclusive of handle)

WEIGHT: 3.5 pounds less detector

FINISH: drawn-and-cast aluminum, with computer-beige polyurethane enamel and silk-screened nomenclature.

3. DESCRIPTION OF CONTROLS AND FUNCTIONS

(1) Meter has a readout of 0 to 4K CPM and 0 to 2 mR/hr for an actual count of 0 to 400,000 CPM or 0 to 200 mR/hr. A battery test scale is also provided to check battery-charge status.

(2) A Series "C" connector is provided for connection of the cable and probe.

(3) Range Calibration Adjustments are recessed potentiometers located on line with each multiplier position. These adjustment controls allow individual calibration for each range multiplier.

(4) Range Multiplier Selector Switch is a 6-position switch marked OFF, BAT, X100, X10, X1, X0.1. Turning the range selector switch from OFF to BAT position provides operator a battery check of the instrument. A BAT check scale on the meter provides a visual means of checking the battery status. Moving the range selector switch to one of the range multiplier positions (X0.1, X1, X10, X100) provides the operator with an overall range of 0-200 mR/Hr. Multiply the scale reading by the multiplier for determining the actual reading.

(5) High Voltage Adjustment provides a means to vary the high voltage from 400 to 1500 volts. The high voltage setting may be checked at the connector with an appropriate voltmeter.

(6) RES Button, when depressed, provides a rapid means to drive the meter to zero.

(7) LAMP Pushbutton Switch, when depressed, lights the meter face.

(8) AUDIO ON-OFF Toggle Switch in the ON position operates the unimorph speaker, located on the left side of the instrument. The frequency of the clicks is relative to the rate of the incoming pulses. The higher the rate is, the higher the audio frequency. The audio should be turned OFF when not required to reduce battery drain.

(9) Fast-Slow Toggle Switch provides meter response. Selecting the "F" position of the toggle switch provides 90% of the final meter reading in 5 seconds. In "S" position, 90% of the final meter reading takes 11 seconds. In "F" position there is fast response and large meter deviation. In "S" position there is a slow response and damped meter deviation.

4. OPERATING PROCEDURES

4.1 Remove the battery box lid and install two "D" size batteries. Note (+) (-) marks on the inside of the lid. Match the battery polarity to these marks.

NOTE: Center post of flashlight battery is positive.

Replace the battery box lid.

4.2 Turn the range switch to BAT. The meter should deflect to the battery check portion of the meter scale. If the meter does not respond, recheck that the batteries have proper polarity. Press the LAMP button and check for a light on the meter.

4.3 Connect the cable to the instrument and detector.

4.4 Turn the instrument range switch to X100. Expose the detector to a check source. The speaker should click with the AUDIO ON-OFF switched to ON.

4.5 Move the range switch to the lower scales until a meter reading is indicated. The toggle switch labeled F-S should have fast response in "F"and slow response in "S".

4.6 Depress the RES switch. The meter should zero.

4.7 Proceed to use the instrument.

5. CALIBRATION

5.1 Detector Operating Point: Adjust the HV control for 900 volts at the instrument connector for G-M detectors.

NOTE: If an electrostatic voltmeter is not available, use an ordinary volt-ohm-milliameter with an attenuator to provide at least 100 Meg ohm meter resistance. Select the appropriate scale and then adjust high voltage to read 850 volts.

Do not use a vacuum-tube-type voltmeter for this adjustment unless an external high voltage multiplier probe is used.

Turn the instrument to X100. Expose the instrument to a calibrated gamma field and vary the range calibration adjustment control for proper reading.

5.2 Special Use Calibration: For special G-M detector applications, the power supply may be adjusted for 450--volt and 1200-volt G-M tubes. Follow the above procedure, only set the supply at the new operating voltage.

For scintillation counters, connect the scintillator. Expose the unit to a source and develop an operating voltage versus count-rate plot. Set the operating voltage at the flattest portion of this curve; then proceed to adjust each calibration control for the desired meter reading.

5.3 Calibrating CPM Scale: To calibrate the CPM scale, a precision pulse generator is required. The pulse generator should be capable of providing a 75-millivolt, or greater, negative pulse with a pulse-width of 5 microseconds.

Connect the pulse generator to the instrument and adjust the pulse frequency to provide a 4/5-scale deflection on the X100 range (400,000 CPM). Adjust the X100 range calibration potentiometer as required. Decrease the

pulse frequency by decades and adjust each range calibration potentiometer accordingly.

