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# Model 328
# Percent Oxygen Analyzer

## Instruction Manual

**DANGER**

HIGHLY TOXIC AND OR FLAMMABLE LIQUIDS OR GASES MAY BE PRESENT IN THIS MONITORING SYSTEM.

PERSONAL PROTECTIVE EQUIPMENT MAY BE REQUIRED WHEN SERVICING THIS SYSTEM.

HAZARDOUS VOLTAGES EXIST ON CERTAIN COMPONENTS INTERNALLY WHICH MAY PERSIST FOR A TIME EVEN AFTER THE POWER IS TURNED OFF AND DISCONNECTED.

ONLY AUTHORIZED PERSONNEL SHOULD CONDUCT MAINTENANCE AND/OR SERVICING. BEFORE CONDUCTING ANY MAINTENANCE OR SERVICING CONSULT WITH AUTHORIZED SUPERVISOR/MANAGER.

P/N M35163
06/28/99
ECO # 99-0277

# OXYGEN ANALYZER

# MODEL 328

**SERIAL NUMBER:**

**RANGE:**

**TAG NUMBER:**

**CUSTOMER ORDER NUMBER:**

**SALES ORDER NUMBER:**

## WARNING

This warning applies to all AC Powered/AC Recharging Circuit instruments. Before opening the unit, for any reason, turn the power OFF or use extreme caution. This unit contains 100V/220V AC.

## IMPORTANT NOTICE

This instrument provides measurement readings to its user, and serves as a tool by which valuable data can be gathered. The information provided by the instrument may assist the user in eliminating potential hazards caused by his process; however, it is essential that all personnel involved in the use of the instrument or its interface with the process being measured, be properly trained in the process itself, as well as all instrumentation related to it.

The safety of personnel is ultimately the responsibility of those who control process conditions. While this instrument may be able to provide early warning of imminent danger, it has no control over process conditions, and it can be misused. In particular, any alarm or control systems installed must be tested and understood, both as they operate and as they can be defeated. Any safeguards required such as locks, labels, or redundancy, must be provided by the user or specifically requested of Teledyne.

Therefore, the purchaser must be aware of his hazardous process conditions. He is responsible for training his personnel, for providing hazard warning methods and instrumentation per the appropriate standards, and for ensuring that hazard warning devices and instrumentation are maintained and operated properly.

TAI, the manufacturer of this instrument, cannot acceptable responsibility for conditions beyond its knowledge and control. No statement expressed or implied by this document or any information disseminated by the manufacturer or his agents is to be construed as a warranty of adequate safety control under the user's process conditions.

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# MATERIAL SAFETY DATA SHEET

## Section I - Product Identification

Product Name: Micro-Fuel Cells, all classes except A-2, A-3, A-5, B-2F and B-2CF.
Electrochemical Oxygen Sensors, all classes except R-19.
Mini Micro-Fuel Cells, all classes.

Manufacturer: Teledyne Analytical Instruments

Address: 16830 Chestnut Street, City of Industry, CA 91749

Phone Number: (626) 934-1500

MSDS Prepared By: Chuck Molloy

Date Prepared or Last Revised: 3-31-88

Emergency Phone No.: (626) 934-1500

## Section II - Physical and Chemical Data

Chemical and Common Names: Potassium Hydroxide (KOH) 15%
Granular Lead (Pb) pure

CAS Number: KOH 1310-58-3
Pb 7439-92-1

Melting Point/Range: -10 to 0 Deg. C

Boiling Point/Range: 100 to 115 Deg. C

Specific Gravity: 1.09 @ 20 Deg. C

pH: >14

Solubility in Water: Completely soluble

Percent Volatiles by Volume: None

Appearance and Odor: Colorless, odorless solution

## Section III - Physical Hazards

Potential for Fire and Explosion: The electrolyte in micro-fuel cells is not flammable. There are no fire or explosion hazards associated with micro-fuel cells.

Potential for Reactivity: The sensors are stable under normal conditions of use. Avoid contact between the sensor electrolyte and strong acids.

