

A-Plus Oxygen Analyzer

Instruction Manual

P/N 99000003
Revision C

DELTA F CORPORATION
4 Constitution Way
Woburn, MA 01801-1087
Telephone: (781) 935-4600
FAX: (781) 938-0531
Service FAX: (781) 932-0053

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Delta F Telephone Number Area Code Change

Since this manual was printed the area code for Woburn, Massachusetts has changed from 617 to 781.

The main **Delta F** contact numbers are now:

Telephone: 781-935-4600
Fax: 781-938-0531

The **Customer Support Services Department** direct contact numbers are now:

Telephone: 781-935-5808
Fax: 781-932-0053

Please use these new telephone numbers in place of the numbers listed in the manual.

ELECTROLYTE SOLUTION
MATERIAL SAFETY DATA SHEET
ADDENDUM

CAUTION



The information found in this Electrolyte Solution Material Safety Data Sheet Addendum is the latest available for the DF-E05, DF-E06, DF-E07, and DF-E09 electrolyte solutions.

This addendum supersedes the MSDS found in the Safety chapter of this manual.

Please read the new MSDS prior to setting up the analyzer.

MATERIAL SAFETY DATA SHEET

1. IDENTIFICATION OF THE SUBSTANCE

Trade Name Electrolyte Solution, DF-E05, DF-E06, DF-E07, DF-E09

Manufacturer Delta F Corp., 4 Constitution Way, Woburn, MA
01801-1087, USA, Tel: 1-781-935-4600

Emergency Contact USA: 1-800-424-9300
International: 1-813-979-0626 (collect)

Supplier and contact in UK (for use in the UK only)	
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2. COMPOSITION

<u>CAS #</u>	<u>Component</u>	<u>EC Code/class</u>	<u>Concentration</u>	<u>Risk Phrase</u>	<u>Risk Description</u>
1310-58-3	Potassium Hydroxide in aqueous solution	215-181-3 C	1N: 5.6%w/w	R35	Causes severe burns

3. HAZARDS IDENTIFICATION

Main Hazard Corrosive. Causes severe burns on contact with skin, eyes and mucous membrane

CERCLA Ratings (scale 0-3) Health = 3 Fire = 0 Reactivity = 1 Persistence = 0

NFPA Ratings (scale 0-4) Health = 3 Fire = 0 Reactivity = 1

Potential Health Effects:

Eye Contact Causes severe eye burns. May cause irreversible eye injury. Contact may cause ulceration of the conjunctiva and cornea. Eye damage may be delayed.

Skin Contact Causes skin burns. May cause deep, penetrating ulcers of the skin.

Ingestion May cause circulatory system failure. May cause perforation of the digestive tract. Causes severe digestive tract burns with abdominal pain, vomiting, and possible death.

Inhalation Inhalation under normal use would not be expected as this product is supplied as an aqueous solution and no hazardous vapors are emitted. Effects of inhalation are irritation which may lead to chemical pneumonitis and pulmonary edema. Causes severe irritation of upper respiratory tract with coughing, burns, breathing difficulty, and possible coma.

Chronic Prolonged or repeated skin contact may cause dermatitis. Prolonged or repeated eye contact may cause conjunctivitis.

4. FIRST-AID MEASURES

Skin Contact	In case of skin contact, remove contaminated clothing and shoes immediately. Wash affected area with soap or mild detergent and large amounts of water for at least 15 minutes. Obtain medical attention immediately.
Eye Contact	If the substance has entered the eyes, wash out with plenty of water for at least 15 - 20 minutes, occasionally lifting the upper and lower lids. Obtain medical attention immediately.
Ingestion	If the chemical has been confined to the mouth, give large quantities of water as a mouthwash. Ensure the mouthwash has not been swallowed. If the chemical has been swallowed, do NOT induce vomiting. Give 470 - 950ml (2 - 4 cups) of water or milk. Never give anything by mouth to an unconscious person. Obtain medical attention immediately.
Inhalation	Inhalation under normal use would not be expected as this product is supplied as an aqueous solution and no hazardous vapors are emitted; however, if inhalation should somehow occur, remove from exposure to fresh air immediately. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Seek medical aid immediately.

5. FIRE FIGHTING MEASURES

Special Exposure Hazard	Not applicable
Extinguishing Media	Not Combustible. Select extinguishing media appropriate to the surrounding fire conditions.
Protective Equipment	Wear appropriate protective clothing to prevent contact with skin and eyes. Wear a self-contained breathing apparatus (SCBA) to prevent contact with thermal decomposition products.

6. ACCIDENTAL RELEASE MEASURES

Personal Protection	Use proper personal protective equipment as indicated in Section 8.
Leaks and Spills	Absorb spill with inert material (e.g., dry sand or earth), then place into a chemical waste container. Neutralize spill with a weak acid such as vinegar or acetic acid.
Clean-up Procedures	Wash the spillage site with large amounts of water.

7. HANDLING AND STORAGE

Handling Precautions	Complete eye and face protection, protective clothing, and appropriate gloves must be used. Do not get in eyes, on skin, or on clothing. Wash thoroughly after handling. Remove contaminated clothing and wash before reuse. Do not ingest or inhale.
Storage Precautions	Store in a tightly closed container. Store in a cool, dry, well-ventilated area away from incompatible substances. Keep away from strong acids.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

Personal Protection

Eyes	Wear appropriate protective chemical safety goggles and face shield as described by OSHA's eye and face protection regulations in 29 CFR 1910.133 or European Standard EN166.
Skin	Wear appropriate gloves to prevent skin exposure.
Clothing	Wear appropriate protective clothing to prevent skin exposure.
Respirators	Not Applicable. Inhalation under normal use would not be expected as this product is supplied as an aqueous solution and no hazardous vapors are emitted.
Airborne Exposure	This material is supplied as an aqueous solution and will not be present in the atmosphere in normal use.
Exposure Limits	Potassium Hydroxide UK EH40, OEL (8hr TWA) 2mg/m ³ NIOSH, (8hr TWA) 2mg/m ³ ACGIH, Ceiling 2mg/m ³ OSHA, not listed

9. Physical & Chemical Properties

Molecular Formula	KOH Mixture
Physical State	1N aqueous solution. Colorless, odorless
pH	Alkaline
Solubility	Completely soluble in water
Bolling Point	104.5°C
Melting Point	-3.5°C
Flash Point	Not applicable
Flammability	Not flammable
Explosion Limits	Not applicable
Specific Gravity	1.15
Vapor Pressure	16.1 mm Hg @ 20°C

10. Stability & Reactivity

Chemical Stability	Stable
Conditions/Materials to Avoid	Incompatible materials, acids and metals
Incompatibilities with other Materials	Reacts with chlorine dioxide, nitrobenzene, nitromethane, nitrogen trichloride, peroxidized tetrahydrofuran, 2,4,6-trinitrotoluene, bromoform+ crown ethers, acids alcohols, sugars, germanium cyclopentadiene, maleic dicarbide. Corrosive to metals such as aluminum, tin, and zinc to cause formation of flammable hydrogen gas.
Hazardous Decomposition Products	Oxides of potassium

Hazardous Polymerization Has not been reported

11. Toxicological Information

Toxicity (Potassium Hydroxide) CAS# 1310-58-3: Oral, rat: LD50 = 273 mg/kg
Carcinogen Status Not listed by ACGIH, IARC, NIOSH, NTP, or OSHA

Potassium Hydroxide Solution is a severe eye, mucus membrane, and skin irritant.

12. Ecological Information

Mobility Completely soluble in water
Degradability Will degrade by reaction with carbon dioxide from the atmosphere to produce a non-hazardous product.
Accumulation No
Ecotoxicity Information not available. No long-term effects expected due to degradation. The preparation is already in dilute solution and adverse aquatic effects are not expected due to further dilution. The preparation is corrosive, and direct contact with fauna will cause burns.

13. Disposal Considerations

Waste Disposal Dispose of in a manner consistent with federal, state, and local regulations.

14. Transportation Information

	<u>Shipping Name</u>	<u>Hazard Class</u>	<u>UN Number</u>	<u>Packaging Group</u>
US DOT	Potassium Hydroxide Solution	8	UN1814	II
IATA	Potassium Hydroxide Solution	8	UN1814	II
ADR/RID	Potassium Hydroxide Solution	8	UN1814	II
IMDG Code	Potassium Hydroxide Solution	8	UN1814	II
Canadian TDG	Potassium Hydroxide Solution	8(9.2)	UN1814	Not Available

15. Regulatory Information

European/International Regulations
European Labeling in Accordance with EC Directives

Classification Corrosive

Hazard Symbol	C	
EC Number	215-181-3	
Risk Phrases	R35	Causes severe burns.
Safety Phrases	S1/2	Keep locked up and out of reach of children.
	S26	In case of contact with the eyes, rinse immediately with plenty of water and seek medical advice.
	S36	Wear suitable protective clothing.
	S37/39	Wear suitable gloves and eye/face protection.
	S45	In case of accident or if you feel unwell, seek medical advice immediately (show label where possible).

16. Other Information

MSDS Creation Date: 09/30/94

MSDS Revised: 09/24/98

The information above is believed to be accurate and represents the best information currently available to us. However, we make no warranty of merchantability or any other warranty, express or implied, with respect to such information. Liability is expressly disclaimed for loss or injury arising out of use of this information or the use of any materials designated. Users should make their own investigation to determine the suitability of the information for their particular purpose.

TABLE OF CONTENTS

1.0	Overview of This Manual	1-1
1.1	Introduction	1-1
1.2	Definitions and Warnings	1-2
1.2.1	Explanation of Graphic Symbols	1-2
1.2.2	Definitions	1-3
1.3	Unpacking	1-4
1.4	Verify Operating Voltage	1-5
2.0	Quick Setup Procedure	2-1
2.1	Tools Required	2-1
2.2	Electrolyte Maintenance	2-1
2.3	Sample Gas Connections	2-2
2.4	Electrical Connections	2-3
2.5	Standard Outputs	2-3
2.6	Powering Up	2-4
3.0	The Options	3-1
3.1	STAB-EL	3-1
3.2	Scale Range	3-1
3.2.1	Single Range Instruments	3-1
3.2.2	Multi-Range	3-1
3.3	Digital Displays	3-2
3.4	Analog Displays	3-2
3.5	Oxygen Alarm Options	3-3
3.5.1	Alarm Contacts	3-3
3.5.2	Single Set-point Alarm	3-3
3.5.3	Dual Set-point Alarms	3-3
3.5.4	Special Alarm Configurations	3-4
3.5.5	Changing or Checking the Alarm Set-Point	3-4
3.6	Pressure Regulator	3-5
3.6.1	Standard Regulator	3-5
3.6.2	Absolute Pressure Regulator	3-5
3.7	Filter	3-5
3.7.1	Replacement Elements	3-5
3.8	Filter and Regulator	3-6
3.9	Flow Control Valve	3-6
3.10	Stainless Steel Outlet Tubing	3-7
3.11	Nicad Battery Pack	3-7
3.11.1	Operation	3-8

3.12	Inboard Pumps	3-10
3.12.1	Pump Control	3-11
3.12.2	External Pump Control	3-11
3.12.3	Externally Powered Pump	3-12
3.13	Output Signals	3-12
3.13.1	4-20 mADC Fully Isolated Output	3-12
3.13.2	Optional Outputs	3-12
3.13.3	RS232C	3-13
3.14	Quick-Start	3-14
3.15	Gas Scale Factor	3-14
3.16	Audible/Visual Alarm	3-14
3.17	Panel Mounting	3-15
3.18	Remote Range Indication	3-16
3.19	Off Primary Range Indication	3-16
3.20	Electrolyte Condition	3-16
3.21	External Control of Sensor Voltage	3-17
4.0	Output	4-1
4.1	Standard Output	4-1
4.2	4-20 mADC	4-1
4.3	Alarms	4-2
4.3.1	High Alarm	4-2
4.3.2	Low Alarm	4-2
4.3.3	Electrolyte Alarm	4-2
4.4	Switched AC	4-2
4.5	Ground	4-3
5.0	Operation	5-1
5.1	Sampling Considerations under Normal Operation	5-1
5.2	Sampling Considerations when Calibrating	5-3
5.2.1	Calibration Standards	5-3
5.2.2	Process Conditions During Calibration	5-3
5.3	Purging the Analyzer	5-3
5.4	Regulators	5-4
5.5	Background Gas Correction Factor	5-4
5.6	Control Potentiometers	5-5
5.6.1	Zero Adjustment	5-5
5.6.2	Span Adjustment	5-6
5.7	Calibration Frequency	5-7
5.8	Factory Settings	5-7
5.9	Electrolyte Condition	5-7

5.10	Controls	5-7
5.10.1	Range Selection Switches	5-8
5.10.2	Power	5-8
5.10.3	Pump Control	5-8
5.10.4	Quick-Start	5-8
6.0	Theory of Operation	6-1
6.1	The Sensor	6-1
6.2	The STAB-EL Electrolyte System	6-2
6.2.1	STAB-EL and Carbon Dioxide	6-2
6.2.2	STAB-EL and Gases in the Halogen Family	6-3
6.2.3	STAB-EL with Nitrogen- and Sulfur-Containing Acid Gases ...	6-3
6.2.4	Capability of the STAB-EL System	6-3
6.3	Regulating Sensor Input Voltage	6-4
6.4	Effects of Sample Flow Rate, Pressure, and Temperature	6-5
6.4.1	Positive Pressure Operation	6-5
6.4.2	Pressure Effects on Sensor Performance	6-6
6.4.3	Negative Pressure Operation	6-6
6.4.4	Temperature Effects on Sensor Performance	6-7
7.0	Service	7-1
7.1	Maintenance	7-1
7.1.1	Calibration	7-1
7.1.2	Sensor Maintenance	7-1
7.2	Storage Conditions	7-2
7.3	Shipping	7-3
7.4	Replaceable Spare Parts List	7-3
7.5	Troubleshooting	7-4
8.0	Safety	8-1
8.1	General Warnings	8-1
8.2	Electrolyte Material Safety Data Sheet (MSDS)	8-2
9.0	Specifications	9-1
10.0	Warranty	10-1
Index	i-1

1.0 Overview of This Manual

This manual is organized into sections that will provide progressively more detailed information about the features and capabilities of the Delta F Corporation A-Plus Oxygen Analyzer. Section 1.0 provides information about this manual, and defines some terms that will occur throughout the manual.

In Section 2.0, we will describe a procedure to get the analyzer up-and-running quickly. The A-Plus Oxygen Analyzer has many features that will be discussed in detail in later sections of this manual.

Section 2.0 assumes that the user has an instrument that does not include options. If your instrument has any of the options listed below, some changes to the Quick Setup Procedure in Section 2.0 may be necessary. These changes can be found in Section 3.0 under the selected option.

Option	Section	Change to Quick Start-up Procedure
Multi-Range	3.2.2	Scale Selection
Pressure Regulator	3.6	Plumbing Setup
Filter	3.7	Plumbing Setup
Filter and Regulator	3.8	Plumbing Setup
Flow Control Valve	3.9	Setting Flow Rate
Pump	3.13	Start-up Sequence
Quick-start	3.15	Start-up Sequence
Panel Mounting	3.18	Enclosure Mounting

Section 3 briefly discusses optional equipment and features. Useful information about specific options for the analyzer can be found in this section. Section 4 describes how the analyzer can be connected to external devices. Details about optional alarm contacts and output signals can be found in this section.

Section 5 discusses Operation. Section 6 covers Theory of Operation. The remainder of the manual covers Service (Section 7), Safety (Section 8), Specifications (Section 9), and Warranty (Section 10).