6. MAINTENANCE

NOTE: NEVER STORE THE INSTRUMENT OVER 30 DAYS WITHOUT REMOVING BATTERIES. ALTHOUGH THIS INSTRUMENT WILL OPERATE AT VERY HIGH AMBIENT TEMPERATURES, BATTERY SEAL FAILURE CAN OCCUR AT TEMPERATURES AS LOW AS 100 DEGREES FAHRENHEIT. NEGLECTED BATTERY SEAL FAILURE WILL SURELY CAUSE ONE AWFUL MESS!

Instrument maintenance consists of keeping the instrument clean and periodically checking batteries and calibration. Once initial calibration is performed, recalibration should not be required if batteries are maintained in good condition.

An instrument operational check should be performed prior to each use by exposing detector to a known source and confirming proper reading on each scale.

Under certain conditions, NRC requires instrument recalibration every three months. Check the appropriate regulations to determine recalibration schedule.

Also at three month intervals, the batteries should be removed and the battery contacts cleaned of any corrosion. If the instrument has been exposed to very dusty or corrosive atmosphere, more frequent battery servicing should be used.

Use a spanner wrench to unscrew the battery contact insulators, exposing internal contacts and battery spring. Removing the handle will facilitate access to these contacts.

	LO	
	DI	
	CF	
	CF	
	CF	07-6253
	CF	07-6274
	CF	07-6254
	CF	07-6272
04-5532	CF	07-6254
04-5523		07-6272
04-5555		07-6269
04-5513	RI	
04-5523		
04-5507	RI	
04-5576	R	
04-5578	R	10-7070
04-5521	R	10-7029
04-5578	R	10-7016
04-5579	R	10-7026
04-5523	R	10-7028
04-5521	R	10-7048
04-5576	R	10-7060
04-5575	R	10-7028
04-5521	R	10-7013
04-5532	R	10-7027
04-5520	R	10-7023
04-5518	R	10-7026
04-5519	R	10-7028
04-5523	R	10-7029
04-5555	R	10-7022
	R	10-7019
	R	10-7070
	R	10-7015
	R	10-7022
05-5755	R	10-7023
05-5778	R	10-7066
05-5763	R	10-7053
05-5758	R	10-7026
05-5763	R	10-7016
	R	10-7017
	R	10-7050
	R	10-7017
	R	10-7016
06-6023	R	10-7065
06-6030	R	10-7006
06-6066	R	10-7028
06-6023	F	
06-6024	F	10-7028
		10-7023
		10-7014