## Section IV - Health Hazard Data

Primary Route(s) of Entry: Ingestion, Eye/Skin Contact

Exposure Limits: OSHA PEL .05 mg/cu.m. (pB)
ACGIH TLV 2 mg/cu.m. (KOH)

Effects of Overexposure:

Ingestion: The electrolyte could be harmful or fatal if swallowed.
Oral LD50 (RAT) = 2433 mg/kg

Eye: The electrolyte is corrosive and eye contact could result in a chemical burn.

Inhalation: Liquid inhalation is unlikely.

Signs/Symptoms of Exposure: Contact with skin or eyes will cause a burning sensation and/or a soapy feeling for skin contact.

Medical Conditions Aggravated by Exposure: None

Carcinogenicity:

NTP Annual Report on Carcinogens: Not listed.

LARC Monographs: Not listed.

OSHA: Not listed.

Other Health Hazards: Lead is listed as a chemical known to the State of California to cause birth defects or other reproductive harm.

## Section V - Emergency and First Aid Procedures

Eye Contact: Flush eyes with water for at least 15 minutes and get immediate medical attention.

Skin Contact: Wash affected area with plenty of water and remove contaminated clothing. If burning persists, seek medical attention.

Ingestion: Give plenty of cold water. Do not induce vomiting. Get medical attention.

Inhalation: Liquid inhalation is unlikely.

## Section VI - Handling Information

Handling Precautions: Note: The oxygen sensors are sealed and under normal circumstances, the contents of the sensors do not present a health hazard. The following information is given as a guide in the event that a cell leaks.

Protective Clothing: Rubber gloves, chemical splash goggles.

Clean-up Procedures: Wipe down the area several times with a wet paper towel. Use a fresh paper towel. Use a fresh towel each time.

Protective Measures during Cell Replacement: Before opening the bag containing the cell, check the cell for leakage. If the cell leaks, do not open the bag. If there is liquid around the cell while in the instrument, put on gloves and eye protection before removing the cell.

Disposal: Should be in accordance with all applicable state, local and federal regulations.

NEW DESIGN INFORMATION

MODULAR ELECTRONIC CIRCUITRY

Electronics control and signal conditioning within the Control Unit are accomplished by individual plug-in printed circuit boards which fit into connector sockets mounted upon the main circuit board (designated as the "Mother Board"). Electronics troubleshooting and repair are thus reduced to simply removing the suspect circuit board and inserting the replacement to test or replace circuit.

Optional, as well as standard, circuits are contained on individual circuit boards, and the receptacles on the Mother Board are reserved for specific circuits, whether they are employed or deleted. Consequently, not all circuits (or connectors on the Mother Board) will be used for every instrument. Suffixes to the instrument's model number indicate the optional circuits that are employed. The standard and optional circuit boards used for a standard analyzer with all options will be described in the Circuit Description section of this manual text. Specially designed circuits will be covered as addenda. Part numbers for the circuit boards are listed as recommended spare parts on the parts list at the rear of the manual. If the instrument's ease of troubleshooting and repair is to be realized, it is essential that spare circuit boards be kept on hand at all times.

The control panel of the standard, general purpose instrument is mounted on the outer front surface of the enclosure door, along with a meter for measurement indication. Standard controls include OFF-ON and RANGE selector switches, ZERO and SPAN control potentiometers, and optional potentiometers to set the alarm trip points for alarm-equipped instruments. Design variations may involve different configurations or appearances, but the purpose of the control panel remains the same; to provide easy accessibility of adjustment and calibration controls and indicators for the instrument.

When solenoid valves are used in the sample system to select sample or calibration fluids in the sample flowpath, an additional SAMPLE/CALIBRATE (or SAMPLE/SPAN, MAN/AUTO, AUTO/ZERO/SPAN, etc.) selector switch may be used at the control panel to shift the valve or valves.

Sample/calibration lines or tubing may connect to bulkhead fittings at the instrument enclosure if the electronics control and sample cell are housed together, or the measurement cell may be placed at the process sample point, remote from the control unit. If required, a second enclosure may contain the measurement cell.