1.1 Introduction

Many factory options are available for the A-Plus Oxygen Analyzer. However, the Quick Setup procedure, Section 2.0, assumes that the user has a standard analyzer without options.

The standard analyzer is a single-range instrument equipped with an analog meter to display oxygen concentration in percent or parts per million (ppm). Connections to the analyzer are made to 1/8 inch stainless steel compression inlet and outlet fittings at the back of the analyzer. An internal flowmeter is used display sample flow rate. The instrument provides an output signal of 0-10 VDC.

A list of optional equipment is shown in Section 3.0 of the Table of Contents. Figure 1-1 shows an outline drawing of the standard A-Plus Oxygen Analyzer. Figure 1-2 shows some of the major internal components.

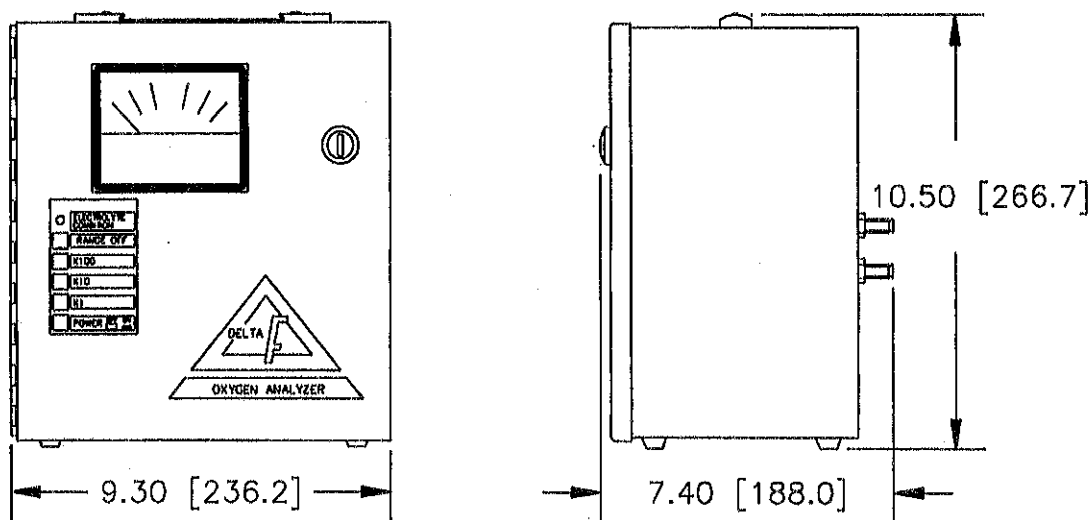


Figure 1-1. Outline Dimension of the A-Plus Oxygen Analyzer

1.2 Definitions and Warnings

Before setting up the analyzer, some definitions and warnings need to be stated.

1.2.1 Explanation of Graphic Symbols



This symbol alerts you to the presence of "Dangerous Voltage" within the analyzer's enclosure. This voltage may be of significant magnitude to cause a risk of electrocution. It also alerts the user that if procedures are not followed, damage to the analyzer may result.



This symbol alerts you to the presence of important operations and/or maintenance instructions in this manual.

1.2.2 Definitions

DANGER: Indicates that the information is provided to alert the user to a potential personal hazard, or the potential of damage to the product.

CAUTION: Indicates that the information is provided to alert the user to the potential of damage to the instrument, or an incorrect result if the directions are not followed.

NOTE: Indicates that the information is provided to increase the efficiency, accuracy or reliability of the analyzer.

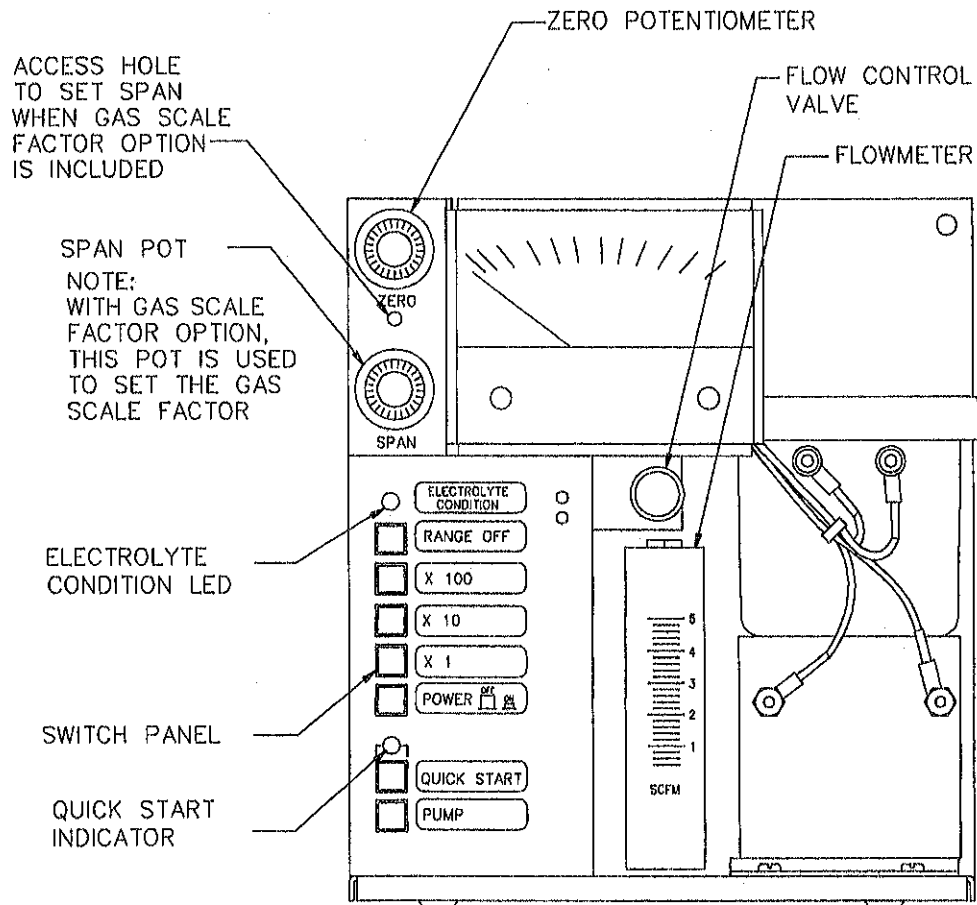


Figure 1-2. Major Internal Components in the A-Plus Oxygen Analyzer

DANGER



Potentially hazardous AC voltages are present within this instrument. Leave all servicing to qualified personnel. Disconnect the AC power source when installing or removing AC power or data signal connections as well as when installing or removing the sensor or the electronics, or changing or draining electrolyte.

CAUTION



Do not setup or operate the Oxygen Analyzer without a complete understanding of the instructions in this manual. Chapter 8.0 Safety, contains safety instructions and the electrolyte Material Safety Data Sheet (MSDS).

Do not connect this analyzer to a power source until all signal and plumbing connections are made.

RF DISCLAIMER

This analyzer generates small amounts of radio frequency energy. There is no guarantee that interference to radio or television signals will not occur in a particular installation. If interference is experienced, turn-off the analyzer. If the interference disappears, try one or more of the following methods to correct the problem:

1. Reorient the receiving antenna.
2. Move the instrument with respect to the receiver.
3. Place the analyzer and receiver on different AC circuits.

1.3 Unpacking

When unpacking the instrument, notice the condition of the package and its contents. If any damage is apparent, immediately notify the carrier and Delta F Corporation (617) 935-4600. Do not proceed with the installation.

Check the contents against the packing slip to make sure that the shipment is complete. Unattached equipment may be included with the analyzer in supplemental packaging.

All analyzers are shipped with the following parts:

Two Bottles of EO-5 Electrolyte	P/N DF-E05
Power Cord w/Connector (115 VAC)	P/N 59017237
or w/o Connector (230 VAC)	P/N 59036140
This Instruction Manual	P/N 99000003

NOTE: Any damage claims and shortage reports must be reported to Delta F Corporation within 10 days after receipt of the shipment

Keep the packing materials for future use. These materials are designed to protect the analyzer and should be reused if shipping becomes necessary.

Open the analyzer door and inspect the inside of the unit to be sure that no components have loosened or dislodged. Remove any shipping materials.

1.4 Verify Operating Voltage

The A-Plus Oxygen Analyzer is configured at the factory to operate on 90-120 VAC or 220-250 VAC as specified on the purchase order. The factory setting is indicated on the back panel of the analyzer near the power receptacle.

For 115 VAC operation, a 1.0 Amp fuse (P/N 45000100) is required; for 230 VAC operation, a 0.5 Amp fuse (P/N 45000051) is required. The standard analyzer uses less than 15 watts of power; maximum power utilization with all options is 25 watts.

2.0 Quick Setup Procedure

In this procedure, it is assumed that the analyzer is not equipped with options (standard analyzer configuration) and has a voltage output of 0-10 VDC. Options may affect the setup procedure. If your analyzer is equipped with options, refer to Section 1 and Section 3 to determine necessary changes to the setup.

2.1 Tools Required

A standard analyzer configuration requires a 3/16" flat-blade screwdriver to access the sensor for electrolyte charging and draining, and 7/16" and 1/2" open-end wrenches are needed to make the gas connections.

2.2 Electrolyte Maintenance

The sensor is shipped dry and must be charged with electrolyte before it is operated.

DANGER



The electrolyte is a caustic solution. Review the Material Safety Data Sheet (MSDS) in Section 8.2 before handling the electrolyte solution.

DANGER



Use only Electrolyte DF-EO5 for the A-Plus Oxygen Analyzer. Failure to do so will void warranty.

- a. Open the enclosure door.
- b. Remove the four screws at the back of the instrument, Figure 2-1.
- c. Lift and slide the instrument out of the front of its enclosure.
- d. Unscrew the black cap from the electrolyte reservoir.

NOTES:

1. If the sensor is being charged with the electrolyte for the first time, the reservoir should be filled with deionized or distilled water up to the maximum level line on the reservoir label.

Allow the sensor to sit for 15 minutes. Check for leaks. If a leak is found, invert the instrument to drain the water. Call the factory, (617) 935-4600, before proceeding.

2. If the electrolyte is being changed, remove the reservoir cover and drain the electrolyte into a suitable (polyethylene, etc.) container for proper disposal, Figure 2-2. Thoroughly flush the sensor 2 or 3 times with distilled or deionized water before recharging. Properly dispose of the spent electrolyte and rinse water.
 3. **Before applying power, add electrolyte**, and for low range instruments, purge the sample line.
- e. Add the entire contents of one bottle of electrolyte (DF-EO5) to the sensor. Though not required, distilled or deionized water can be added to raise the electrolyte level to the maximum mark on the reservoir. Replace the screw cap and hand tighten securely.
 - f. Reinstall the A-Plus chassis in its enclosure by repeating steps a. to c. in the reverse order.

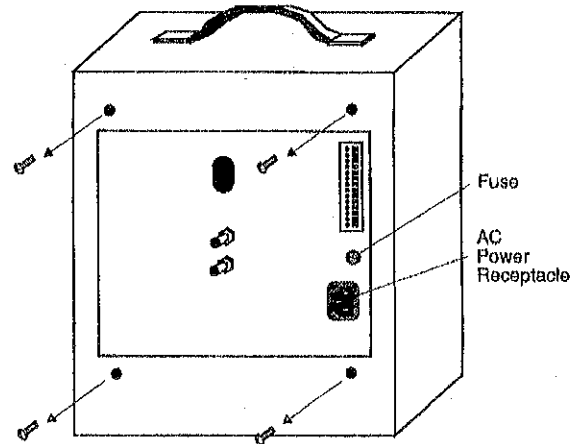


Figure 2-1. Remove Four Screws from Rear of Enclosure.

2.3 Sample Gas Connections

For applications where the gas pressure is between 1.0 and 5.0 psig, use a flow control valve between the inlet to the instrument and the gas line to set flow rate. Above 5 psig, use a pressure regulator such a Delta F p/n DF-PRI-5.

NOTE: It is very important to use a high-quality pressure regulator or flow control valve, and fittings to avoid leaks into the inlet gas stream.

The sample gas inlet and outlet lines at the back of the instrument have 1/8" compression stainless steel bulkhead fittings. Before connecting the gas lines to the analyzer, install a ferrule on the tubing ends using a spare fitting. Connect the sample inlet line and the outlet line to the bulkhead fittings at the back of the analyzer. A backup wrench is not needed at the analyzer fitting. An anti-torque plate on the inlet bulkhead fitting, inside the cabinet, prevents rotation of the fitting. Do not over-tighten the fitting nuts.

CAUTION



If your installation requires long tubing runs, or has many bends or fittings downstream of the analyzer, a flow rate of 2.0 scfh may impose a pressure at the sensor that exceeds 3.0 psig. If this is the case, use larger outlet tubing and/or reduce the complexity of the outlet gas line.

Open the analyzer door to observe the flow meter. Slowly increase the flow rate (using a valve or regulator installed in the inlet gas line) until 2.0 scfh of sample gas is flowing.

2.4 Electrical Connections

Make sure the power switch in the analyzer is in the OFF position, Figure 1-2. Plug the supplied line cord into the receptacle at the back of the analyzer before connecting the line cord to the power. Verify the operating voltage before applying power.

2.5 Standard Outputs

A 0-10 VDC output signal that is proportional to the range of the instrument is available at the connector terminals at the back of the analyzer, Figure 2-3. The minimum impedance of the load is 10 k Ω .

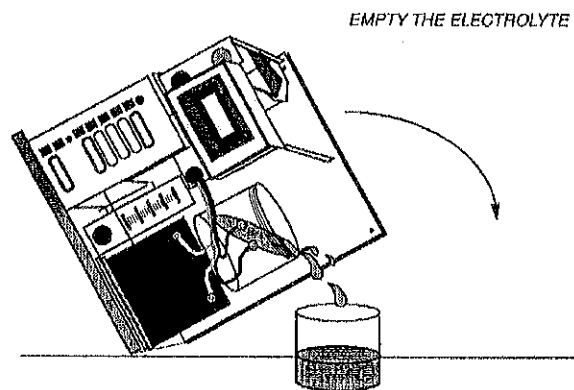


Figure 2-2. Removing Electrolyte.

2.6 Powering Up

After all electrical connections are made and gas is flowing at 2.0 scfh, turn on power.

CAUTION



Over-pressurizing the sensor can result in permanent damage to the sensor. Limit the back-pressure to the analyzer to 3 psig. The analyzer should take less than 5 minutes to come on scale. This completes the quick setup of the standard analyzer.

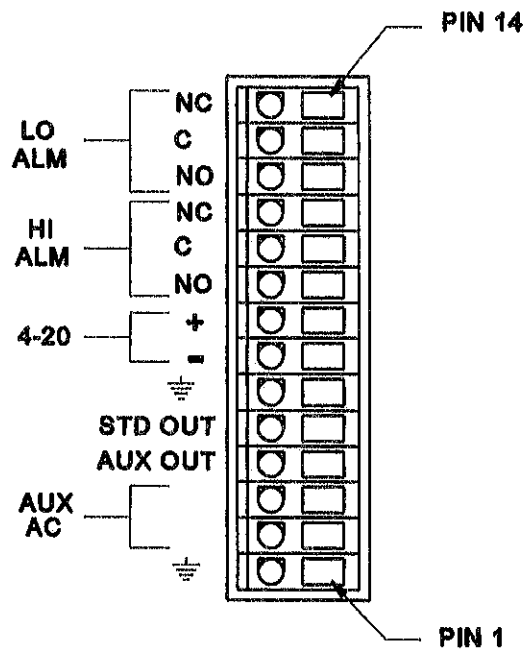


Figure 2-3. Output Connector

3.0 The Options

3.1 STAB-EL

The A-Plus Oxygen Analyzer may be equipped with Delta F's patented STAB-EL electrolyte system. STAB-EL allows the sensor to be used with gases that contain acidic components such as Cl_2 , HCl, CO_2 , SO_2 , H_2S , NO_x , etc. These gases are commonly termed "acid gases".