LUDLUM MODEL 3-5 SURVEY METER

RESISTOR NETWORK

RN1	4 EACH 100 MEG	40-7036

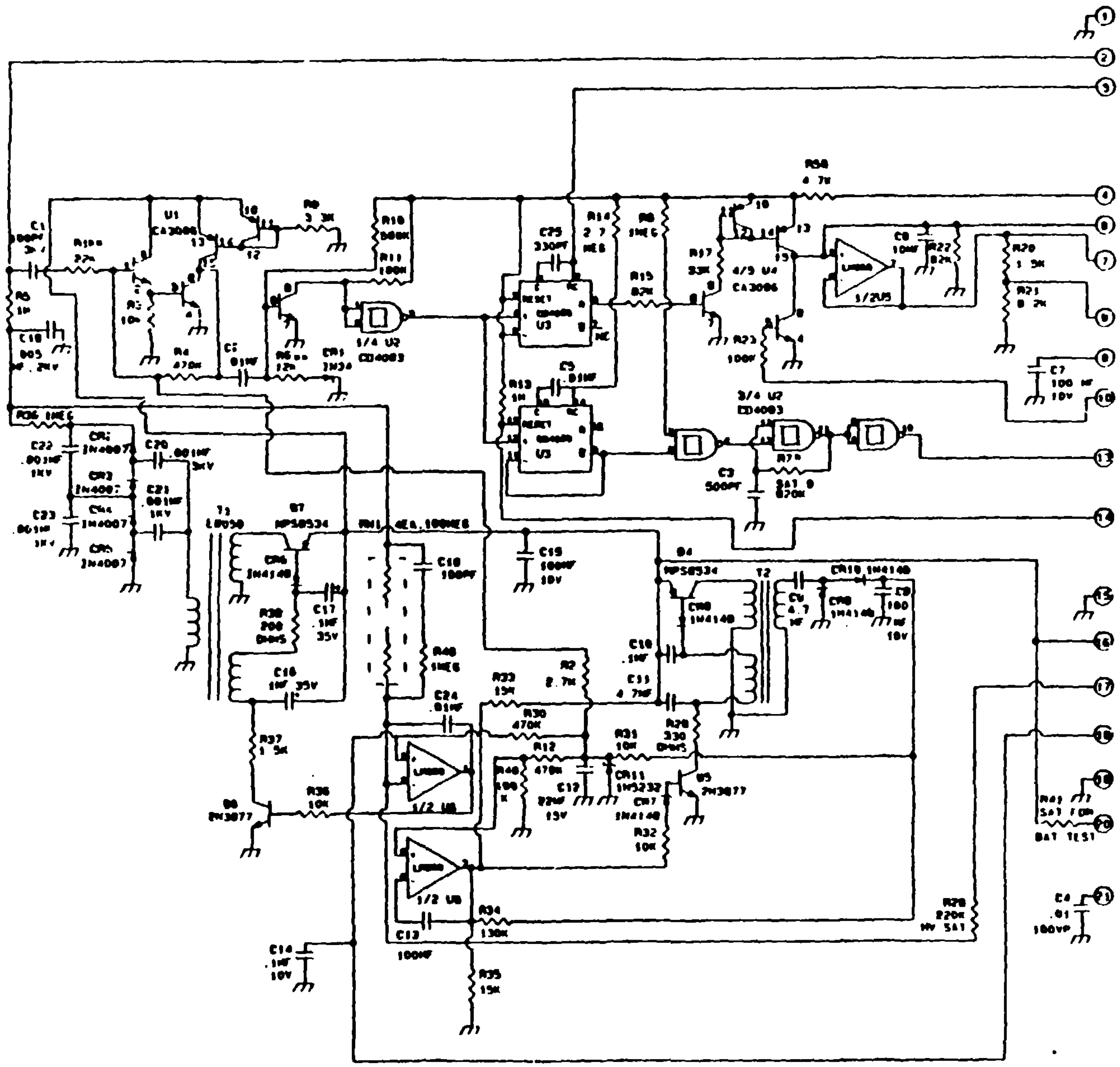
TRANSFORMERS

T1	LB050	40-0902
T2	LVPS	40-0944

MISCELLANEOUS

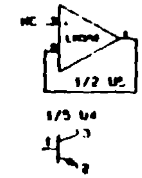
7 EACH	CLOVERLEAF RECEPTACLES 011-6809	18-8771
1 EACH	WALDON 16-06-0007 SMALL RECEPTACLE	18-8792
1 EACH	WALDON 16-06-0004 LARGE PIN	18-8795

ASSEMBLED CIRCUIT BOARD 5176-017-00



NO	DEVICE	POWER CONNECTIONS		
		[illegible]	[illegible]	[illegible]
U1	CA3086		[illegible]	[illegible]
U2	CD4083		14	[illegible]
U3	CD4098		[illegible]	[illegible]
U4	CA3086		[illegible]	12
U5	LM358		8	4
U6	LM358		8	4

UNUSED CONNECTIONS



DESC	CIRCUIT BOARD SCHEMATIC
MODEL	MODEL 3
PART #	5118-017-00
DWN VR	DATE 10/17/83
DSGN	DATE

R47 WAS SAT AT 820K
5/22/84

FOR 10MV INPUT SENSITIVITY
R1 = 10K
R2 = 20K

DWN VR DATE 10/18/83	CHK DATE	APP DATE
TOL: ANGLE ±10	SCALE FULL	
TITLE MODEL 3 CIRCUIT BOARD		
LUDLUM	SERIES 176	SHEET 17

LUDLUM MODEL 3-5 SURVEY METER

BILL OF MATERIALS

CHASSIS WIRING DIAGRAM, DRAWING NO. 62 X 94

AUDIO		PART NO.
DS1	UNIMORPH 60690	21-9251
CONNECTOR		
P1	SERIES "C" UG 706/U	13-7751
SWITCHES		
S1	CENTRALAB PA600-210	08-6501
S2	RESPONSE F/S MST 105-D	08-6511
S3	AUDIO ON-OFF MST 105-D	08-6511
S4	RESET 30-1 P/B	08-6517
S5	LAMP 30-1 P/B	08-6517
POTENTIOMETERS		
R42	5M LOCK POTENTIOMETER	09-6783
R43	500K LOCK POTENTIOMETER	09-6782
R44	50K LOCK POTENTIOMETER	09-6773
R45	100K LOCK POTENTIOMETER	09-6785
R46	5M LOCK POTENTIOMETER	09-6783
BATTERY		
BT1-BT2	"D" DURACELL BATTERY	21-9313
MISCELLANEOUS		
MODEL 3-5 CASTING		9062-134
MODEL 3 HARNESS		8176-020-00
PORTABLE HANDLE		7001-012-01
PORTABLE METER		40-1801
MODEL 3-5 BATTERY BOX LID		9062-132
MODEL 295 BATTERY CONTACT SET		40-1707
PORTABLE KNOB		08-6613