Hazardous areas will require explosion-proof design of the analysis (or measurement) section of remote-control models, or of the entire instrument if the control unit and measurement cell are housed together. Although the physical appearance of the instrument will differ in those cases, as reflected in the reference drawings, the theory of operation and electronic circuits used will of necessity remain the same except in rare cases. Customer-accessible controls and adjustments are designed so as to maintain the hazardous area classification in those cases.

When enclosure temperature control options are employed, temperature stabilization will be required after reclosing the door, and this stabilization is very important to the accuracy and stability of instrument readings.

Purging of an enclosure with a safe gas such as compressed air or nitrogen is sometimes used to avoid entry into the instrument enclosure by hazardous or corrosive substances. Purging systems may take the form of fittings installed in the instrument or system enclosure for use by the customer, or a complete system with flowmeter, pressure gauge, and pressure switch, or a configuration between the two. Enclosure purging may require stabilization periods upon reclosing the door, or certain pressure or flow settings may be required for proper operation of the system; in these cases, a tag may be affixed to the enclosure, usually upon the door itself, and pertinent details are provided by that tag.

In order to tailor the instrument to your specific needs, special designs may be arranged, and these may often times vary from the standard line of instruments. In those cases, specialized drawings relating to the exact configuration of your analyzer or system will be included as part of the drawings package at the rear of the manual. Consult these drawings for all specific details about the instrument.

Drawing required for installation, troubleshooting, and repair of the instrument are included at the rear of the manual, preceded by a sequential drawing list and a spare parts list. Drawings nomenclature is as follows:

| | |
|---|---|
| OUTLINE DIAGRAM | Depicts the external mounting dimensions of the enclosure or assembly to which it applies, as well as conduit sizes and connecting points. |
| PIPING DIAGRAM | Presents a pictorial diagram of the flowpath for sample and calibration fluids through analyzer or system; often times includes instructions concerning settings for pressure and flowrate. |
| ASSEMBLY DRAWING | Shows the physical construction and components used, down to the subassembly level, for the analyzer, sub-assembly, or circuit board which it represents. |
| INTERCONNECTION DIAGRAM | Provides terminal strip designations for the application of power and signal wiring. |

| | | | |
|---|---|---|---|
| WIRING DIAGRAM | | | Points out connecting points and wire paths, size, color coding, etc. within the analyzer. |
| SCHEMATIC DIAGRAM | | 1. | Displays the electronic circuits employed with the analyzer; |
| | or | 2. | Displays the interconnection between various PC Boards and the Mother Board; |
| | or | 3. | Displays interconnection between the Mother Board and various auxiliary circuits within the analyzer. |

**CIRCUIT DESCRIPTION**

Each of the circuits commonly used with the analyzer is briefly described below. If required, more detailed descriptions can be found in the Printed Circuit Description section near the end of this manual. The Mother Board receptacle into which the circuit is fitted is identified (as "J__"), and optional circuits are designated as (optional).

The instrument is powered from line voltage via a stepdown transformer, which can be wired for either 115 or 220 VAC. In addition, a regulated differential power supply provides the various voltages (±15V, regulated, and ±24V, non-regulated) to power the electronic circuits employed.

Measurement Circuit: (J1)

The measurement circuit contains specialized circuitry required to convert the sensor output to a signal which is compatible with the other circuits which make up the total instrument. The first receptacle on the mother board, labeled (J1), holds the measurement circuit board.

Linearizer Circuit: (J2) (optional)

The linearizer circuit converts any non-linear relationships between sample concentration and sensor output to a linear ratio between concentrations and linearizer output.

The circuit utilizes adjustable amplifiers which are used to straighten, or linearize, the measurement signal.

The points of coincidence between amplifiers are called "breakpoints" and are set by the selection of resistors at the amplifier inputs (flagged as application-selectable components on the linearizer schematic). The slopes of the sections of the curve are set by adjusting the potentio- meters which pertain to the amplifiers concerned. Each breakpoint is selected to agree with a standard calibration signal.

The linearizer circuit is factory adjusted as part of the routine instru- ment checkout and should need no readjustment at the time of installation.

Special Output: (J3) (optional)

Normally, Mother Board receptacle J3 is reserved for an optional current output. Use of the current output option is indicated by the inclusion of an "O" (isolated) or "I" (negative ground) in the instrument model number, followed by one or two digits which specify the maximum output level, in mA, of the circuit. "I-20", for example, indicates a negative-grounded 4 to 20 mAmp output. "0-50" indicates an isolated 10 to 50 mA output.