For many applications, the STAB-EL electrolyte system, together with the unique, non-depleting, electrochemical sensor electrodes eliminates the necessity of scrubbing the acidic components prior to making an oxygen measurement. STAB-EL is described in Section 6.2.

3.2 Scale Range

The A-Plus Oxygen Analyzer operates over a wide range of oxygen concentrations. It can be factory ordered in a single range or with a triple range configuration. The following tables list the ranges that are available at the time of order.

3.2.1 Single Range Instruments

Single Range Oxygen Analyzers

Range in ppm O_2	Identification Code	Range in % O_2	Identification Code
0-5000	FA15000	0-25	PA10025
0-1000	FA11000	0-10	PA10010
0-500	FA10500	0-5	PA10005
0-100	FA10100	0-2.5	PA10X25
0-50	FA10050	0-1	PA10001
0-10	FA10010		

3.2.2 Multi-Range

On powering up a multi-range instrument, press the selector switch corresponding to the highest range. (The range switch displays a white color when selected.) The panel meter immediately responds and holds a position beyond full scale. Normally, within a

minute or two, the meter reading falls within scale and continues toward the equilibrium point.

Switching to the lower scales on multi-range instruments should be done only when the meter is able to read within range on that scale.

In general, time to equilibrium increases at lower oxygen levels in the sample gas.

Multi-Range Oxygen Analyzers

Range in ppm O₂	Identification Code	Range in % O₂	Identification Code
0-100/1000/10000	FA3111X	0-5/10/25	PA35125
0-50/500/5000	FA35550	0-1/10/25	PA31125
0-10/100/1000	FA31110	0-1/5/25	PA31525
0-5/50/500	FA30555	0-.25/2.5/25	PA3XX25
0-1/10/100	FA30111	0-.1/1/10	PA3XX10
----	---	0-.05/5/5	PA3XX05

3.3 Digital Displays

Three version of the digital meter are available for the A-Plus Oxygen Analyzer. One version has no alarms, another has dual set-point alarms, and the third uses a single set-point alarm. In addition, depending on instrument range, the display can be a 3½ digit LCD or a 4½ digit LCD. All digital meter configurations are similar except for the alarm controls.

3.4 Analog Displays

Two optional versions of the analog meter are available for the A-Plus Oxygen Analyzer. One version has dual set-point alarms, and the other uses a single set-point alarm.

3.5 Oxygen Alarm Options

The A-Plus Oxygen Analyzer can be equipped with an oxygen alarm option. Up to two oxygen alarms are available on either analog or digital meters. The operation of analog and digital meter alarms is identical, although the location of the set-point adjustment potentiometers is different.

The alarm set-points are fully adjustable from zero to full scale on the selected range. However, on multi-range analyzers the oxygen concentration associated with an alarm set-point *holds a relative position* as you switch from range to range. If you set the alarm for mid-scale on one range, the alarm will occur at mid-scale on the other ranges.

3.5.1 Alarm Contacts

There is a separate SPDT (Form C) relay for each oxygen alarm. The contacts are rated 5 Amps at 115 or 230 VAC, and 3 Amps at 30 VDC, resistive loads. Contact material is gold flashed silver alloy.

The alarm contacts are accessible on the 14-pin rear panel connector, see Figure 2-3. Contact designations assume that NORMAL is a "No Alarm Occurring" condition, NC is connected to C. Consequently, when an alarm occurs the Normally Open contact connects to Common, and the Normally Close contact disconnects from Common.

With an audible alarm option, the reverse is true. Normally closed contacts connect to common during an alarm, see Section 3.16, Audible/Visual Alarms.

The alarm relays feature failsafe operation. If a power failure occurs, or the instrument power is turned off, the alarm contacts will switch to the alarm position.

3.5.2 Single Set-point Alarm

The single set-point alarm is configured to alarm if the oxygen concentration is higher than the set-point.

3.5.3 Dual Set-point Alarms

Dual alarms consist of one high and one low alarm. The high alarm will signal an alarm condition if the oxygen concentration is higher than the set-point. Conversely, the low alarm will signal an alarm condition if the oxygen concentration falls below the set-point.

3.5.4 Special Alarm Configurations

On special order, it is possible to choose two high or two low alarms. On the digital meters, two high alarms are present if there are two red push buttons; two low alarms are present if there are two green push buttons. On the analog meter if there are two buttons of the same color the association between buttons and pots is as follows: left button uses top potentiometer, right button uses bottom potentiometer. Note: Potentiometers are accessed through the two holes below the meter, Figure 3-1.

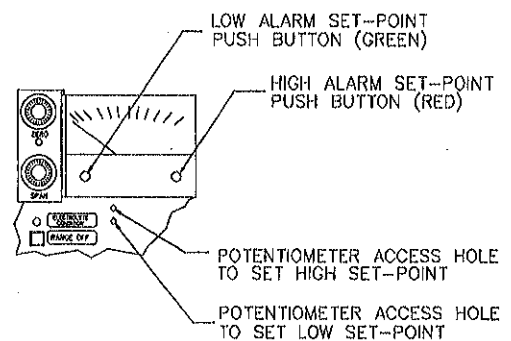
Figure 3-1 shows the location of the optional analog and digital meter alarm controls.

3.5.5 Changing or Checking the Alarm Set-Point

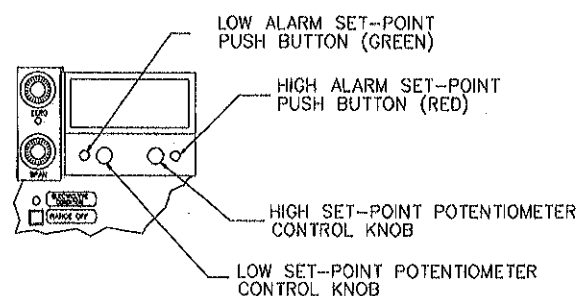
The digital meters display the current oxygen concentration until an alarm set-point push button is pressed. The push buttons are located just below the meter face. On dual set-point systems the high alarm push button is red and the low alarm push button is green. To check the alarm set-point depress and hold the desired push button. The meter will display the alarm set-point.

To change the set-point press the push button and adjust the associated alarm adjustment pot until the meter reads the appropriate set-point value.

On instruments that have analog meters, the pots are located on the front panel, just above the range switch, Figure 3-1. The pots are colored coded with their push buttons. A screwdriver is required to set the pot.



ANALOG METER ALARM CONTROLS



DIGITAL METER ALARM CONTROLS

Figure 3-1 Meter Alarm Controls

On digital meters the pots are located right next to the push buttons, and an adjustment knob is provided.

NOTE: On 4½ digit meters, the digital meter reading will lag the actual analog signal by a few seconds. Alarm contacts will trip before the alarm set-point value is displayed.

3.6 Pressure Regulator

The 316 stainless steel sample gas pressure regulators mount on the back panel. The option includes a bracket, hardware and a formed 1/8 inch stainless steel tube with fittings that connect the regulator outlet to the analyzer inlet. The sample gas line is connected to the 1/8 inch compression fitting at the regulator inlet.

3.6.1 Standard Regulator

The standard pressure regulator is rated for 3000 pounds per square inch gauge (psig) inlet pressure. It regulates down to 0-10 psig. Five psig is the minimum required inlet pressure to the regulator.

3.6.2 Absolute Pressure Regulator

The absolute pressure regulator is rated to 1000 psig inlet pressure. The outlet pressure range can be regulated from 4 pounds per square inch absolute (psia) to 25 psia (-10 psig to +10 psig).

3.7 Filter

A 316 stainless steel filter housing can be externally mounted. A standard coalescing filter element is supplied with this option. The option includes a bracket, hardware and a formed 1/8 inch stainless steel tube with fittings that connect the filter outlet to the analyzer inlet. The sample gas line is connected to the 1/8 inch compression fitting at the filter inlet.

3.7.1 Replacement Elements

On units equipped with a filter, the filter element should be replaced on a periodic basis. The life of the filter is dependent on the nature of the gas that is being analyzed. Thus, a general statement about the frequency of filter replacement cannot be provided. Delta F suggests that the filter be inspected on a weekly basis until the operator gains an understanding of the effect of the sample gas on the filter.

Replacement filters can be obtained from Delta F Corporation (617) 935-4600. Two filter grades are available:

Fine grade (BQ) (< 1 micron)	P/N DF-F2R-B
Coarse grade (DQ) (> 1 micron)	P/N DF-F2R

3.8 Filter and Regulator

The filter and regulator assembly includes a bracket, hardware and a formed stainless steel tube with fittings. The assembly is mounted on the back of the analyzer.

3.9 Flow Control Valve

A stainless steel flow control valve can be mounted upstream of the sensor to regulate flow rate when sample pressure is <5 psig. The valve is shown mounted in Figure 1-2. Make sure that the valve is fully closed (clockwise) before connecting the sample line to the analyzer.

After gas connections are made, open the control valve slowly until 2 standard cubic feet per hour (scfh) of gas is flowing.

NOTE: For gases other than nitrogen or air, the flow rate may be different. The table below lists the correct flow rate to use with common background gases. If the background gas that is used is not listed in the table, contact the factory at (617) 935-4600 for the recommended flow rate setting.

Table of Flowmeter Settings for Background Gases

Background Gas	Flowmeter Setting (scfh)
Argon	2.4
Ethylene	2.0
Nitrogen or Air	2.0
Carbon Monoxide	2.0
Methane	1.5
Hydrogen	0.5
Helium	0.7

3.10 Stainless Steel Outlet Tubing

A stainless steel outlet line can be fitted to the flowmeter outlet for applications that require high integrity outlet connections such as toxic or explosive gas measurement applications.

3.11 Nicad Battery Pack

The A-Plus Battery Pack Option allows the analyzer to operate without a source of AC power for an extended period of time. With this option, the A-Plus can be used as a portable instrument, and it also provides continuous operation during power failures.

The nickel-cadmium (nicad) cells and power supply attach externally to the lower rear of the A-Plus enclosure in a 9" x 3.25" x 2.12" metal housing. The housing contains six D-size, 4000 mAh, nicads with a charging circuit and connecting cable.

NOTE: The battery receives a trickle charge whenever the instrument is connected to AC power, even if the POWER switch is OFF.

The battery charging circuit is a constant current system which continuously charges the batteries whenever the instrument is connected to AC power. Charging occurs as

long as the instrument is connected to line power, even if the POWER switch is OFF. However, charging time is affected by whether the instrument power switch is ON or OFF. Shortest charging time occurs with the POWER switch OFF. From full discharge to full charge, 24 hours is required.

With a full charge, operating time depends on the options installed, see the table below.

Configuration	Operating Time (hours)*
Standard Analyzer	47
Analyzer with STAB-EL	25
Analyzer with Battery Powered Pump	29
Analyzer with STAB-EL and Pump	19

*All times assume start from full charge. Actual times may vary due to operating temperature, battery aging, etc.

When operating on battery power, an automatic circuit continuously monitors battery condition. When it is time to recharge an LED flashes. In addition, a push-button activated feature provides verification that the battery is fully charged.

3.11.1 Operation

a. Low Battery Warning

An LED located to the left of the flowmeter, inside the A-Plus cabinet, will begin flashing if the battery voltage drops below 7.2 volts when the instrument POWER switch is ON. When the LED begins flashing, approximately one hour of operation remains.

NOTE: If the instrument is operated after this light begins flashing, the low battery voltage may prevent the 0-10 volt output from reaching 10 volts. This means that front panel readings over 90% of full scale will read inaccurately. However, the instrument continues to measure oxygen accurately up to 90% of full scale. The output voltage and the display cannot indicate higher oxygen concentrations.

b. Push to Test

Behind the A-Plus cabinet door, to the left of the flowmeter there is a PUSH TO TEST button. When the POWER switch is ON, the PUSH TO TEST button can activate a battery condition test. Pressing the button temporarily disconnects the battery from the charging circuit and connects it to a resistive load. The button should be held down for 10 seconds. If the battery voltage remains above 8.1 volts, the LED will illuminate to indicate that the battery is fully charged.

NOTE: The battery condition test should only be performed when the instrument is connected to AC power and the POWER switch is ON. During the test a precise resistive load is imposed on the battery and the resultant battery voltage measured. If the analyzer is not connected to AC power the battery will be powering both the unit and the resistive load, which may cause a fully charged battery to appear less than fully charged.

c. Adding or Changing Electrolyte with the Battery Pack Option

If service to the battery pack is required or when adding or changing electrolyte, the battery pack must be removed from the enclosure. A flat-blade (3/16") screwdriver is required.

1. Disconnect the instrument from AC power. Turn the POWER switch to the OFF position.
2. At the rear of the instrument, remove the two screws on the top of the battery pack. Also, remove the single screw on the bottom rear of the battery pack, Figure 3-2.
3. The power supply printed circuit board is mounted under the metal cover, Figure 3-2. Carefully remove the cover. The circuit board is connected to the batteries via two wires that have polarized connectors which snap on the battery pack,

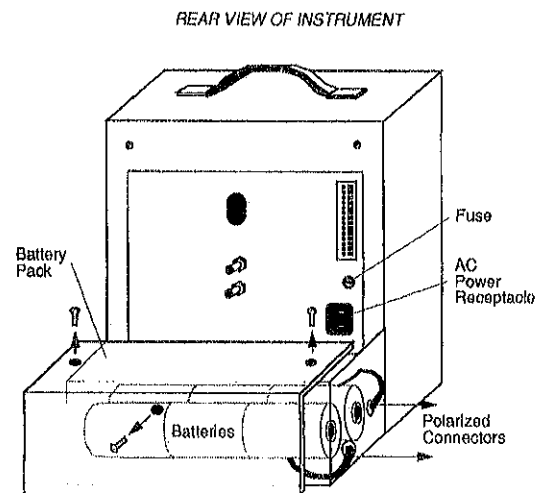


Figure 3-2. Removing Battery Pack Cover

Figure 3-3. Unsnap the two connectors.

4. The printed circuit board is connected to the analyzer by a cable which will be disconnected in Step 6. Locate the two screws which secure the battery pack enclosure to the rear of the A-Plus cabinet. These screws are on the wall of the box just above the battery pack. Remove these screws and the two screws above them, Figure 3-4.
5. From the front of the A-Plus, open the cabinet door, and lift the chassis. Pull the chassis forward about two inches out of the cabinet. A connector access hole will be uncovered behind the battery pack enclosure.
6. The battery printed circuit board cable passes through the connector access hole. Pull about six inches of the cable out of the A-Plus to reveal the nine pin connector. Unplug the connector.
7. The entire battery pack may now be removed.

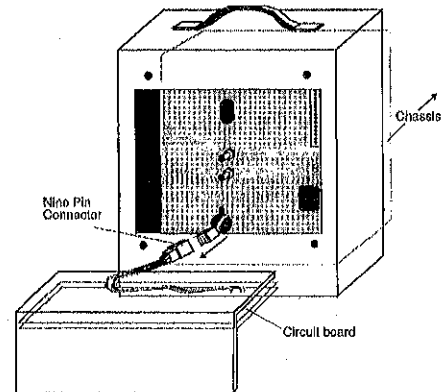


Figure 3-3. Battery Power Supply PCB and Connecting Cable

With the battery pack removed, electrolyte maintenance can be performed according to Section 2.2. Reverse the above steps to reconnect the battery pack to the enclosure.