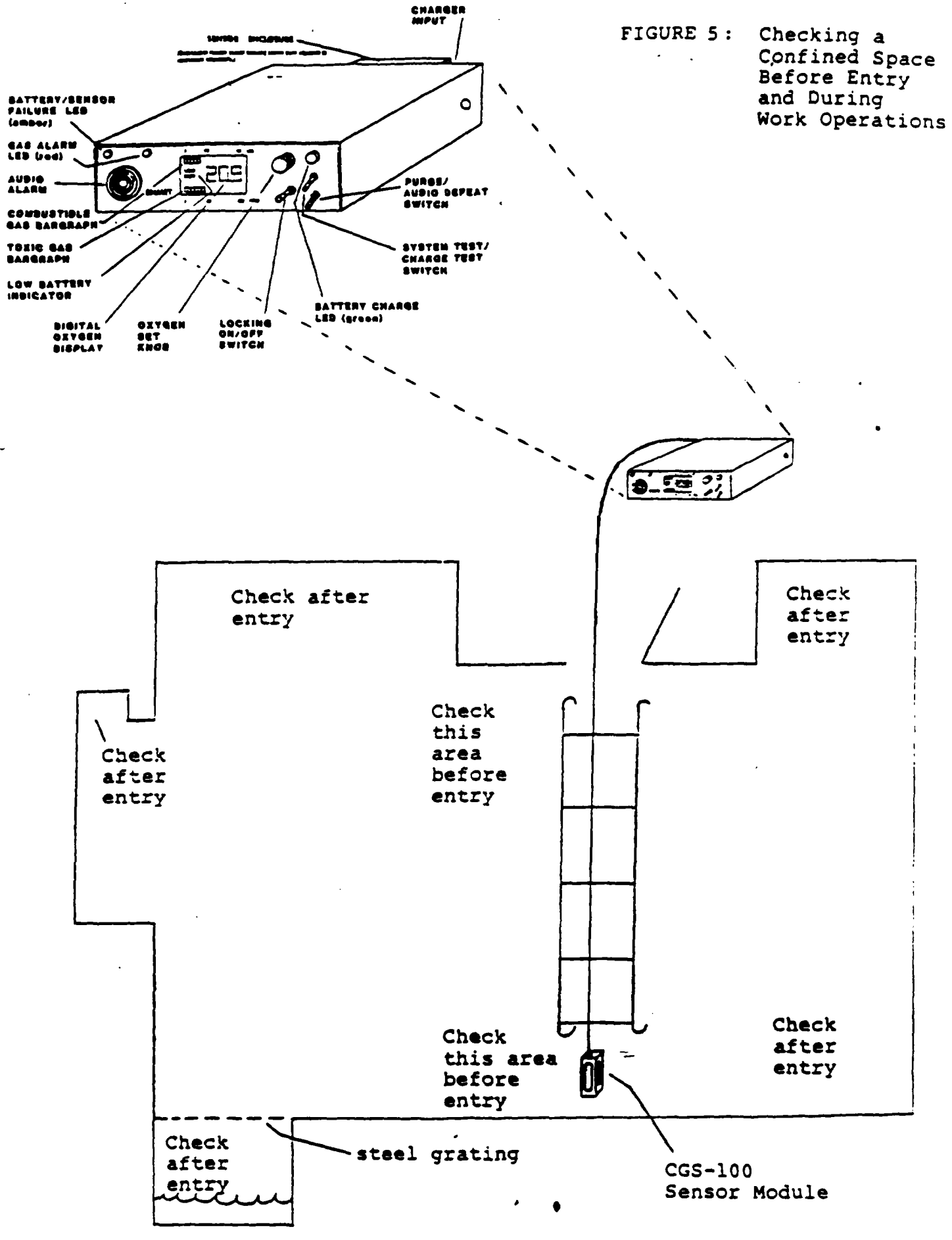


FIGURE 5: Checking a Confined Space Before Entry and During Work Operations

2.5 Operation (continued)

Periodically check the LCD for gas concentrations. If any alarm activates, or if the oxygen concentration rises above 23-25% by volume, exit the hazardous area immediately.