If specially ordered, an isolated voltage output can be used.

Alarm Comparator: (J4) (optional)

Use of the Alarm option is indicated by -1 (single alarm) or -2 (dual alarm) following the model number. Alarm output indication is made by shifting Form "C" relay contacts. The alarm relays are plugged into reserved sockets (K1, K2) mounted to the Mother Board. The relay contacts are rated at 3 A non-inductive. Control over the alarm setpoints is achieved by the setting of a panel-mounted potentiometer for each alarm used. Normally, these are 10-turn potentiometers, and each turn of the control represents 10% of the fullscale range of a properly calibrated instrument.

"Scrapping" (jumpering) points on the plug-in circuit board for the alarms are used to program the normal and tripping condition of each relay used. In the fail-safe configuration, the alarms are kept energized in the operating region of the instrument's range, and an alarm condition exists whenever the instrument's power fails (relay drops out) or the instrument output rises above (for high alarm) or drops below (for low alarm) the adjusted control point. Alternately, non-fail-safe alarm relays are de-energized within the operating region and energize upon passing the control point in the increasing or decreasing direction. No contact switching occurs upon instrument power failure if non-fail-safe alarms are used.

Power Supply: (J5)

The Power Supply is also a plug-in printed circuit board, which converts 40-50 VAC (from a center-tapped transformer) to ±24 VDC, non-regulated, to power the 24 VDC relays which may be used, and also to ±15 VDC, regulated, to supply the regulated voltage required by the other circuits of the system. A major troubleshooting consideration for the system will be the checking of the power supply output; the schematic for the power supply clearly indicates the connector points at which these voltages can be tested. **NOTE:** Power supply for percent oxygen analyzers having no options is on the measurement circuit board, and no power supply board is used.

Temperature Controller: (J6) (optional)

In some analysis instrumentation, it is necessary that the temperature surrounding the sensor be stabilized to avoid temperature-related output fluctuations. Mother Board slot J-6 is reserved for a Temperature Controller PC Board, which is used with the temperature control option. It is conceivable, however, that the slot could in some instances be occupied by a circuit board used with a specialized design. Normal temperature control design involves the circuit board in the control unit, interfaced with a temperature-sensing thermistor and heating element located in the compartment to be regulated.

Integral-control models, in which the sensor and control unit share the same enclosure, require temperature regulation of the common enclosure. Applications which require that the sensor be placed apart from the control unit and in an analysis unit enclosure may require temperature regulation of that enclosure. Some applications may not require temperature control, and in those cases, no Temperature Controller PC Board is used.

# 1. INTRODUCTION

1.1 Purpose. The Teledyne Analytical Instruments (TAI) Series 328 Oxygen Analyzer was specifically designed to perform the analytical role in TAI's Model 9502 Flue Gas System. The analyzer may also be used as a separate entity to perform oxygen measurements ranging from one (1) to one hundred (100) percent oxygen in virtually any parent gas.

1.2 Method of Analysis. The analyzer employs TAI's patented Micro-Fuel Cell (U.S. Pat. #3,429,796) to provide an electrical signal that is directly proportional (and specific) to the oxygen concentration in the gas phase immediately adjacent to its sensing surface.

The Micro-Fuel Cell is incapable of producing a significant electrical signal in the absence of oxygen. This unique feature obviates the necessity of having to employ an expensive, cumbersome, questionable gas to "zero" standardize the instrument.

As a further convenience, one of the three (3) available ranges of analysis is always 0-25% so that air (20.9% oxygen) may be used to calibrate the sensitivity of the analyzer. Again, this obviates the expense and doubt accompanying the use of so-called "certified" gas mixtures for calibration purposes.

The Micro-Fuel Cell is a completely enclosed, maintenance-free device with a predictable life span that is covered by warranty. When the cell is expended, it is thrown away as one would discard a worn-out flashlight battery. TAI's extensive line of Micro-Fuel Cell equipped oxygen measuring instruments are all designed so that the cell may be replaced in a matter of moments by non-technical personnel without the use of tools.