3.12 Inboard Pumps

Two inboard diaphragm pumps are offered as optional equipment: one version uses line power; the other is battery powered.

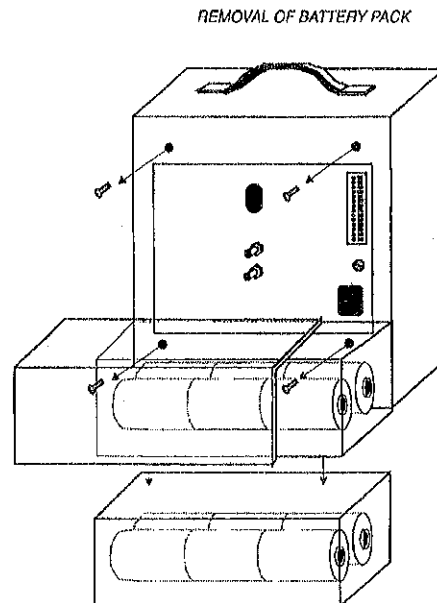


Figure 3-4. Remove Four Screws that Secure the Chassis to the Enclosure.

If a gas sample stream is between 2.0 psig vacuum (12.7 psia) and 0.2 psig, a pump is recommended. If the analyzer is equipped with a pump, it will also have a flow control valve in the flowmeter.

When the analyzer has a pump, and the analyzer's outlet is vented to atmosphere, the sensor will operate under negative pressure. The downstream flow control valve (in the flow meter) between the sensor and the low-pressure side of the pump, allows only slight pressure changes at the sensor when adjusting the sample flow rate.

NOTE: Do not use an upstream valve to control the flow rate if the analyzer is operating on a pump.

If a pressure change causes the flow rate to move outside the recommended range, an adjustment of the flow may be made downstream of the sensor. If the adjustment is not made, the analyzer may not operate within its stated accuracy.

Analyzers with a pump are calibrated with the pump operating even if the calibration gas has sufficient pressure to preclude the use of the pump. The operating pump will create a pressure condition at the sensor that simulates the operating condition.

3.12.1 Pump Control

If the instrument has a sample gas pump, pressing the switch, Figure 1-2, will turn the pump ON and OFF. The switch displays a green color when the pump is switched ON.

3.12.2 External Pump Control

The internal sample pump may be remotely controlled by a switch that is customer provided. To control the internal pump connect the closure to rear panel connector terminals marked AUX AC, Figure 2-3. The voltage and current at AUX AC are, respectively, 115 VAC and 0.06 Amps or 220 VAC and 0.03 Amps.

The front panel PUMP switch is series connected to the pump. The front panel switch must be turned on in order for the external switch to operate. Either switch may be turned off to halt pump operation.

Pump power is supplied from the instrument POWER switch, so the pump will turn off when the instrument is turned off.

AUX AC terminals are normally used to provide switched AC power to a remote chart recorder. This normal function is not available with the External Pump Control option.

3.12.3 Externally Powered Pump

The internal sample pump in this instrument can be operated from an externally provided AC power source of 115 VAC, or 220 VAC at 50 to 60 Hz. The pump voltage corresponds to the line voltage specified at the time the analyzer was ordered. Power is applied to the rear panel connector terminals marked AUX AC. Connect AC HI to the top AUX AC terminal and AC LO to the bottom AUX AC terminal. Pump power consumption is approximately 5 Watts.

The front panel pump switch is series connected to the pump. The front panel switch must be turned on in order for the pump to operate.

AUX AC terminals are normally used to provide switched AC power to a remote chart recorder. This function is not available with the Externally Powered Pump option.

3.13 Output Signals

The standard output is 0-10 VDC. Optional outputs are available at the time of order. These include those mentioned in Sections 3.14.1, 3.14.2, and 3.14.3.

3.13.1 4-20 mADC Fully Isolated Output

This output provides a 4-20 mADC output that is completely isolated from any other output of the instrument. The 4-20 mADC signal directly corresponds to the range selected. For example, on a three range oxygen analyzer the 4-20 mADC output is fully scaled over the specific range selected. Maximum load resistance for this output is 600 Ω . The A-Plus provides a loop supply of approximately 15 VAC. The 4-20 mADC option must be selected at the time of order.

NOTE: The 4-20 mA output is only valid when the analyzer is operating on AC power. When operating on batteries, this output does not provide valid information.

3.13.2 Optional Outputs

Other output options are available at the time of order. These include 0-100 mVDC, 0-1 VDC or 0-5 VDC, etc. These outputs are also scaled over the specific range that is selected in a multi-range instrument.

3.13.3 RS232C

With this option the instrument can provide oxygen readings to an RS-232 port in a computer or dumb terminal. By using a voltage-to-RS-232C converter the A-Plus provides a digital representation of the observed oxygen concentration.

NOTE: The external RS-232 converter does not sense range changes and consequently cannot automatically scale readings. The oxygen output values sent to the external converter are range dependent and therefore selecting the correct concentration range is very important.

With this option on a multi-range analyzer, the output would be valid for only one range at a time. The user can manually reconfigure the converter for another range. To create custom configurations or communication parameters, please refer to the manual and software supplied with this option.

The table below lists the connections required for the default configuration. Carefully examine the wiring and interconnection table below prior to installation. When wired as indicated by the table, the communication parameters default to a BAUD of 300, 8 bit word length, 1 stop bit and no parity. Regardless of the communication configuration, the instrument must always supply +15 VDC (AUX AC) and 0-10 VDC (STD OUT) to the externally-mounted "Voltage to RS-232C" converter.

Pin Number	External RS232 Module Connections	Computer and Instrument Connections
1	+IN	Pin 5 of instrument, STD OUT
2	-IN	Pin 6 of instrument, ground (GND)
3	DO1	Not Applicable
4	DI0	Not Applicable
5	DO0	Not Applicable
6	DEFAULT	GND for Default Configuration
7	TRANSMIT	Computer or PC serial port, pin 3 of DB25
8	RECEIVE	Computer or PC serial port, pin 2 of DB25
9	+VS	Pin 3 of instrument, AUX AC (+15 VDC)
10	GND	Pin 1 of instrument, computer or PC pins 1 & 7 of DB25, GND

3.14 Quick-Start

The Quick-Start feature is used to obtain low ppm readings from the A-Plus quickly. This feature rejects oxygen within the sensor that would otherwise desorb slowly as the sample gas reaches the lowest level of oxygen content. Quick-Start is used only when the gas sample is expected to be below 10 ppm. For gas compositions above 10 ppm, Quick-Start has little or no effect.

Quick-Start is initiated by **momentarily** pressing the front panel button marked Quick-Start. Its operation is indicated by the LED above the button, Figure 1-2. After the Quick-Start sequence finishes, the A-Plus automatically returns to normal operation. The display will indicate actual oxygen concentration.

NOTE: In some cases a negative oxygen reading may occur immediately following Quick-Start. An accurate reading will be displayed after a few minutes.

3.15 Gas Scale Factor

The optional Gas Scale Factor (GSF) is used to correct for changes in the rate of oxygen diffusion when background gases other than nitrogen are present in the sample gas. This option is factory-set for a specific gas at the time or order. In many applications, a GSF other than 1.00 is not required. However, for some background gases with significantly different diffusivities compared to nitrogen (such as helium or hydrogen), the GSF can be important. Enter the GSF of the sample gas by dialing in the percentage (by volume) of the background gas.

CAUTION



The GSF for the gas used to calibrate the system may be different from that used during analysis. If the GSF is changed to reflect the composition of the calibrating gas, be sure to reset the GSF before resuming sample analysis.

3.16 Audible/Visual Alarm

The A-Plus Oxygen Analyzer can be equipped with an audible and visual alarm function. The audible alarm is mounted on the cabinet door. The alarm transducer has a sound level in excess of 80 db. A high intensity LED, mounted in the enclosure door near the lock, provides a visual alarm.

There are two adjustable set-point high alarms. Each alarm has an independent set of SPDT (Form C) contacts. An alarm occurs when the oxygen level is above the set-point. When an alarm condition occurs, the audible alarm will sound, and it will continue to sound unless the alarm(s) clear by themselves or the CANCEL push-button on the front panel is momentarily pressed. In addition, during an alarm condition the front panel visual alarm indicator will blink. This indicator continues to blink until the alarm condition clears. The visual indication cannot be canceled by the CANCEL push-button. Cancellation of the audible portion of the alarm does not effect the alarm relay.

NOTE: With the addition of the audible alarm feature, the alarm relay contact functions, indicated on the analyzer rear panel, are reversed. In other words, when an alarm condition is *not* occurring the N.O. (Normally Open) contact is connected to the common contact, and the N.C. (Normally Closed) contact is open. (See Section 3.5.1 Alarm Contacts.)

3.17 Panel Mounting

A panel mount is available for the A-Plus Oxygen Analyzer. Figure 3-5 shows the outline dimensions of the panel-mounted analyzer; Figure 3-6 gives the cutout dimensions for mounting the panel.

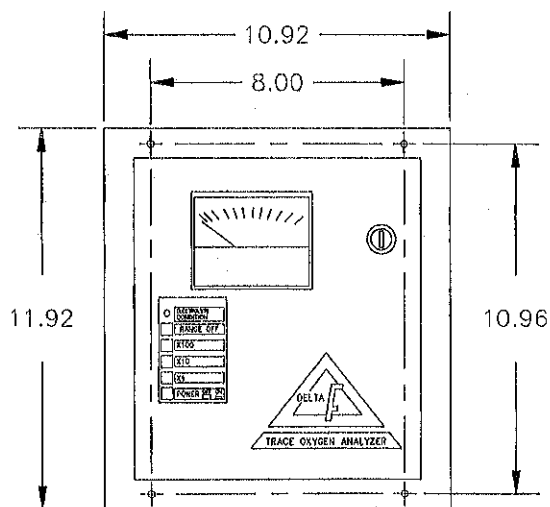


Figure 3-5. Outline Dimensions of Panel Mounted A-Plus

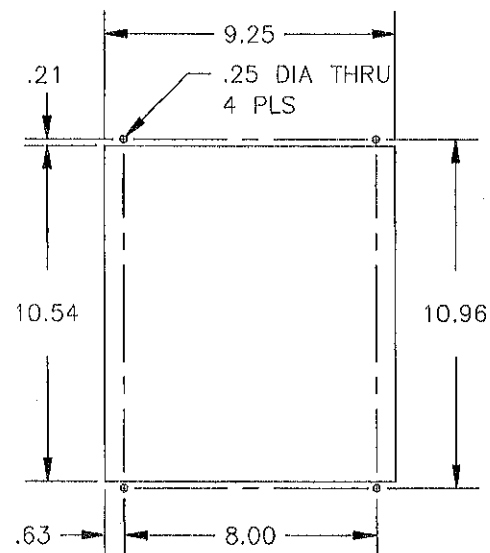


Figure 3-6. Panel Cutout Dimensions

3.18 Remote Range Indication

With remote range indication, the range selected by the front panel switches can be remotely detected. The range selection signals are available at the rear panel connector for convenience in connecting to external instrumentation. Signals are provided at the top four output connector terminals labeled: LO ALM NC, LO ALM C, LO ALM NO, and HI ALM NC. The LO ALM NC is the common terminal.

Range	Connected Terminals
X 1	LO ALM NC to LO ALM C
X 10	LO ALM NC to LO ALM NO
X 100	LO ALM NC to HI ALM NC
OFF	LO ALM NC not connected

3.19 Off Primary Range Indication

The A-Plus can provide remote indication when the primary range is selected by the front panel range switches. The primary range switch contacts are brought out to the rear panel output connector positions labeled AUX AC (J3-2 and J3-3). A contact closure occurs when the primary range is selected. This closure is directly provided by the range switch, and will continue to occur even if the power to the analyzer is removed.

NOTE: The off range contact closure is provided by a switch contact that is normally used to switch optional digital meter decimal points. Consequently, it is not possible to equip an analyzer with both a digital meter and the Off Primary Range Alarm.

3.20 Electrolyte Condition

The Electrolyte Condition alarm detects low electrolyte level or loss of electrolyte effectiveness due to contamination. This alarm turns on a red LED on the front panel, see Figure 1-2.

3.21 External Control of Sensor Voltage

The analyzer can be equipped with a means to externally control the sensor excitation voltage. The sensor voltage supply line is brought out to one of the AUX AC terminals on the signal output connector at the rear of the A-Plus. The second AUX AC terminal returns the line to the sensor.

NOTE: For normal analyzer operation, it is necessary to provide a contact closure between the two signal output connector terminals labeled AUX AC.

This modification allows the sensor to be turned ON or OFF by the removal of the contact closure.

CAUTION



The sensor signal level is in microamps at 1.3 VDC or 1.4 VDC. A dry contact switch or relay, rated for very low current operation (usually having gold plated contacts) is necessary. Also, the cable should be shielded with the shield attached to earth ground at the instrument end. Recommend wire size is as follows:

Cable Length (feet)	Wire Gauge (AWG)
0-50	#20
51-500	#18
500-1000	#16

4.0 Output

Output signals such as analog output, optional 4-20 mA output, alarm relays, range indication output, and pump control are made at a 14-position connector at the rear of the electronics chassis, Figure 4-1. Connections are made by stripping 3/16 inch of insulation from the wire, inserting the stripped end into the appropriate connector receptacle, and tightening the screw with a small (1/8") flat-blade screwdriver. No special tools, insulation, or soldering is required to make connections.

4.1 Standard Output

Standard output is 0 to 10 VDC. Auxiliary analog outputs such as 5 VDC, 1 VDC or 0.1 VDC full scale are optional. The analog output is directly related to the range selected for display on the front panel meter. For instance, when the 0-1 ppm range is selected for display on a three-range 0-1/10/100 ppm analyzer, the output corresponds directly to 0-1 ppm. Similarly, if the 0-100 ppm range is selected for display, then the output corresponds directly to 0-100 ppm.

All A-Plus Oxygen Analyzers have standard 0 to 10 VDC output even when an optional auxiliary output is installed. Connections for the standard and optional output are shown in Figures 4-1.

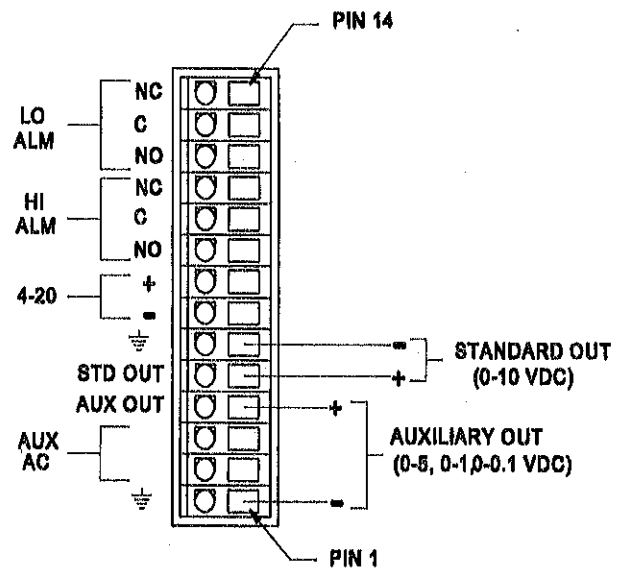


Figure 4-1. Output Connections

4.2 4-20 mADC

The 4-20 mADC output is completely isolated from AC power, earth ground and any other output of the instrument. This signal corresponds directly to the range selected for display on the front panel meter as described above for the standard output. Maximum load resistance for this output is 600 ohms.