2.6 Storage

Do not store the CGS-100 in a contaminated environment. Examples of contaminated environments: closets with oily rags; near chemicals; in the vicinity of combustion.

2.7 Precautions

-- Operating Temperatures: In ENMET portable instruments, the oxygen cell operates effectively in ambient air temperatures of 20-130 degrees F. The resistor-thermistor temperature compensation network is verified for + or - 1.0% linearity in ambient air temperatures of 32-112 degrees F. The unit should be operated for more than one hour in temperatures between 20-32 degrees F. The instrument should not be used in environmental temperatures below 20 degrees F, unless the duration of usage is short, and some means are used to protect the cell against intense cold and wind. If the cell is frozen, its current output drops, and the instrument goes into alarm. The instrument should also not be used in temperatures greater than 130 degrees F. The oxygen cell freezes when subjected to sustained use or storage at or below 25.7 degrees F.

-- NEVER ALLOW AN INSTRUMENT OR SENSOR MODULE TO BE SUBMERGED!! This can ruin the instrument. However, if the instrument is accidentally submerged, immediately remove yellow body cover of the instrument (8 screws) and allow the unit to dry out. Then have the instrument examined and approved by qualified repair personnel before using it again.

-- Always begin operation with fully charged batteries.

-- Do not use the instrument if an MOS sensor or oxygen cell fails the Field Test.

-- Do not smoke while operating the instrument.

-- If the unit has been inoperative for long periods of time (one week or more), perform the weekly maintenance exercise in section 4.3.

2.7 Precautions (continued)

-- Avoid gross exposure to toxic gas environments.

-- Do not try to make precise gas measurements in fast-moving air currents (conduits, vents, etc.). High air flow rate can cool the electronically-heated MOS sensor and interfere with a true gas signal.

-- Always allow a few minutes for the unit to adjust to large scale temperature changes.

-- Always allow at least 3 minutes of sampling time to fully test any atmosphere prior to entry.

-- Check both high and low areas of the work area prior to entry and during confined space work operations. There are two reasons for this. First, some gases are heavier than air, some lighter. Methane, for example, is approximately half as dense as air and is found at the upper levels of an enclosed work area. Second, many confined space work operations cause the atmosphere in an area to change; this is why it is necessary to continuously monitor the atmosphere of a work area even if the area has been tested before entry.

3.0 FIELD TESTS

For CGS-100 instruments with Below Ground/Public Works calibration, Field Tests determine whether or not the instrument is grossly out of calibration. A fully purged and accurately calibrated CGS-100 (or CGS-100SP) should respond as outlined below. These tests must be performed in a clean, uncontaminated environment. To verify instrument accuracy, we recommend that a Field Test be performed upon receipt of the instrument and at least weekly thereafter. Refer to Figures 6 and 7 for illustration. NOTE: The Toxic and Combustible Field Tests as described in this section do not apply for instruments with Petrochemical calibration (the Oxygen Field Test does apply); to maintain instrument accuracy, refer to section 4.2. In addition, Toxic and Combustible Field Tests in this section do not apply for Special Calibration instruments; to maintain instrument accuracy, refer to addendums in this manual. The Oxygen Field Test in this section applies for all instruments with 19.5% by volume oxygen alarm point.

When using a Field Test gas to test the alarm levels of the toxic and combustible sensors, two important precautions are necessary. First, never perform a Field Test for the toxic or combustible alarm levels with compressed gases flowing directly from compressed air cylinders, due to the fact that these gases are extremely dry. Field Test procedures require gases to have at least 10% relative humidity; testing apparatus available from ENMET provide this humidity when used correctly. Second, do not use a Field Test gas set in a background of pure inert gas (such as nitrogen or argon). The MOS sensor will pick up the background gas and render an inaccurate alarm response. Field Test gases should be set in a background of hydcarbon-free air.

3.1 Toxic and Combustible Response Field Test for Instruments with Below Ground/Public Works Calibration

MATERIALS:

-- cylinder of compressed air containing 75 ppm carbon monoxide Field Test gas* (ENMET part number 03219-075)

-- cylinder of compressed air containing 25% LEL methane Field Test gas* (ENMET part number 03220-025)

-- calibration regulator assembly* (CGS-100: ENMET part number 03700-003; CGS-100SP: ENMET part number 03700-007) including regulator, humidifier (adapter for CGS-100 also includes sensor cover).