1.3 Configuration. The analyzer is housed in an explosion-proof condulet with a safety glass access port cover - so that the oxygen reading can be easily monitored without disturbing the explosion-proof integrity of the assembly.

The necessary electrical controls (span adjustment and range switch) are accessible from the outside - so that nothing has to be opened or removed to calibrate or change the range of the analyzer. The span potentiometer and range switch are assembled on special explosion-proof screw-in plug assemblies, and are interconnected with the detection circuitry on the interior panel, as is the cell assembly, by means of a system of quick disconnect electrical plugs and cables. Each of the three (3) cables uses a different style plug - so that the circuits cannot be accidentally interchanged. Such a system permits quick dismantlement of the analyzer, and prevents key-locking components in place in a housing that only offers one route of access.

Models supplied independent from the Model 9502 Flue Gas System are equipped with an integral sample control panel that features a toggle valve controlled input manifold for the selection of span (air) and sample gas as well as a throttle valve and flowmeter for sample path flow control.

1.4 Standard Features. The following features are standard in the Series 328 line of analyzers. Instruments equipped with only these features are identifiable by the basic number of the series, i.e., Model 328.

1.4.1 Three Ranges of Analysis. The standard ranges of analysis are 0-5, 0-10 and 0-25% oxygen. Range control is achieved through the positioning of the selector switch which is accessible from outside of the housing. The standard ranges have been selected to best cover the oxygen content of flue gas. Upon request, any three ranges of analysis from 0-1 to 0-100% can be provided.

1.4.2 Integral Meter Readout. All models of the Series 328 are equipped with an accurate panel meter for direct (visible through viewing window) readout of the analysis.

1.4.3 Output Signal. For those applications requiring a remote indication and/or recording of the sample oxygen, a linear output signal of from 0-1 millivolt to 0-1 volt D.C. is available at no extra charge. The desired magnitude of signal should be specified at the time of purchase. Unless otherwise specified, the output signal will be 0-1 volt D.C.

The output signal is not suitable for driving low impedance devices. Accessory equipment must have an input impedance of 10,000 ohms or more.

1.4.4 Temperature Control and Compensation. To eliminate the inaccuracies caused by varying temperature conditions that are inherent in most methods of analysis employing transducers, a system composed of a combination of temperature compensation and control is used in the Series 328.

To protect the Micro-Fuel Cell against damage from low ambient temperatures and reduce the range required of the Compensation circuit, the analyzer is equipped with a thermostatically controlled radiant heating system that will not permit the interior of the instrument to drop below 85°F.

To eliminate the inaccuracies accompanying the positive temperature coefficient of the Micro-Fuel Cell, a specially selected thermistor and network of precision resistors is utilized to produce a negative coefficient of matching characteristics. The variable element (thermistor) in the compensation-network is physically located in the same assembly as the Micro-Fuel Cell so that both devices are exposed to essentially the same temperature conditions.

1.4.5 Modular Electronics. The amplifier features the latest in integrated circuit (IC) semi-conductor components. The electronic components are mounted on a plug-in printed circuit board - - as are the various optional (see Section 1.5) electronic features. Although circuit failure is unlikely, plug-in capability of the critical elements of the circuit facilitates instant solution in the event of a semi-conductor failure--providing the customer backs up his instrument with a recommended spare. The faulty circuit board may then be returned to the factory for repairs. The economy of having an available spare part in contrast to requiring the services of a highly trained service man should be apparent. The printed circuit assemblies are pre-set and adjusted that they may be instantly interchanged.

1.5 Optional Features. The following optional features are available at extra cost, and are offered by TAI to make the Series 328 as nearly independent of accessory equipment as possible.

1.5.1 Integral Alarm Circuitry. One (Model 328-1 or two (Model 328-2)) adjustable (full scale) alarm and/or control circuits are available.