4.3 Alarms

The analyzer may be equipped with up to two alarms; usually one high and one low. Single alarm units have one HIGH alarm and double alarm units have one HIGH and one LOW alarm. A HIGH alarm provides alarm detection when the oxygen value exceeds the alarm set-point, and conversely, a LOW alarm provides alarm detection when the oxygen value falls below the alarm set-point. An instrument equipped with a digital meter will directly read oxygen in parts per million or percent, depending upon the range of analyzer ordered. When setting an alarm, the alarm set-point will also be displayed in parts per million or percent.

The alarm circuitry is analog in nature. On multiple range analyzer, e.g. 1/10/100 ppm, with the alarm set-point at 5 ppm on the 0-10 ppm range, the set-point will be 0.5 ppm on the 0-1 ppm range, and 50 ppm on the 0-100 ppm range. The set-point changes as you move from range to range, scaling over the selected range.

4.3.1 High Alarm

Form C contacts are provided when the instrument is equipped with a single or a dual point alarm relay. Contact ratings are 3A, 30 VDC and 5A, 115 or 230 VAC for a resistive load. The relay contacts switch to the alarm position upon loss of analyzer power. Connection terminals are shown in Figure 4-1.

4.3.2 Low Alarm

These contacts are provided when the instrument is equipped with a dual point alarm relay. Contact ratings are 3A, 30 VDC, and 5A, 115 or 230 VAC for a resistive load. The relay contacts switch to the alarm position upon loss of analyzer power. Connection terminals are shown in Figure 4-1.

4.3.3 Electrolyte Alarm

The Electrolyte Condition alarm detects low electrolyte level or loss of electrolyte effectiveness due to contamination. This alarm turns on a red LED on the electronic enclosure's front panel.

4.4 Switched AC

This signal is the input AC that is switched to the output connector whenever power to

the instrument is turned on; its purpose is to provide power to an auxiliary data recorder. It is fused by the main instrument fuse and should only be used for energizing a low-power data recorder (<10 watts). Connections are shown in Figure 4-1.

4.5 Ground

Two ground connections are included at the back connector. One analog return is used with the standard output signal, the other is used with the optional output signal. These two grounds are internally connected to DC common. To avoid possible ground loop problems, do not connect these DC grounds to earth ground.

5.0 Operation

5.1 Sampling Considerations under Normal Operation

Consistent, high performance from the A-Plus Oxygen Analyzer requires an understanding of the gas delivery system and proper installation methods and techniques.

This section describes many issues that the user should be aware of during the installation, operation and calibration of the analyzer.

Condensation: The analyzer should be installed and operated with a sample gas that is preconditioned (if necessary) to avoid condensation in the gas lines. Several methods are available to minimize the possibility of condensation. If the sample gas is a hydrocarbon, maintain the gas temperature 20°F to 40°F above its dew point. In some applications, it may be necessary to chill the sample gas before it enters the analyzer so that the hydrocarbons can be condensed, collected and removed.

Gas sample delivery lines that contain sample gases with high moisture content must not be exposed to temperatures below the dew point.

Sample Gas Temperature Control: Gas temperature should not exceed 150°F (65°C), nor should it fall below 40°F (5°C). Gas temperature can be controlled by passing the gas through 5 to 10 feet of metallic tubing that is within the recommended sample temperature. Because of its low thermal mass, the gas sample will quickly reach the gas line temperature.

Relief Valves: If the sample system can exceed 5.0 psig or 5.0 psig vacuum, a pressure or vacuum relief valve should be installed to protect the sensor. The pressure relief valve must be installed upstream of the sensor in the sample inlet line. For applications in which the vent is under negative pressure, a vacuum relief valve should be installed downstream of the sensor in the sample outlet line.

Leaks: Significant measurement error can be caused by leaks in the plumbing system. A simple test can be performed to identify oxygen leaks into the sample gas stream:

Observe the readout at two flow levels: 0.5 and 3.0 scfh. Only a slight increase, if any, in oxygen readout is expected in a tight system as the flow is increased. If leakage in the plumbing system exists, then the increased flow will result in a substantial decrease in oxygen readout typically dropping in level by as much as 25 to 50%.

When flow sensitivity is observed, check the external plumbing for leaks. If the gas delivery lines are tight, remove the sensor assembly from the enclosure (refer to Section 2.2) to check the internal connections. Carefully check the stem and packing on the sensor inlet flow control valve (if equipped). The valve stem packing should be tight to minimize leaks.

If a leak is suspected in the gas inlet line, and the sensor is equipped with an optional inlet flow control valve, fully close it (clockwise). Pressurize the inlet gas line to 5 to 10 psig. Use a soapy solution (like Snoop) to identify leaks.

CAUTION



After performing the leak test, carefully open the sensor inlet flow control valve to allow the pressurized sample gas line to slowly bleed down to the operating pressure.

Oxygen Shock: Oxygen shock is a temporary condition that puts the sensor in an over-range condition. When a sensor has been exposed to an oxygen concentration greater than its maximum range, it will take some time to come back on scale.

Time to recover from an oxygen shock depends on the extent of exposure and the operating condition of the sensor. On-scale readings can return within seconds if the over-exposure is limited. When first operated, a low-range sensor may take 12 to 24 hours to fully purge itself from residual oxygen.

DANGER



If the sensor is powered while exposed to oxygen concentrations above the sensor's maximum range for prolonged periods (approximately one hour) permanent damage may occur.

To minimize the effects of oxygen shock, turn-off power to the sensor if exposure to concentrations exceed the maximum range of the analyzer.

5.2 Sampling Considerations when Calibrating

Calibrations performed from a bottled calibrated sample gas introduce additional issues that could adversely affect the calibration. Generally, low trace range instruments require more fastidious techniques during the calibration procedure.

5.2.1 Calibration Standards

Certified calibration standards are available from gas manufacturers. These standards are available in steel and aluminum cylinders. Steel cylinders are less expensive but will not dependably maintain a stable oxygen concentration for long periods of time. However if the calibration gas utilization rate is high, steel may be suitable. (At the factory, calibration gases below 10 ppm in steel cylinders are recalibrated every three months.)

For low range analyzers, (100 ppm or less), calibration standards in aluminum cylinders are recommended. Delta F has found that calibration standards in aluminum cylinders are very stable for long periods of time (\approx 6 to 12 months).

5.2.2 Process Conditions During Calibration

The most accurate calibration is obtained when the analyzer is plumbed into the gas sample system so that the analyzer is under actual operating conditions. For systems where the gas sample is not vented to ambient, the analyzer should be connected to the outlet gas line so that any pressure effects from the line are imposed on the sensor.

If the analyzer has a pump that is normally used, turn it on during the calibration. Use the sensor flow control valve in the flowmeter to set 2.0 scfh. Once the flowmeter control valve has been adjusted under the process conditions with an operating pump, do not readjust.

5.3 Purging the Analyzer

Before performing a calibration, the inlet gas lines must be fully purged. If a filter and/or a regulator are installed, disconnect the tubing that connects the filter/regulator to the sample inlet. Connect the calibration gas line directly to the sample inlet connection. Set the flow control valve to provide 2.0 scfh. Allow gas to flow for approximately 30 seconds to purge the system before turning on power to the analyzer.

NOTE: A calibration should be performed only after the analyzer has been operating for at least eight hours. Allow calibration gas to flow through the warm analyzer for 5 to 10 minutes before beginning the calibration.

5.4 Regulators

Regulators used on bottled calibration standards will typically be equipped with two Bourdon pressure gauges, one to measure the cylinder pressure, and the other to measure the outlet pressure. The regulator must have a metal (preferably stainless steel) diaphragm. Set flow rate using a regulator, or with a flow control valve installed between the regulator and the analyzer.

Before the calibration gas is connected to the analyzer follow the procedure listed below to purge ambient air from the regulator:

- a. Securely attach a regulator with a flow control valve to the cylinder. Fully open the flow control valve. Open the cylinder valve. Set the regulator to provide a delivery pressure of 20 psig.
- b. Close the flow control valve until a modest flow rate (hissing sound) occurs.
- c. Close the cylinder valve until the pressure in the regulator body falls to approximately 200 psig.
- d. Open the cylinder valve to restore full delivery pressure.
- e. On the regulator, turn the delivery pressure down to approximately 2 psig.
- f. On the regulator, increase the delivery pressure to the maximum level (regulator dependent).
- g. Repeat steps c. through f. 5 to 10 times to thoroughly purge the regulator and gauges.
- h. Close the flow control valve.
- i. Set the regulated delivery pressure to 5 psig.

The above procedure insures that any ambient air trapped in the pressure gages and cavities of the regulator will be purged prior to performing a gas calibration.

Once the regulator is mounted, do not remove it from the cylinder until a fresh cylinder is required.

5.5 Background Gas Correction Factor

The gas scale factor corrects for the diffusion effects on oxygen due to the composition of the background gas being analyzed. The user can manually set a Gas Scale Factor using the potentiometer shown in Figure 1-2 (if the analyzer is equipped with this option.) Simply dial in the volumetric percentage of background gas in the sample

stream. For example, if the sample stream is composed of 87% helium, set 87 on the potentiometer.

5.6 Control Potentiometers

If it becomes necessary to make adjustments in calibration, both the ZERO and SPAN potentiometers on this analyzer may be used.

5.6.1 Zero Adjustment

After verifying that the loss of accuracy at the zero oxygen point is not due to a plumbing leakage, Section 5.1, perform the following procedure to reset the ZERO-adjust potentiometer:

Select a sample gas that either has no oxygen or that contains oxygen in an amount less than 1% of the analyzer's lowest range; i.e., if the analyzer has a lowest range of 0 to 10 ppm O₂, then for the purpose of resetting the zero point, the sample gas should contain no more than 0.1 ppm O₂.

For trace oxygen analyzers, use a commercially available oxygen zero-gas catalytic reactor in the inlet line.

For percent oxygen analyzers or for any analyzer with a lowest range of 0-0.1% O₂ or more, standard pre-purified nitrogen (with O₂ level at approximately 5 ppm) is more than sufficient for resetting the zero point. No catalytic reactor is necessary, but take proper precautions to deliver a gas to the analyzer that is free of contamination. Set the flow rate to 2.0 scfh.

Maintain the flow conditions established in the previous step until the analyzer exhibits a steady reading. The time required to establish a reliable zero point depends primarily on the analyzer range. The lower the range, the longer the period necessary to reach stability. Typically, resetting of the zero point for a 0 to 25% range should not take more than 10 to 15 minutes. However, reaching stability at zero for the very lowest range of 0 to 1.0 ppm may require as long as 10 to 12 hours. It is recommended that, where possible, a recorder be used to chart the zero point, especially for low trace units.

Turn the Zero Adjust potentiometer, Figure 1-2, to reset the zero point. Allow the reading to be set at an increment above exact zero; this avoids a negative reading due to meter hysteresis.

5.6.2 Span Adjustment

The SPAN adjust potentiometer is located on the analyzer control panel. At the factory, span calibration is performed using NIST traceable oxygen in nitrogen background gas. To check the SPAN, a calibration gas cylinder is required.

The oxygen level in the calibration gas can be any amount within the range of the analyzer. It is customary to select an oxygen content that approximates either the oxygen limit or level encountered in the process to be monitored. This method takes longer at the lower levels of oxygen.

Alternatively, a span check or adjustment can be made with a calibration gas with an oxygen content between 70% and 90% of the primary range of operation.

Resetting the span for an analyzer of 0-25% range can be accomplished in 30 minutes; while an analyzer in the range of 0-10 ppm, the time required for the sensor to reach equilibrium, and thus be ready for span reset may be as much as 60 minutes.

When it is necessary to recalibrate the span, the following procedure is recommended:

Select a certified cylinder of appropriate background gas in which the oxygen content has been accurately determined.

It is important to use gas delivery equipment that is consistent with the level of oxygen at which the analyzer will be calibrated. Delta F recommends using stainless steel tubing and fittings throughout the delivery system. Regulators with welded metal diaphragms are also recommended. Consult the factory if you require more information.

Set a flow of 2.0 scfh on the flowmeter. Turn on the analyzer.

Monitor the analyzer response to the certified gas until a stable reading is obtained. (The use of a recorder is beneficial to verify that the sensor has reached an equilibrium point.)

If necessary, reset the SPAN dial until the analyzer readout corresponds to the oxygen level listed for the certified cylinder.

NOTE: On analyzers equipped with the optional Gas Scale Factor feature, access to the span potentiometer is through a small hole located between the Zero and Gas Scale Factor potentiometer dials. A small screwdriver (1/8" flat blade) is required.

5.7 Calibration Frequency

Except for applications where periodic water replenishment is required, there is no routine maintenance necessary to keep the analyzer operable over extended periods. As a result, the frequency of calibration check should be consistent with the process being monitored. Regardless of the type of application, it is recommended that some form of calibration check be performed at least once every three months for any continuous operation.

5.8 Factory Settings

The factory calibration information is located on a label attached to the inside door of the analyzer. Calibration values are set at the span and zero potentiometers on the control panel.

If the analyzer is equipped with a gas scale factor option, and the span gas does not contain the same volumetric ratio of background gas to oxygen that the sample gas contains, the span calibration is set by the following procedure:

1. Set the Gas Scale Potentiometer to correspond to the volumetric percent of the calibration background gas.
2. Perform the span calibration.
3. Return the gas scale factor potentiometer to the value that corresponds to the sample gas volumetric percentage.

After a user-calibration, record the date, span and zero gas concentrations, and potentiometer settings on the label. This information may be useful for future troubleshooting.

5.9 Electrolyte Condition

Above the switch bank may be an LED that indicates electrolyte condition. If equipped, the Electrolyte Condition Alarm detects low electrolyte level or loss of electrolyte effectiveness due to contamination. This alarm turns on the LED, Figure 1-2.

5.10 Controls

A push-button switch bank, Figure 1-2, controls power and one or more of the following:

Range Selection, Quick-Start, and Pump. Before connecting power, set the Range Selector switch to OFF.

5.10.1 Range Selection Switches

The Range Off switch is used to remove power to the sensor. This switch is used to prevent damage to the sensor when the analyzer must remain powered for extended periods (> 1 hour) while on a gas sample that exceeds the operating range of the sensor.

If the analyzer has the multi-range feature, three switches are used to select the range. Press the range selector switch corresponding to the highest range. (The selected range switch will display a white color.) The meter will immediately respond by showing an over-range condition.

Normally, within a minute or two, the meter reading or analog output will fall within scale and continue toward the equilibrium point. Generally, the time to equilibrium will increase with lower oxygen concentrations. Switching to the lower scales should be done only when the meter is able to read within the range of that scale.

5.10.2 Power

The power switch is located on the lower portion of the electronics chassis. This switch displays an orange color when ON.

5.10.3 Pump Control

If the instrument has a sample gas pump, pressing the switch, located behind the analyzer door, Figure 1-2, will turn the pump ON and OFF. The switch displays a green color when the pump is switched ON.

5.10.4 Quick-Start

If the unit is equipped with the Quick-Start feature, the feature can be used by pressing its momentary push button on the front panel, behind the door. See Section 3.15 for a description of the Quick-Start feature.

6.0 Theory of Operation

6.1 The Sensor

The sensor in the A-Plus Oxygen Analyzer operates on a simple Coulometric principle in which oxygen in the sample gas is reduced by an electrochemical reaction. The use of this technique is widely recognized for its ability to provide the most accurate means of oxygen measurement.

A schematic of the sensor configuration is shown in Figure 6-1. The sample gas stream enters the sensor via the cathode cavity. Oxygen is metered to the cathode through the Bi-Strata® gas diffusion barrier. At the cathode, oxygen in the sample gas is electrochemically reduced to hydroxyl ions (OH^-).