3.1 Toxic and Combustible Response Field Tests for Instruments with Below Ground/Public Works Calibration (continued)

-- clean water

-- CGS-100 or CGS-100SP

* Items marked with an asterisk (*) are available as Field Test Kits: for a CGS-100, the Field Test Kit is ENMET part #04800-123; for a CGS-100SP, the Field Test Kit is ENMET part #04800-172.

PROCEDURE:

1. CGS-100SP only--The CAL-READ Switch must be in the CAL position for Field Testing. See Figure 7 to access switch. Setting switch in CAL position turns off the pump activates the Battery/Sensor Failure alarm when unit is turned on (hold down the Audio Defeat Switch to silence this alarm).

2. Pull ON/OFF Switch away from its base and set it in the ON position. As the sensors heat up, they activate alarms. This is normal.

3. Push in the Push To Set Oxygen Knob and turn it until the Digital Oxygen Display reads 20.9. If the display cannot be set to 20.9, replace the oxygen cell.

4. Hold the Purge/Audio Defeat Switch in the Purge position for 5 minutes.

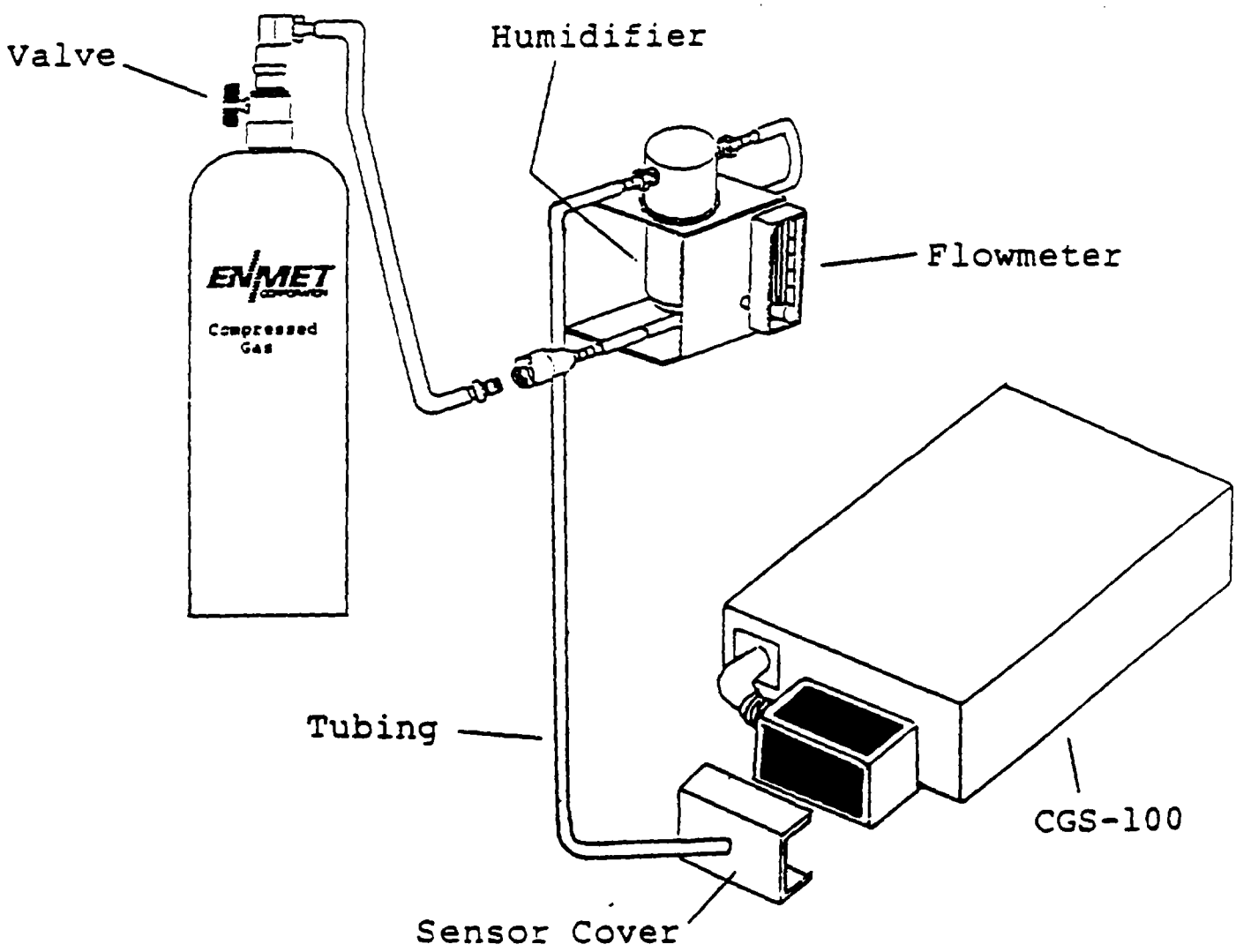
5. Allow the unit to stabilize for 6 minutes after purging.