Control over an external circuit is achieved by a relay whose coil is operated by an electronic comparator circuit. The switch contacts of the relay (N.C. - C - N.O.) are available for interconnection with customer circuitry at the terminal strip within the analyzer. The control point at which the relay operates is determined by the setting of a calibrated dial equipped with potentiometer on the control panel. The linearity of the oxygen signal and 10 turn "set point" potentiometer, plus the resolution (500 discrete divisions) of the turns counting dial, provides precise alarm or control capability at any oxygen concentration within the range capability of the analyzer. NOTE: Housing must be opened to adjust alarm set points.

The integral control circuitry can be arranged so that the relay is energized above or below the set point. Unless otherwise specified, the control relay in a single set point instrument (Model 328-1) will be energized downscale from the set position, and the relays in a double set point instrument (Model 328-2) will be energized when the oxygen level is reading in the scale region between set point #1 (on the lower region of the scale) and set point #2 (on the upper portion of the scale). These configurations provide power supply failure (as well as oxygen alarm) information -- as the relays are arranged to be in an energized condition when the oxygen concentration of the sample is in the safe region of the scale.

The Form "C", SPDT relay contacts are rated at 5 amperes (non-inductive).

1.5.2 E to I Converter. TAI also offers a voltage (E) to current (I) conversion of the output signal generated by the Series 328 amplifier circuit, so that I (current) to P (pneumatic) devices, as well as low impedance current operated indicating and/or recording equipment, may be driven directly without the need of accessory equipment.

Three (3) ranges of current output are available:

1) 1 to 5 milliamperes D.C.
2) 4 to 20 milliamperes D.C.
3) 10 to 50 milliamperes D.C.

The designation "I" signifies an analyzer equipped with a standard E to I converter. The designation "O" signifies an analyzer equipped with an Isolated E to I converter.

1.5.3 Optional Feature Packaging. Both the integral alarm and E to I converter options are plug-in printed circuit boards for quick replaceability. When either or both of the options are employed in an instrument, a highly regulated differential power supply (also a plug-in printed circuit board) is included to supply to positive and negative voltage required by the semi-conductor circuitry. The basic Model 328 employs a simple unregulated power supply. (The rectifying diodes and filtering capacitors are located on the same board as the detection and amplifier circuitry); however, the alarm comparator and converter circuits require that the supply voltage remain at a constant level to all circuitry in the interest of accuracy. When options are employed, the unregulated power supply components are deleted from the amplifier board, and the amplifier, as well as the option circuit, is fed from the regulated differential power supply.

## 2. INSTALLATION

The following information is applicable to Series 328 analyzers that are furnished independently from the Model 9502 Flue Gas System. Installation information contained in this section is superseded by that contained in the "SYSTEM" section of the Model 9502 manual.

2.1 Location. The analyzer is designed to mount in an upright position on a wall or bulkhead plate. For best access to the interior of the instrument, the center of the access port should be from 5 to 5-1/2 feet off the floor.

Fully assembled, and interconnected with rigid conduit, the instrument is rain right, and meets the most rigorous of hazardous area specifications. In areas where the ambient temperature drops below 0°F, auxiliary heating must be provided.

The analyzer should be installed as close to the sample point as possible to minimize sample line lag time.

An outline diagram, showing the location and identification of the gas lines and electrical conduit connections, as well as the physical dimensions of the analyzer, is included among the drawings at the rear of the manual.

2.2 Electrical Connections. Wiring access is gained through 3/4 inch N.P.T. holes in the sides of the analyzer.

The 328 model is equipped with two (2) such holes for power and signal wiring. The 328-1 and 2 series is equipped with three (3) holes for power, signal, and accessory control wiring.

2.2.1 Power. A single phase, 110 to 120 volt, 60 cycle power service, capable of delivering 2 amperes continuously, must be connected to the terminal strip on the panel face. Use the Interconnection Diagram to identify the appropriate terminals, and polarize the connections as indicated.

A cold water pipe ground wire, of the same gauge as the power service wiring, should be run into the instrument with the power wiring and terminated on the terminal identified "G" on the Interconnection drawing.

The instrument power circuit includes a 2 ampere fuse, but does not incorporate a power switch. If desired, primary power switching must be provided by the customer externally.