The electrolyte solution contains potassium hydroxide (KOH) which assists in the migration of hydroxyl ions (OH^-) to the anode. At the anode, hydroxyl ions (OH^-) are oxidized to complete the reaction. A voltage of approximately 1.3 (or 1.4 for 25% range sensors) VDC, imposed on the sensor electrodes, drives the reduction and oxidation reactions. Each O_2 molecule reduced/oxidized generates a flow of $4e^-$. The resulting current is proportional to the oxygen content in the sample gas stream. The processed signal is then displayed on the front panel in ppm or percent units of oxygen.

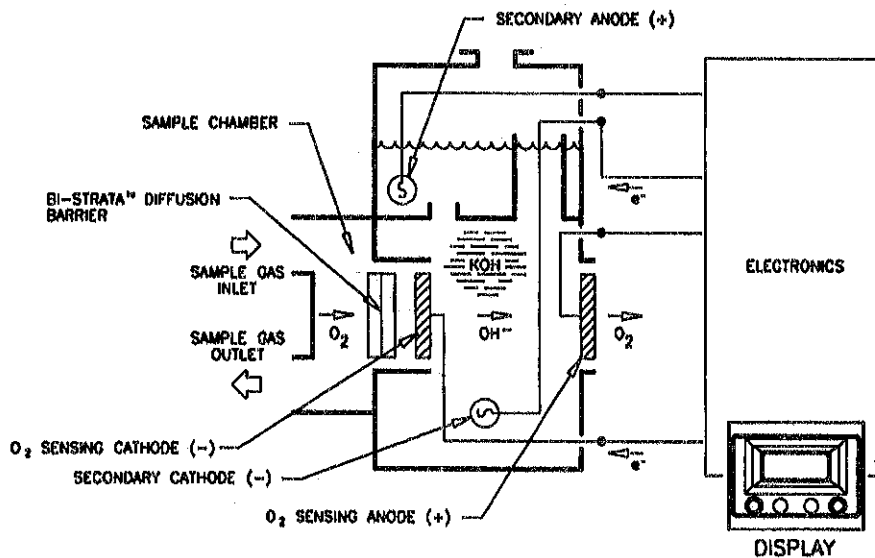


Figure 6-1 Diagram of the Sensor Configuration

6.2 The STAB-EL Electrolyte System

The A-Plus Oxygen Analyzer may be equipped with Delta F's patented STAB-EL electrolyte system. STAB-EL allows the sensor to be used with gases that contain acidic components such as Cl_2 , HCl , CO_2 , SO_2 , H_2S , NO_x , etc. These gases are commonly termed "acid gases".

For many applications, the STAB-EL electrolyte system, together with the unique, non-depleting, electrochemical sensor electrodes eliminates the necessity of scrubbing the acidic components prior to making an oxygen measurement.

The STAB-EL electrolyte system consists of special measuring electrodes, sensor construction, and a second pair of electrodes placed within the oxygen sensor as shown in Figure 6-1.

A current flows between the secondary anode in the electrolyte reservoir and the secondary cathode in the sensor cavity. The electrodes are connected via immersion in the electrolyte solution.

In the STAB-EL system, anions (negatively charged ions) that are formed by the neutralization reaction of the acid gas with the KOH electrolyte will migrate to the anode. Cations (positively charged ions) are attracted to the cathode.

The constant secondary electrode current produces a modest water electrolysis reaction. Since potassium has a very strong equilibrium with OH^- , the measurement cavity maintains an adequate concentration of hydroxyl ions to assist in the O_2 sensing reaction.

In a STAB-EL equipped oxygen sensor, acid forming components are prohibited from excessive buildup within the sensor cavity. Instead, they are induced to migrate toward the reservoir where they concentrate.

The internal geometry of the sensor prevents back diffusion of unwanted anionic species into the measuring cavity.

6.2.1 STAB-EL and Carbon Dioxide

In situations where the analyzer is exposed to carbon dioxide (CO_2), carbonate ions are formed by reaction with the electrolyte. The anions will migrate to the secondary anode, where they will increase in concentration. When the solubility limit of the carbonate ion is reached, CO_2 will begin to effervesce from the reservoir solution.

6.2.2 STAB-EL and Gases in the Halogen Family

In situations where the analyzer is exposed to halogen gases such as chlorine or fluorine, the anionic species will also migrate to the anode. However, unlike the situation with carbon dioxide, the anion will be oxidized at the anode and be vented from the sensor.

6.2.3 STAB-EL with Nitrogen- and Sulfur-Containing Acid Gases

In situations where the analyzer is exposed to nitrogen- and sulfur-containing acid gases, the anionic neutralization species will migrate to the anode in the reservoir. Since these anionic species are not removed by effervescence or oxidation, they will continually increase in concentration. When the concentration becomes excessive, the electrolyte solution must be changed.

Frequency of electrolyte changes directly relates to the levels of acid gases in the sample gas. Typically, changes may be necessary 1 to 4 times per year. Actual operating experience will determine frequency of electrolyte change.

6.2.4 Capability of the STAB-EL System

With the STAB-EL system oxygen measurements in sample gases containing varying amounts of acid gases are possible. As a general guide, the data in Table 6-1 represents the maximum allowable limits of acid gases under continuous operation that can be tolerated with the STAB-EL system.

There are applications where the acid gas components may exceed the upper limits of the STAB-EL system. In such circumstances, the inherent capabilities of the sensor can be enhanced by using a scrubber system. The scrubber will remove the bulk of the acid gases, allowing the analyzer to provide continuous stable measurements. If a breakthrough occurs, the sensor's ability to tolerate high levels of acid gas for limited periods of time may avoid catastrophic loss of performance (assuming that the scrubber is maintained properly).

Sample gases that contain higher levels of acid gases than the limits in Table 6-1 may be used if the duty cycle is adjusted, or if a dilution system is installed. Consult the factory for specific recommendations.

Table 6-1
Maximum Allowable Acid Gas Limits
Using the STAB-EL Sensor

Measuring Range	CO ₂	SO ₂	H ₂ S	NO _x	Cl ₂	HCL
0-50 ppm	0.1	100	100	100	50	50
0-100 ppm	0.1	100	100	100	50	50
0-500 ppm	0.1	100	100	100	50	50
0-1000 ppm	0.2	250	250	250	100	100
0-5000 ppm	0.3	500	500	500	200	200
0-10,000 ppm	0.4	750	750	750	400	400
0-5%	1.0	1300	1300	1300	700	700
0-10%	2.0	2000	2000	2000	1000	1000
0-25%	3.0	3000	3000	3000	1500	1500

* Concentrations of CO₂ are in percent. One percent is equivalent to 10,000 ppm.

Contact Delta F for recommendations on using the STAB-EL sensor on acid gases other than those listed above.

6.3 Regulating Sensor Input Voltage

In function, the sensor reacts in a manner similar to a variable resistor. As the cathode of the sensor is exposed to greater amounts of oxygen, the conductivity of the sensor increases. A DC voltage, applied to the sensor, is the driving force to complete the electrode reactions.

This DC voltage must be regulated within reasonably strict limits. For example, if the voltage is too low (less than 1.20 VDC), the cell lacks sufficient potential to maintain a linear response to oxygen, particularly at the higher levels. If the voltage input to the sensor is too high (above 1.34 VDC), the short-term effect is to drive the readout in a negative direction. In fact, when monitoring gas on the lowest range, high sensor voltage may produce a negative peg on the meter. Over a long period, high input voltage is corrosive to the sensor and may cause premature failure.

For satisfactory performance, maintain a sensor input voltage between 1.24 and 1.33 VDC and, preferably, between 1.25 and 1.31 VDC. Single and multi-range analyzers that measure up to 25% oxygen have a polarization voltage of 1.40 VDC.

The sensor input voltage can be measured as follows:

- a. Disconnect the 4-pin connector at the sensor. (The readings to be taken are open circuit values.)
- b. Use a DC voltmeter to read to two decimal points (3 1/2 digits on a 2-volt scale).
- c. Observing polarity, connect the voltmeter to the sensor voltage leads. The white/black/red wire is positive (+).
- d. Switch the analyzer power ON. Press the selector switches to each range position and observe the open circuit input voltage. The values at each position should be the same (within .01 VDC) and should be within 1.24 and 1.33 VDC (1.40 VDC for 25% sensors).

If the sensor voltage deviates from that discussed above, consult the factory.

6.4 Effects of Sample Flow Rate, Pressure, and Temperature

6.4.1 Positive Pressure Operation

The analyzer is factory calibrated and should be operated at the recommended flow rate of 2.0 scfh. If the sample gas is at constant pressure between 0.2 psig and 5.0 psig, a flow control valve at the sensor inlet can be used to adjust flow rate.

If the pressure in the sample line varies, but does not drop below 2.0 psig, use a regulator to drop the pressure to approximately 1.0 psig. Set the final flow rate with a flow control valve.

If a regulator is not used, the flow rate will change when the pressure at the inlet of the flow control valve changes. As long as this pressure variation does not bring the flow rate out of the recommended flow range (1.0 - 3.0 scfh) there is no action required.

NOTE: It is not recommended that gauges be permanently installed upstream of the analyzer. The presence of a gauge will increase purging time and slow the response.

For analyzers with a pump, an outlet (vent) pressure greater than 3 psig will influence the sensor pressure, causing changes to the flow rate and output.

Sample gas line lengths, fittings and bends should be kept to a minimum to maintain low pressure drops. Larger diameter tubing and fittings will reduce pressure drop but will also lengthen response time. In general, 1/8 inch tubing should be limited to 15 foot runs; longer runs should be made with 1/4 inch tubing.

If you have questions about your specific application, contact the Delta F Corporation at (617) 935-4600.

6.4.2 Pressure Effects on Sensor Performance

Sensor output may change with sensor pressure. Typically sensor output increases as pressure increases, and decreases as pressure decreases.

There should be no concern with sensor pressure effects if the flow rate is set to 2.0 scfh and the analyzer vents to atmosphere (assuming sea level). Sensor pressure will duplicate that of the factory.

If the analyzer is not vented to atmosphere, the sensor pressure will be influenced by the conditions downstream of the analyzer. A recalibration under the user's operating condition may be desirable to remain within the stated accuracy specifications. However, in most cases the error introduced is relatively small, and may not affect the process application. See Section 6.5, Sampling Considerations for more information.

For analyzers without a pump, the sensor pressure may be determined by inserting an in-line pressure gauge at the analyzer's outlet bulkhead fitting. Add 0.5 psig to the measured pressure to estimate the sensor pressure.

6.4.3 Negative Pressure Operation

If a gas sample stream is between 2.0 psig vacuum (12.7 psia) and 0.2 psig, a pump is recommended. If the analyzer is equipped with a pump, it will also have a flow control valve in the flowmeter in addition to the sensor upstream valve. Section 3.13 describes operation with a pump.

When an analyzer has a pump, and the analyzer's outlet is vented to atmosphere, the sensor will operate under negative pressure. By installing a flow control valve between the sensor and the low-pressure side of the pump, only slight pressure changes at the sensor will occur when adjusting the sample flow rate. For this reason analyzers that are equipped with an optional pump have a flow control valve in the flowmeter.

NOTE: The sensor upstream valve must be fully opened (counter-clockwise) before setting the flow rate to 2.0 scfh. Flow rate adjustments are done only with the flow control valve in the flowmeter.

If a pressure change causes the flow rate to move outside the recommended range, an adjustment of the flow control valve must be made at the flowmeter valve. If the adjustment is not made, the analyzer may not be operating within its stated accuracy.

Analyzers with a pump are calibrated with the pump operating even if the calibration gas has sufficient pressure to preclude the use of the pump. The operating pump will create a pressure condition at the sensor that simulates the operating condition.

6.4.4 Temperature Effects on Sensor Performance

The electrical current output of the oxygen sensor operating on a constant sample concentration will change with sensor temperature. Sensor output may increase with increasing sensor temperature and decrease with decreasing sensor temperature, particularly when oxygen reading is close to the sensor's zero level.

The effect of sensor temperature on output is specific to the range of the sensor. The trace range sensors experience more temperature sensitivity, while percent range sensors experience almost no temperature sensitivity. Typical output drift due to sensor temperature change is expressed in the following table for the different range sensors.

Analyzer drift is shown in two columns in Table 6-2. The first column should be applied to gas concentrations which are between 2% and 100% of the range. When measuring in the lower 2% of the range, use the second column for typical drift over the 45°F - 95°F temperature range.

Table 6-2
Typical Output Drift with Specific Analyzer Range

Range	Temp Range (70°F nominal)	% of reading/°F (2%-100% of range)	Typical Drift (lower 2% of range)
0-50 ppm	45°F-95°F	±0.32	±65 ppb
0-100 ppm	45°F-95°F	±0.32	±125 ppb
0-500 ppm	45°F-95°F	±0.32	±250 ppb
0-1000 ppm	45°F-95°F	±0.32	±500 ppb
0-5000 ppm	45°F-95°F	±0.24	±2.5 ppm
0-10000 ppm	45°F-95°F	±0.20	±5 ppm
0-5 %	45°F-95°F	±0.12	±0.003%
0-10 %	45°F-95°F	±0.04	±0.005%
0-25 %	45°F-95°F	±0.01	±0.013%

7.0 Service

If the analyzer is to be returned to the factory, it will be necessary to obtain a Return Authorization Number by contacting Delta F Corporation at (617) 935-4600, Service Fax (617) 932-0053.

7.1 Maintenance

7.1.1 Calibration

All Delta F A-Plus Oxygen Analyzers are calibrated with certified gas standards at the factory prior to shipment. If the analyzer is operated within its specified conditions, no initial calibration is required after delivery.

Depending upon the nature of the application, Delta F suggests verifying the span calibration of the analyzer approximately every 6 months using a gas with a known level of oxygen. Refer to Section 5.5 for information on using calibration standards with background gases that differ from the process background gas.

The zero calibration is most important for applications requiring accuracy in the lower end of the instrument's range.

From an initial start-up, the analyzer may take 10 to 12 hours to reach a stable zero (especially for the lowest range analyzer.) After achieving a stable zero baseline, the analyzer will require periodic zero checks and possibly adjustments to ensure accuracy. Experience with a particular application will determine the optimum frequency of zero checking.

7.1.2 Sensor Maintenance

The analyzer does not require routine maintenance other than water addition. Exposure to dry gas for an extended time will gradually extract water from the sensor. The water will need to be replenished occasionally.

CAUTION



If the electrolyte level is low, only distilled or deionized water needs to be added to the sensor. **Do not add electrolyte solution to restore the electrolyte level.** Do not overfill.

The sensor assembly consists of two connected chambers. The operation of the sensor will be satisfactory as long as the level of electrolyte is above the minimum indicator line on the reservoir label.

One bottle of electrolyte, DF-EO5 contains 100 ml. This quantity is sufficient for satisfactory operation. Additional water can be added to bring the level to the maximum mark on the reservoir.

Typically, bone dry sample gas can extract approximately 10 to 20 ml of water per month. The electrolyte level should be checked every 1 to 2 months. Add water if needed. Operation with sample gases with very low dew points increases the frequency of replenishing water.

To add water:

- a. Open the front door.
- b. Unscrew the black sensor cap. Be careful of drips of electrolyte from the cover.
- c. Add distilled or deionized water. Fill to the max level indicator line on the reservoir label. Be careful not to spill water on the electronics or on the outside of the sensor. Do not overfill.
- d. Replace the cover securely.

NOTE: Once the sensor has been charged with electrolyte, no further addition of electrolyte solution is required. The dissolved components in the electrolyte are neither consumed nor converted during operation, so only periodic replenishment with distilled or deionized water is necessary.

To drain the electrolyte, follow the procedure in Section 2.2. Dispose of the electrolyte and rinse water in accordance with Federal, State and Local regulations.