6. Unscrew the plastic humidifier bottle of the calibration regulator assembly, and fill the bottle halfway with water. Replace the bottle, being careful to hold it upright so that water does not flow into the gas supply line of the assembly.

7. Making sure that the regulator on the assembly is in the off position, attach the calibration fixture to the cylinder containing 75 ppm carbon monoxide. Then set the humidifier /flowmeter assembly upright on a level surface.

8. Open the regulator valve slowly in order to provide 0.9 - 1.1 scfh (standard cubic feet/hour) flow through the flowmeter on the assembly. Do not allow the gas to flow so fast as to force water into gas supply line leading to sensors.

FIGURE 6 : Applying Gas to CGS-100 Sensors



3.1 Toxic and Combustible Response Field Tests for Instruments with Below Ground/Public Works Calibration (continued)

9. CGS-100: Place the sensor cover of the calibration regulator assembly over the sensor module of the CGS-100 (see Fig. 6).

   CGS-100SP: On the CGS-100SP, remove the sample tubing connector from the hydrophobic filter intake tubing connector (see Fig. 7). Then snap the calibration regulator assembly tubing connector on to the hydrophobic filter intake tubing connector.

10. The CGS-100 or CGS-100SP instrument should activate the audio alarm (pulsed tone) and red Gas Alarm LED at some point between 15-90 seconds. The toxic (PPM) bargraph on either instrument should indicate alarm concentration or slightly higher.

11. Turn off the gas, remove the sensor cover from the CGS-100 sensor module (or remove calibration regulator tubing connector from CGS-100SP hydrophobic filter intake tubing connector) and remove the calibration regulator assembly from the 75 ppm CO toxic Test gas cylinder.

12. Attach the calibration regulator assembly to the cylinder of 25% LEL methane Field Test gas

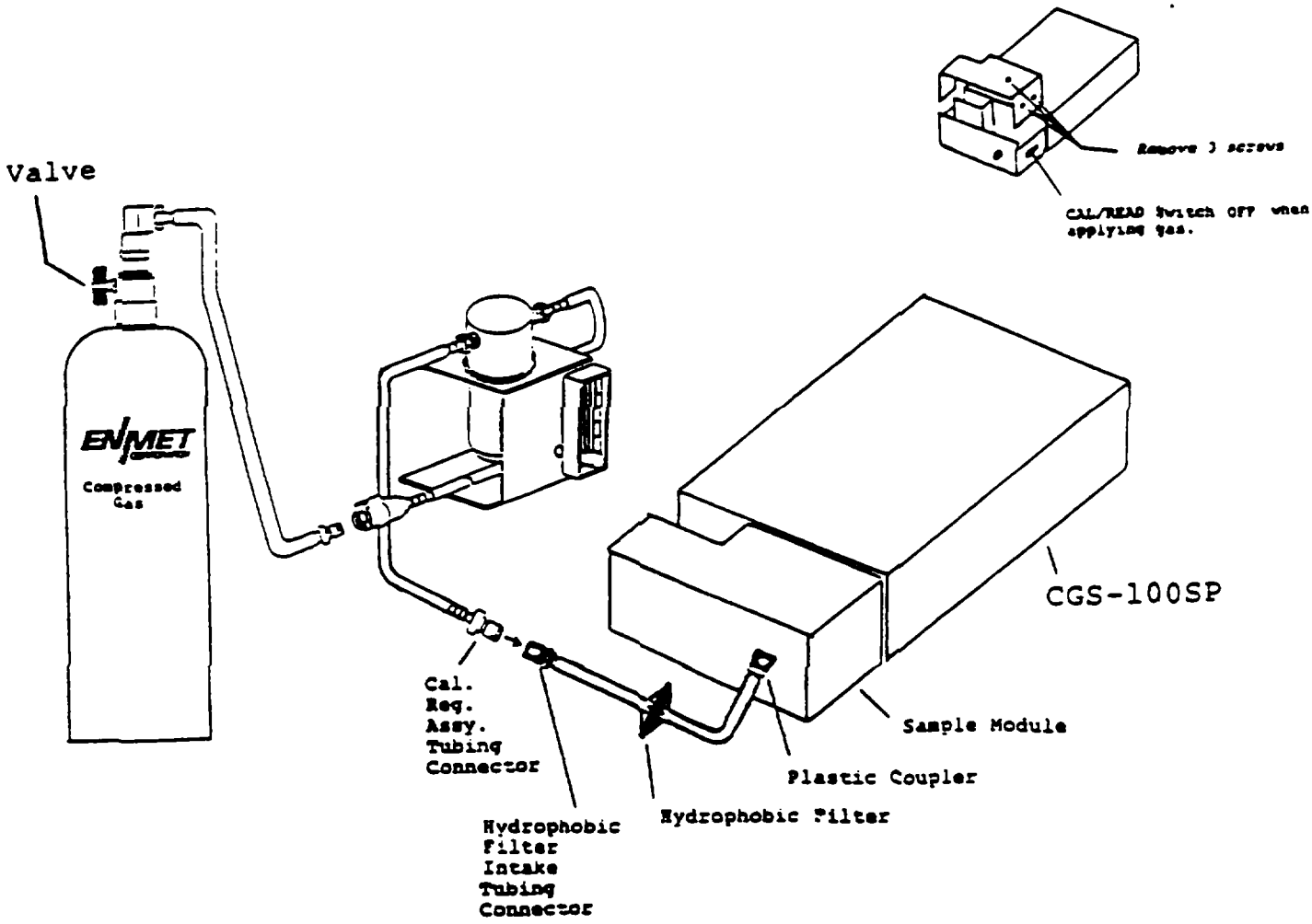
13. Repeat step 8.