2.2.2 Output Signal Voltage. All models (except 328-1) of the Series 328 are equipped to provide an output signal voltage. The magnitude of the signal, which is determined at the time of purchase, can be preset by TAI to any value from between one (1) volt and one (1) millivolt. Unless otherwise specified, the output will be 0-1 volt D.C. Refer to the "Specification Data" section of the manual to determine the output signal magnitude.

The output signal, regardless of magnitude, is suitable for high impedance devices only (10,000 ohms minimum).

Two (2) conductor, 22 gauge (AWG), shielded cable is recommended for interconnection purposes. Polarize the signal connections as shown on the Interconnection Diagram and connect the shield to the analyzer only.

2.2.3 Alarm and/or Control Circuitry. Models having a -1 or -2 as part of their model number are equipped with single (-1) or double (-2) alarm and/or control circuits (see Section 1.5.1 for descriptive information).

The SPDT Form "C" contacts (normally closed-common-normally open) of the relay (or relays) are available on the terminal strip within the analyzer. To properly use the switch that the relay contacts represent, the customer must determine when the relay (or relays) is energized (above or below set point). When applicable, this information is documented in the "Application Section" of the manual. The appropriate terminal strip connections are identified on the Interconnection Diagram.

For those not familiar with relay terminology, the terms normally open (N.O.) and normally closed (N.C.) refer to the relay contact configuration when the relay is in a de-energized condition.

The load current per relay must be limited to five (5) amperes (non-inductive).

2.2.4 Output Signal Current. Instruments which include the designation "I" as part of their model number are equipped with an E to I converter to provide a DC milliampere output signal.

Three (3) ranges of current output are available. They are:

1) 1 to 5 mA DC; suitable for devices with from 0 to 6,000 ohms impedance (resistive).

2) 4 to 20 mA DC; suitable for devices with from 0 to 1,500 ohms impedance (resistive).

3) 10 to 50 mA DC; suitable for devices with from 0 to 600 ohms impedance (resistive)

The appropriate terminal strip connections are identified on the Interconnection Diagram, and the applicable output current range will be found documented in the "Application Section" of the manual.

2.3 Gas Connections. The sample, span, and vent gas connections are 1/4" tubing fittings, and are located at the bottom of the analyzer behind the sample control panel. See the "Outline Diagram" for proper identification of the gas connection points.

2.3.1 Sample Line Installation. The Series 328 analyzer has been designed to operate with a sample that is at positive pressure. If the sample is at atmospheric or negative pressure, the necessary sample pump must be connected between the sample point and the analyzer, so that the sample is delivered under positive pressure. DO NOT DRAW THE SAMPLE THROUGH THE ANALYZER. The Micro-Fuel Cell is a partial pressure sensitive device; therefore, TBE/AI has arranged the integral sampling system so that the cell vents directly to atmosphere.

The analyzer is equipped with its own input manifold selection and flow control devices. To operate from a positive pressure sample, only a pressure reducing regulator is required. The regulator should be equipped with a metallic diaphragm, installed as close to the sample point as is possible, and set to provide from 5 to 50 psig output pressure (10 psig is nominal). NOTE: Any positive pressure (even only a few inches water) will usually provide adequate flow through the analyzer.

If a pump is required, TAI suggests that the bulk of the sample be bypassed to atmosphere -- as the normal flowrate required by the analyzer is 2.0 SCFH. Most pumps will deliver flowrates many times that required. Bypassing the sample ahead of the analyzer will improve the response time of the sampling system, alleviate pump loading, and smooth the sample flow through the analyzer.

TAI suggests 1/4" tubing be used for interconnecting all devices in the customer's sampling system.

2.3.2 Span Gas Line Installation. The Series 328 has been designed to employ air as its span (or calibration) gas. A source of compressed air should be connected to the appropriate toggle valve. The air line should include a pressure reducing regulator. The regulator need not be of the same quality as the sample regulator--as atmospheric diffusion will obviously not alter the oxygen content of the gas supply. The regulator should be adjusted so that the air pressure closely approximates the sample pressure (See Section 2.3.1).

If a sample pump is being used, and compressed air is not available, DO NOT UTILIZE THE SPAN GAS CONNECTION ON THE ANALYZER. Install a shutoff valve between the sample point and the pump inlet port, and another shutoff valve between the pump inlet port, and atmosphere. When calibration is necessary, arrange the two valves so that the one in series with the sample is closed, and the other open. The pump will then deliver atmospheric air to the analyzer for calibration purposes.