7.2 Storage Conditions

If the analyzer is to be stored for extended periods of time, be sure that the temperature of storage location does not exceed 122°F (50°C). Storage in direct sunlight can cause temperatures to exceed the recommended limits even though ambient temperatures may be below the maximum temperature. **Drain the electrolyte before storing the analyzer.**

7.3 Shipping

If the analyzer is to be returned to Delta F, it will be necessary to obtain a Return Authorization Number by contacting Delta F at (617) 935-4600, Fax (617) 938-0531.

If it becomes necessary to ship the analyzer to the factory or to another location, follow these instructions to prevent damage to the analyzer during shipping.

CAUTION



DO NOT SHIP THE ANALYZER WITH ELECTROLYTE - THOROUGHLY DRAIN AND RINSE BEFORE SHIPPING

- a. Disconnect any source of AC power from the analyzer.
- b. Disconnect all external electrical connections, e.g. alarms, data output, etc. Mark each for easy reattachment later.
- c. Remove the chassis with sensor as described in Section 2.2
- d. Drain the electrolyte into a receptacle suitable for proper disposal.
- e. Rinse the sensor with distilled or deionized water. Drain the water into the receptacle. Repeat this step two more times.
- f. Securely hand tighten the cover.

When shipping use the original container if possible. Ensure that all internal components are adequately secured. It is recommended that bubble packing or similar protective material be added inside the enclosure for additional protection of the analyzer.

Because of its non-depleting sensor electrodes, the analyzer does not require special precautions to protect the sensor from exposure to oxygen during shipment or in storage.

If you are returning the analyzer to Delta F, clearly mark the Return Authorization Number on the outside of the shipping container and on the packing list. The analyzer should be returned to Delta F Corporation, 4 Constitution Way, Woburn, MA 01801, freight prepaid.

7.4 Replaceable Spare Parts List

When Ordering spare parts, always include the analyzer's model and serial numbers. It is imperative that this information be provided in order to ensure that the correct parts are ordered.

Part Number	Part Description
54003513	Panel Meter, Analog (specify range)
16216372	Panel Meter, Analog w/alarms (specify range)
54218506	Panel Meter, Digital, 3½ digit LCD
54218508	Panel Meter, Digital, 4½ digit LCD
10304410	PCB, Digital/Analog Meter, no alarms
10304411	PCB, Digital Meter, Single Point Alarm
10304412	PCB, Digital Meter, Two Point Alarm
10404391	PCB, Main w/power supply
10404392	PCB, Main, OEM Version
10409740	PCB, Main w/battery option
13204730	Cable, Sensor to Main Board (4 conductor)
13205340	Cable, Main to Meter board (ribbon)
45000100	Fuse, 1 Amp (110 VAC)
45000051	Fuse, ½ Amp (220 VAC)
51004006	Fuse Holder
62000224	Flow Control Valve
59017280	Power Cord
47000440	Battery, Rechargeable, D-size
47012161	Battery Holder, D-size
64005011	Filter Element, Standard
64005012	Filter Element, Fine (less than 1 micron)
63000303	Vacuum Pump, 110 VAC
DF-EO5	Electrolyte, 100 ml bottle

7.5 Troubleshooting

The following operational recommendations should be observed:

1. Always establish sample flow before powering the analyzer up.
2. Never operate a trace level or low percent analyzer for more than a few minutes while exposed to air.
3. Never operate the analyzer for more than a few minutes without sample flow.
4. Check the electrolyte level at least once every 3 months. On very dry gas streams check monthly. Always top off with distilled or de-ionized water. **Never top off with electrolyte.**
5. Check calibration every three months.
6. Avoid using plastic tubing to deliver sample gas to the analyzer. Stainless steel tubing is recommended for all applications.
7. Never use a graphite pencil to manipulate a DIP switch.
8. Avoid exceeding recommended pressure and flow limitations under both transient and steady state conditions.

The Troubleshooting Guide will help the user resolve many of the common operational situations that occur with the analyzer. Investigate possible remedies in the listed order.

Troubleshooting Guide for the a-Plus Oxygen Analyzer

Observation	Possible Remedy (See Key below)
1. Analyzer reads low.	G A B D E H I F J K
2. Analyzer reads high.	A B C D E I J K
3. Analyzer output noisy.	A E I K
4. Analyzer reads high with pump on.	C K
5. Analyzer reads 0.00 or less at all times.	D K
6. Slow speed of response.	G C D E F K
7. Electrolyte residue visible on the sensor.	K
8. Electrolyte Condition indicator ON	E K

Key:

- A. Check instrument performance using a gas standard of known Oxygen content. (Span)
- B. Check that the analyzer zero setting matches the original factory setting. Consult the manual or the factory to verify these settings
- C. Check the sample delivery system for leaks using the procedure provided with this document.
- D. Verify that the correct voltages are being supplied to the sensor. These voltages should be checked with the leads disconnected from the sensor. The voltages measured should be as follows.

Primary Electrodes wht/yel (-) wht/blk/red (+): 1.3 ± 0.03 VDC
(for 25% sensors only): 1.4 ± 0.03 VDC
Secondary Electrodes wht/blu (-) wht/red (+): 7.0 ± 0.5 VDC

Voltage levels between any other combination of wires should be less than .10 VDC. If there is any deviation from these values, contact Delta F Corporation, (617) 935-4600.

- E. Change the electrolyte. Use only electrolyte supplied by Delta F. Use of other types of electrolyte can damage the sensor and will void the warranty. Always

rinse the cell with distilled or de-ionized water before refilling the sensor with fresh electrolyte. Allow the analyzer to operate for several hours on Nitrogen or other inert gas and attempt to calibrate.

- F. Establish a flow of Nitrogen or other inert gas through the sensor. Reverse the positions the two lower leads on the sensor. Turn the analyzer on and allow it to operate in this fashion for at least 1 hour but not more than 3 hours. Drain the sensor, rinse with distilled or de-ionized water, and install fresh electrolyte. Return the sensor leads to their original positions and allow the analyzer to operate on a purge gas for several hours and attempt to calibrate.
- G. Remove and check the filter element. Replace if needed.
- H. Check for contaminated plumbing. This is most easily done by examining the flowmeter (if so equipped) or vinyl tubing downstream from the sensor for evidence of oil, powder, or other material that may have made its way from your process to the analyzer.
- I. Remove any devices being driven by the analyzer output, i.e. chart recorders, data acquisition systems etc. Also disconnect anything controlled by the analyzer alarm relays. Attempt operation with these devices removed.
- J. Ensure that the background gas you are using is compatible with your analyzers' current calibration. Consult your manual for information regarding Background Gas Correction Factors and optional Scale Factor Control.
- K. Contact Delta F Service Dept. Phone: (617) 935-4600, Fax: (617) 932-0053
Always be certain to drain the sensor of electrolyte before returning it to the factory for repair.

8.0 Safety

DANGER



Line voltage exists in the Oxygen Analyzer Enclosure. If the enclosure is removed, **DO NOT** touch any of the electrical components when the analyzer is connected to AC power.

CAUTION



Do not operate the A-Plus Oxygen Analyzer at oxygen concentrations that are over-range for extended periods of time. Sensors may be damaged if exposed to high levels of oxygen, e.g. air, for long periods of time (>15 minutes) while on power.

If an exposure is unavoidable, turn-off power to the instrument.

8.1 General Warnings

- a. **The sensor must be drained and flushed prior to shipment.**
- b. To reduce the risk of fire or electric shock, do not expose this equipment to rain or water spray unless it is specifically rated as NEMA 4.
- c. Verify that the analyzer power setting is consistent with the line voltage.
- d. Over-pressurizing the analyzer can result in permanent damage to the sensor.
- e. Do not operate an analyzer unless a sample gas is flowing through the sensor.
- f. The GSF for the gas used to calibrate the system may be different from that used for analysis. If the GSF is changed to reflect the composition of the calibrating gas, be sure to reset the GSF before analyzing samples.
- g. **USE ONLY DF-EO5 ELECTROLYTE**

8.2 Electrolyte Material Safety Data Sheet (MSDS)

The information below is believed to be accurate and represents the best information currently available to us. However, we make no warranty of merchantability or any other warranty, express or implied, with respect to such information, and we assume no liability resulting from its use. Users should make their own investigations to determine the suitability of the information for their particular purposes.

EMERGENCY CONTACT: 1-800-424-9300

To be used ONLY in the event of chemical emergencies involving a spill, leak, fire, exposure or accident involving this chemical.

SUBSTANCE IDENTIFICATION

SUBSTANCE:	Potassium Hydroxide Solution, 1N			
CAS NUMBER:	1310-58-3			
TRADE NAME:	DF-E05			
CHEMICAL FAMILY:	Inorganic Base			
MOLECULAR FORMULA:	Mixture			
CERCLA RATINGS (SCALE 0-3):	Health=3	Fire=0	Reactivity=1	Persistence=0
NFPA RATINGS (SCALE 0-4):	Health=3	Fire=0	Reactivity=1	

COMPONENTS AND CONTAMINANTS

COMPONENT:	Potassium Hydroxide	PERCENT:	5.0 - 6.0
COMPONENTS:	Water & Inorganic Salts	PERCENT:	94.0 - 95.0
OTHER CONTAMINANTS:	None		
EXPOSURE LIMITS:	Potassium Hydroxide:	2 mg/m ³ ACGIH Ceiling 2 mg/m ³ OSHA Ceiling	

PHYSICAL DATA

DESCRIPTION:	Colorless Liquid	SPECIFIC GRAVITY:	1.15
BOILING POINT:	104.5 °C	SOLUBILITY IN WATER:	Complete
MELTING POINT:	- 3.5 °C	Vapor Pressure:	16.1 mm Hg @ 20°C

FIRE AND EXPLOSION DATA

FIRE AND EXPLOSION HAZARD: Negligible fire and explosion hazard when exposed to heat or flame.

FLASH POINT: Non-Combustible

FIRE FIGHTING MEDIA: Dry chemical, carbon dioxide, water spray or foam (1987 Emergency Response Guidebook, Dot P 5800.4). For larger fires, use water spray, fog or standard foam (1987 Emergency Response Guidebook).

FIRE FIGHTING: Move containers from fire area if possible. Cool containers exposed to flames with water from side until well after fire is out (1987 Emergency Response Guidebook, DOT P 5800.4, p.60).

Extinguish using agents indicated; do not use water directly on material. If large amounts of combustible materials are involved, use water spray or fog in flooding amounts. Use water spray to absorb corrosive vapors. Cool containers with flooding amounts of water from as far a distance as possible. Avoid breathing corrosive vapors; keep upwind (Bureau of Explosives, Emergency Handling of Hazardous Materials in Surface Transportation, 1981).

TRANSPORTATION DATA

DOT Hazard Classification 49CFR172.101: Potassium Hydroxide Solution, Class 8, UN1814, Packing Group III

- ▶ Exceptions: When transported by Air 49CFR173.154 (b) (1) + (2)
- ▶ Exceptions: By Motor Vehicle or Rail Car 49CFR173.154 (d) (1)

IATA Hazard Classification 4.2: Potassium Hydroxide Solution, Class 8, UN1814, Packing Group III

- ▶ Exceptions: 2.8 (Ltd. Qty.)

TOXICITY

Potassium Hydroxide: 50 mg/24 hours skin-Human severe irritation;
50 mg/24 hours skin-Rabbit severe irritation;
50 mg/24 hours skin-Guinea Pig severe irritation;
1 mg/24 hours eye-Rabbit moderate irritation;
273/mg/Kg oral-Rat LD50;
Carcinogen status: None
Mutagenic data (RTECS).

Potassium Hydroxide Solution is a severe eye, mucous membrane, and skin irritant.

HEALTH EFFECTS & FIRST AID

- Inhalation:** Potassium Hydroxide: Corrosive.
- Acute Exposure-** Inhalation of dust or mist may cause symptoms of respiratory tract irritation, possibly including coughing, choking, and pain in the nose, mouth and throat, lesion of the nasal septum, and burns of the mucous membranes. If sufficient quantities are inhaled, pulmonary edema may develop, often with a latent period of 5-72 hours. The symptoms may include tightness in the chest, dyspnea, frothy sputum, cyanosis and dizziness. Physical findings may include weak rapid pulse, hypotension, hemoconcentration, and moist rales.
- Chronic Exposure-** Depending on the concentration and duration of exposure, repeated or prolonged exposure to corrosive substances may cause inflammatory and ulcerative changes in the mouth and possibly bronchial and gastrointestinal disturbances.
- First Aid-** Remove from exposure area to fresh air immediately. If breathing has stopped, give artificial respiration. Maintain airway and blood pressure and administer oxygen if available. Keep affected person warm and at rest. Treat symptomatically and supportively. Administration of oxygen should be performed by qualified personnel. Get medical attention immediately.
- Skin Contact:** Potassium Hydroxide: Corrosive.
- Acute Exposure-** Direct contact may cause severe pain, burns, and possibly brownish stains. The corroded areas are soft, gelatinous and necrotic, and the tissue destruction may be deep.
- Chronic Exposure-** Repeated or prolonged contact may cause dermatitis or effects similar to acute exposure. Frequent applications of aqueous solutions (3-6 percent) of Potassium Hydroxide to the skin of mice for 46 weeks produced tumors identical to those from coal tar; warts occurred first and then skin tumors developed.
- First Aid-** Remove contaminated clothing and shoes immediately. Wash affected area with soap or mild detergent and large amounts of water until no evidence of chemical remains (at least 15-20 minutes). In case of chemical burns, cover area with sterile, dry dressing. Bandage securely, but not too tightly. Get medical attention immediately.

Eye Contact:	Potassium Hydroxide: Corrosive.
Acute Exposure-	Direct contact with solid or solutions may cause pain and burns, possibly severe. The degree of injury depends on the concentration and duration of contact. There may be edema, destruction of epithelium, corneal opacification, and iritis. When damage is less than excessive, these symptoms tend to ameliorate. In severe burns, the full extent of the injury may not be immediately apparent. Late complications may include persistent edema, vascularization, and scarring of the cornea, permanent opacity, staphyloma, cataract and symblepharon.
Chronic Exposure-	Effects depend on concentration and duration of exposure. Repeated for prolonged exposure to vapors and/or fumes may result in conjunctivitis or effects as in acute exposure.
First Aid-	Wash eyes immediately with large amounts of water, occasionally lifting upper and lower lids, until no evidence of chemical remains (at least 15-20 minutes). Continue irrigating with normal saline until the pH has returned to normal (30-60 minutes). Cover with sterile bandages. Get medical attention immediately.
Ingestion:	Potassium Hydroxide: Corrosive/Toxic.
Acute Exposure-	Ingestion of 273 mg/Kg of Potassium Hydroxide was lethal to rats tested. Ingestion of strong alkalis may be followed by severe pain, vomiting, diarrhea, and collapse. The vomitus contains blood and desquamated mucosal lining. If death does not occur in the first 24 hours, the patient may improve for 2-4 days and then have a sudden onset of severe abdominal pain, board-like abdominal rigidity, and rapid fall of blood pressure indicating delayed gastric or esophageal perforation. Damage to esophagus and stomach after ingestion may progress for 2-3 weeks. Death from peritonitis may occur as late as 1 month after ingestion. Even though the patient recovers from the immediate damage, esophageal stricture may occur in weeks, months, or even years later to make swallowing difficult.
Chronic Exposure-	The Food and Drug Administration lists Potassium Hydroxide as a direct food substance affirmed as generally recognized as safe at levels not to exceed current good manufacturing practices.
First Aid-	Dilute the alkali by giving water or milk immediately and allow vomiting to occur. Avoid gastric lavage or emetics. Esophagoscopy is the only way to exclude the possibility of corrosion in the upper gastrointestinal tract; if corrosion is suspected, esophagoscopy should usually be performed within 24 hours (Dreisbach, Handbook of Poisoning, 11th Ed.). Maintain airway and treat shock. If vomiting occurs, keep head below hips to prevent aspiration. Get medical attention immediately.
Antidote:	No specific antidote. Treat symptomatically and supportively.