14. Repeat step 9.

15. The CGS-100 instrument should activate the audio alarm (pulsed tone) and red Gas Alarm LED (flashing) at some point between 10-45 seconds. The CGS-100SP instrument should activate the same alarm signals within 15 seconds. Combustible (LEL) bargraph on either instrument should indicate alarm level concentration or slightly higher.

16. Turn off the gas. Remove the calibration regulator assembly sensor cover from the sensor module (CGS-100) or the calibration regulator assembly tubing connector from the hydrophobic filter intake tubing connector (CGS-100SP). Toxic and combustible Field Testing is complete. NOTE: If instrument does not respond with the designated alarm signals within the time period indicated, the instrument must be recalibrated for that response (toxic or combustible). In addition, if Oxygen Field Test is not to be performed, make sure the CAL-READ switch of the CGS-100SP is in the READ position before using the instrument.

FIGURE 7: Applying Gas to CGS-100SP



3.2 Oxygen Response Field Test

The Oxygen Response Field Test is applicable for any instrument with a 19.5% by volume oxygen alarm point. This includes instruments with Below Ground/Public Works Calibration and Petrochemical Calibration. NOTE: See end of procedure for CGS-100 quick Field Test without test gas.

MATERIALS:

-- cylinder of compressed air containing 17.0% oxygen by volume* (ENMET part #03296-170)

-- calibration regulator assembly* (CGS-100: ENMET part #03700-003); CGS-100SP: ENMET part #03700-007) including humidifier, regulator (CGS-100 assembly also includes sensor cover).

*Items marked with an asterisk (*) are available as part of the Field Test Kit for instruments with Below Ground/Public Works Calibration (CGS-100 Field Test Kit: ENMET part #04800-123; CGS-100SP Field Test Kit: ENMET part #04800-172).

PROCEDURE:

1. Instrument must operate for 15 minutes before Field Test for oxygen response is performed. If this test is performed immediately after toxic and combustible response tests, the 15 minute operating requirement has already been fulfilled.

2. CGS-100SP only: Move CAL/READ Switch to CAL position (see Fig. 7 to access this switch).

3. Push in and turn the Push To Set Oxygen Knob until the digital display on the LCD indicates 20.9.

4. Unscrew the humidifier bottle of the calibration regulator assembly, fill halfway with water, and reinstall onto assembly. Making sure the regulator is in the "off" position, attach the assembly to the cylinder of 17.0% oxygen by volume. Set the humidifier/flowmeter upright on a level surface.

5. Open the regulator valve slowly in order to provide 0.9 - 1.1 scfh (standard cubic feet/hour) flow through the flowmeter on the assembly. Do not allow the gas to flow so fast as to force water into gas supply line leading to sensors.

6. CGS-100: Place the sensor cover of the calibration regulator assembly over the sensor module of the CGS-