REACTIVITY

Reactivity:	Vigorous, exothermic reaction with water.	
Incompatibilities:	Potassium Hydroxide:	
	Acetic Acid:	Reacts violently
	Acids:	Violent reaction
	Acrolein:	Violent polymerization
	Acrylonitrile:	Violent polymerization
	Alcohols:	Dissolves exothermically
	Aluminum:	Corrosive in the presence of moisture
	Ammonium Hexachloroplatinate:	Formation of explosive product
	Ammonium Salts:	Evolution of Ammonia gas
	Benzoyl Chloride & Sodium Azide:	Violent exothermic reaction
	P-BIS (1,2-Dibromoethyl) Benzene:	Highly exothermic reaction
	Bromoform:	Violent exothermic reaction
	Bromoform & Cyclic Polyethylene Oxides:	Possible explosive reaction
	Calcium Carbide & Chlorine:	Formation of explosive Dichloroacetylene
	Chlorine:	Explosive reaction
	Chlorine Dioxide:	Explosion on contact
	Chlorine & Hydrogen Peroxide:	Produces red luminescence during reaction.
	Chlorine Trifluoride:	Ignition
	Chloroform & Methanol:	Intense exothermic reaction
	Cyclopentadiene:	Vigorous exothermic resin formation
	1,2-Dichloroethylene:	Formation of explosive & spontaneously flammable Chloroacetylene
	Germanium:	Incandescent reaction
	Glass:	Slowly attacked
	Hydrocarbons (Halogenated):	Violent reaction
	Hyponitrous Acid:	Ignition reaction
	Lead:	Corrosive in the presence of moisture
	Magnesium:	Incandescent reaction
	Maleic Anhydride:	Decomposes exothermically or explosively
	Metals:	Corrosive reaction with formation of flammable Hydrogen gas
	N-Methyl-N-Nitrosourea & Methylene Chloride:	Explosive reaction
	Nitric Trichloride:	Explosive reaction
	Nitroalkanes:	Formation of explosive salts.
	Nitrobenzene & Methanol (Trace):	Violent, exothermic reaction
	Nitroethane:	Formation of explosive salt
	Nitrogen Trichloride:	Explosive reaction
	Nitromethane:	Formation of explosive salt
	O-Nitrophenol (Molten):	Reacts violently
	Nitropropane:	Formation of explosive salt
	N-Nitrosomethylurea & N-Butyl Ether:	Formation of explosive compound
	Phosphorus:	Evolution of flammable Phosphine
	Potassium Peroxodisulfate:	Ignition reaction
	Potassium Persulfate & Water:	Exothermic reaction
	Sugars:	Evolve Carbon Monoxide at or above 84°C
	Tetrachloroethane:	Formation of flammable Chloroacetylene gas
	2,2,3,3-Tetrafluoropropanol:	Exothermic reaction

Tetrahydrofuran (Peroxidised):	Possible explosive reaction
Thorium Dicarbide:	Incandescent reaction on heating
Tin:	Corrosive in the presence of moisture
Trichloroethylene:	Formation of Explosive
	Dichloroacetylene on heating
2,4,6-Trinitrotoluene & Methanol:	Formation of explosive product
Zinc:	Corrosive in the presence of moisture

Decomposition: Thermal decomposition products may include corrosive fumes of Potassium Oxide and toxic Oxides of Carbon.

Polymerization: Hazardous polymerization has not been reported to occur under normal temperatures and pressures.

STORAGE AND DISPOSAL

Observe all federal, state and local regulations when storing or disposing of this substance. For assistance, contact the district director of Environmental Protection Agency.

Storage: Store away from incompatible substances.

Disposal: Disposal must be in accordance with standards applicable to generators of hazardous waste, 40CFR 262. EPA Hazardous waste number D002.

CONDITIONS TO AVOID

May burn, but does not ignite readily. Flammable, poisonous gases may accumulate in tanks and hopper cars. May ignite combustibles (wood, paper, oil, etc.).

SPILL AND LEAK PROCEDURES

Soil Spill: Dig a holding area such as a pit, pond, or lagoon to contain spill and dike surface flow using barrier of soil, sandbags, foamed polyurethane or foamed concrete. Absorb liquid mass with fly ash or cement powder. Add dilute acid to neutralize.

Air Spill: Apply water spray to knock down vapors. Knock-down water is corrosive and should be diked for containment.

Water Spill: Neutralize with dilute acid or removable strong acid.

Occupational Spill: Do not touch spilled material. Stop leak if you can do it without risk. For small spills, take up with sand or other absorbent material and place into containers for later disposal. For small dry spills, with clean shovel place material into clean, dry container and cover. Move containers from spill area. For larger spills, dike far ahead of spill for later disposal. Keep unnecessary people away. Isolate hazard area and deny entry.

PROTECTIVE EQUIPMENT

- Ventilation:** Provide local exhaust or process enclosure ventilation to meet published exposure limits.
- Respirator:** The following respirators are recommended based on information found in the physical data, toxicity and health effects sections. They are ranked in order from minimum to maximum respiratory protection.
- Specific respirator selected must be based on contamination levels found in the work place, must not exceed the working limits of the respirator and be jointly approved by the National Institute for Occupational Safety and Health and the Mine Safety and Health Administration (NIOSH - MSHA).
- Chemical cartridge respirator with full face piece.
- Type "C" supplied air respirator with full face piece operated in pressure-demand or other positive pressure mode or with a full face piece, helmet, or hood operated in continuous flow mode.
- Self-contained breathing apparatus with full face piece operated in pressure-demand or other positive pressure mode.
- Fire fighting and other immediately-dangerous-to-life-and-health conditions:
- Self-contained breathing apparatus with a full face piece operated in pressure-demand or other positive pressure mode.
- Supplied-air respirator with full face piece and operated in pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode.
- Clothing:** Employee must wear appropriate protective clothing and equipment to prevent any possibility of skin contact with this substance.
- Gloves:** Employee must wear appropriate protective gloves to prevent contact with this substance.
- Eye Protection:** Employee must wear splash-proof or dust-resistant safety goggles and a face shield to prevent contact with this substance.
- Where there is any possibility that an employee's eyes and/or skin may be exposed to this substance, the employer shall provide an eye-wash fountain and quick drench shower within the immediate work area for emergency use.
- Authorized -** Delta F Corporation
4 Constitution Way
Woburn, MA 01801-1087
Tel: (617) 935-4600
Fax: (617) 938-0531

Creation Date: 08/30/90

Revision Date: 6/14/95

9.0 Specifications

ACCURACY:	±2% of range (±5% of range for ranges < 2.5 ppm)
RESPONSE TIME:	Typically less than 20 seconds to read 90% of a step change. Equilibrium time depends on the specific conditions.
TEMPERATURE:	
Gas sample:	32°F to 122°F (0°C to 50°C)
Sensor Temperature:	32°F to 122°F (0°C to 50°C)
STORAGE TEMPERATURE:	Not to exceed 122°F (50°C)
GAS COMPATIBILITY:	
Standard Sensor:	All inert and passive gases, including N ₂ , H ₂ , CO, Ar, freons, hydrocarbons, etc.
STAB-EL Sensor:	Limited tolerance to gas compositions containing "acid" gases such as CO ₂ , H ₂ S, Cl ₂ , NO _x , SO ₂ , HCl, etc.
SENSOR TYPE:	Non-depleting Coulometric
SENSOR WARRANTY:	Five (5) years (limited). See Section 10.
OUTPUT:	0-10 VDC Standard. 0-0.1, 0-1, 0-5 VDC available. 4-20 mA available.
ALARM RELAYS:	Up to two, rated at 5 amps, 250 VAC; 30 VDC under resistive load. Set-points independently adjustable as % of range. Failsafe alarm contacts upon loss of power.
POWER REQUIREMENTS:	Analyzer, 10 Watts; AC Pump, 5 Watts; 115 or 230 VAC 50/60 Hz.
SAMPLE INLET PRESSURE:	0.2 psig to 1.0 psig
SAMPLE FLOW RATE:	1.0 to 3.0 scfh
GAS SAMPLE MOISTURE CONTENT:	No limit (avoid condensation)

10.0 Warranty

Delta F warrants each instrument manufactured by them to be free from defects in material and workmanship at the F.O.B. point specified in the order, its liability under this warranty being limited to repairing or replacing, at the Seller's option, items which are returned to it prepaid within one year from delivery to the carrier and found, to the Seller's satisfaction, to have been so defective.

Delta F's five (5) year Sensor Warranty offers extended protection such that, if any Sensor of a Delta F Oxygen Analyzer fails under normal use, within four (4) years after the expiration of the one-year warranty, such sensor may be returned to the Seller and, if such sensor is determined by the Seller to be defective, the Seller shall provide the Buyer a repaired or replacement sensor at the then current purchase price, equal to such current price multiplied by a fraction thereof in which the numerator is the number of months from the date of shipment by the Seller of the defective sensor to the time it is received back at Delta F Corporation and the denominator of which is sixty (60).

In no event shall the Seller be liable for consequential damages. NO PRODUCT IS WARRANTED AS BEING FIT FOR A PARTICULAR PURPOSE AND THERE IS NO WARRANTY OF MERCHANTABILITY. Additionally, this warranty applies only if: (i) the items are used solely under the operating conditions and in the manner recommended in the Seller's instruction manual, specifications, or other literature; (ii) the items have not been misused or abused in any manner or repairs attempted thereon; (iii) written notice of the failure within the warranty period is forwarded to the Seller and the directions received for properly identifying items returned under warranty are followed; and (iv) with return, notice authorizes the Seller to examine and disassemble returned products to the extent the Seller deems necessary to ascertain the cause of failure. The warranties stated herein are exclusive. THERE ARE NO OTHER WARRANTIES, EITHER EXPRESSED OR IMPLIED, BEYOND THOSE SET FORTH HEREIN, and the Seller does not assume any other obligation or liability in connection with the sale or use of said products.

Index

4-20 mADC output		changing	2-1, 7-2
load resistance	4-1	charging	2-1
Alarm		charging, first time	2-1
electrolyte condition	3-16	type	2-1
Alarm Contacts		warning	2-1
access	3-3	Electrolyte	
audible alarm	3-3	water addition	2-2
rating	3-3	Electrolyte Alarm	
Alarm Relays	3-3	operation of	4-2
power failure	3-3	Electrolyte Change	2-2
Alarm Set-Point		with batter pack	3-9
changing or checking	3-4	Electrolyte Charging	
Alarms		chassis removal	2-1
audible/visual	3-14	first time	2-1
function of	3-14	quantity	2-2
function of indicators	3-15	Electrolyte Condition	
special configurations	3-4	LED	5-7
Alarms	4-2	Electrolyte Condition Alarm	
Analog Displays	3-2	operation of	3-16
set-point alarms	3-2	Electrolyte Maintenance	2-1
Background Gas Correction Factor		Electrolyte Material Safety Data Sheet	
	5-4		8-2
Battery		Electrolyte Material Safety Data Sheet	
test	3-9	(MSDS)	8-2
Bi-Strata® gas diffusion barrier	6-1	External Control of Sensor Voltage	
Calibration		connections	3-17
frequency	5-7	wire size	3-17
process conditions	5-3	Externally Powered Pump	3-12
purging the analyzer	5-3	connections	3-12
span checks, frequency of	7-1	operation	3-12
zero checks, initial	7-1	Factory Settings	5-7
Calibration Standards	5-3	Filter	
Control Potentiometers	5-5	replacement elements	3-5
Controls	5-7	Flow Control Valve	
Digital Displays	3-2	upstream	3-6
set-point alarms	3-2	use of	2-2
Dual Set-point Alarms	3-3	Fuse Specification	1-5
high and low	3-3	Gas connections	2-2
Electrical connections	2-3	downstream	2-3
Electrolyte		Gas Flow	
		flow rate	2-4
		gas dependent	3-6
		over-pressurizing	2-4

start-up	2-3	Panel Mounting	3-15
Gas Leaks		cutout dimensions	3-15
troubleshooting	5-1	Positive Pressure Operation	
Gas Scale Factor	3-14	effects of	6-5
use of	3-14, 5-4	Power Consumption	1-5
Graphic Symbols		Power Switch	5-8
explanation of	1-2	Pressure Regulator	3-5
Ground Connections	4-3	absolute	3-5
High Alarm	4-2	Pressure rating	3-5
contact ratings	4-2	Pump Control	3-11
Inboard Pumps	3-10	external	3-11
Low Alarm contact ratings	4-2	wiring	3-11
Low Battery Warning	3-8	Pump Control Switch	5-8
oxygen readings	3-8	Pump Control, External	
Maintenance	7-1	operation	3-11
calibration	7-1	Quick Setup Procedure	2-1
sensor	7-1	changes	1-1
Multi-Range Configurations		changes to	2-1
switching scales	3-2	Quick-Start	3-14
Nicad Battery Pack	3-7	use of	3-14, 5-8
charging	3-7	Range Configurations	3-1, 3-2
charging, power off	3-8	Range Selection Switches	5-8
continuous operation	3-7	Regulators	
fully charged, verification of	3-8	purging ambient air	5-4
operating time	3-8	Remote Range Indication	3-16
operation	3-8	connections	3-16
recharging	3-8	Replacement Elements	
specifications	3-7	frequency	3-5
Off Primary Range Indication		grades	3-6
connections	3-16	Return Authorization Number	7-1, 7-3
Operating Voltage	1-5	RF Disclaimer	1-4
Outline Lines		RS232C	3-13
back pressure	2-3	connections	3-13
Output Signals	3-12, 4-1	range changes	3-13
4-20 mA DC	3-12, 4-1	Safety	
connections	4-1	EMERGENCY CONTACT	8-2
optional	3-12	Sample Lines	
standard	4-1	make-up	2-3
Outputs		size	2-3
standard	2-3	Sampling Considerations	5-1
Oxygen Alarms	3-3	calibrating	5-3
multi-range analyzers	3-3	calibration standards	5-3
Oxygen Shock		condensation	5-1
minimize effects of	5-2	flow sensitivity	5-2

leaks	5-1	Theory of Operation	
oxygen shock	5-2	Coulometric	6-1
relief valves	5-1	Troubleshooting	7-4
sample delivery lines	5-1	Unpacking	1-4
temperature	5-1	Warranty	10-1
Sensor		Water Addition	7-2
operating principle	6-1	Zero Adjustment	5-5
removal	2-1	procedure	5-5
schematic of	6-1		
water addition	7-2		
Sensor Input Voltage			
measuring of	6-5		
regulation of	6-4		
Sensor Performance			
negative pressure operation	6-6		
pressure effects	6-6		
temperature effects	6-7		
Sensor Signal			
level	3-17		
Service	7-1		
Set-up			
quick procedure	1		
tools required	2-1		
Setup Procedure			
tools required	2-1		
Shipping	7-3		
Shipping Procedures	7-3		
Single Set-point Alarm	3-3		
Span Adjustment	5-6		
procedure	5-6		
with gas scale factor	5-6		
Span Calibration			
with gas scale factor	5-7		
Spare Parts List	7-3, 7-4		
Specifications	9-1		
STAB-EL	3-1		
acid gas	3-1		
allowable limits	6-3, 6-4		
use of	6-2		
standard analyzer			
configuration	1-2		
Standard components	1-5		
Storage Conditions	7-2		
Switched AC	4-2		