2.3.3 Vent Connection. Wherever possible, TAI recommends that the analyzer be allowed to vent directly to the atmosphere. If venting directly is not possible, the following conditions must be satisfied.

1) The vent line must be constructed of 1/4 inch tubing (or the equivalent so that no appreciable back pressure can be developed.

2) The vent line must terminate in an area that experiences no more than normal barometric pressure change.

3) The vent line must be installed so that water and dirt (or other obstructions) cannot accumulate on it.

2.3.4 Sample Conditioning Accessories. The sample must be free of entrained solids and water. A high humidity sample gas; however, is ideal--as it will prevent water loss from the cells electrolyte.

## 3. STARTUP

3.1 Preliminary. Before supplying power to the instrument, TAI suggests that the electrical wiring installation be checked against the Interconnection Diagram--particularly if the installation has been made by personnel other than those responsible for startup and operation.

All accessory hardware and fittings between the analyzer and sample point should be leak tested under pressure prior to startup.

In many instances, proper attention to these two preliminaries will prevent severe damage (accidental wiring transpositions) and ambiguous analysis (diffusion leaks in the sampling system).

3.2 Meter Zero. Before turning the power to the analyzer on, the mechanical zero of the meter should be checked and adjusted (if necessary). The meter indicating pointer should be in precise coincidence with the scale zero mark. Adjust the screw on the face of the meter to zero the pointer. This step is important if remote indicating and/or recording equipment is involved in the system. An offset zero on the meter will result in a tracking error between the two devices, which would be significant if the meter is used to calibrate the analyzer (normal procedure).

**IMPORTANT: NEVER ATTEMPT TO MAKE THIS ADJUSTMENT WITH THE POWER ON.**

3.3 Measuring Cell Installation. The Micro-Fuel Cell is supplied separately in a controlled atmosphere package, and must be installed prior to startup. To install the cell, use the following procedure:

1) Make sure that the power service to the analyzer is turned off.

2) Remove viewing window cover from housing.

3) Locate the cell holder assembly (on the back plate assembly under the meter panel), and withdraw the cell probe from holder (use twisting motion); remove the cap by unscrewing (ccw).

4) Open the cell package and remove the shorting clip.

5) Place the Micro-Fuel Cell in the probe with the sensing surface facing towards the outside and the printed circuit contact end facing the contacts inside the probe body. Replace cap previously removed (refer to instructions furnished in cell box).

6) Insert the cell probe back into the probe holder by pushing and a slight twist until it strikes bottom.

7) Replace housing cover. Turn on electrical service.

3.4 Initial Calibration and Equilibration. Before stable, reliable operation can be guaranteed, the Micro-Fuel Cell will require a period of time to adjust itself to its new environment. To the casual observer monitoring the integral meter, this period of time will appear to be about 15 minutes. In actuality, true stability is not achieved for many hours, which can be demonstrated by recording the output on a circular chart recorder, and analyzing the results of the first 24 hours of operation. The user will note a few percentage points of drift covering a period of hours after the initial first 15 minutes of equilibration.

If speed is of the essence, TAI suggests that the instrument be placed in service after it appears to have stabilized (usually about 15 minutes), and the slight instability of the ensuing hours tolerated. Any error incurred during this period will be eliminated during the first operational calibration.

If, on the other hand, reliable analysis, free of instrument distortion, is required from the very onset of operation, TAI recommends a 24 hour run-in period before operational calibration and service.

In either case, employ the following procedure:

1) Turn the analyzer range switch to the 0-25% position.

2) Arrange the input manifold valves so that calibration (span) air is being delivered to the analyzer.

3) Adjust the throttle valve so that an indicated flowrate of 2.0 SCFH is registered on the flowmeter. Wait about three to five minutes (allow reading to stabilize) before proceeding to next step.

4) Unlock and adjust the span control (accessible from outside of housing) until the meter pointer is in coincidence with the "CAL" mark (20.9% $O_2$) on the meter scale. Relock the span control.

5) Rearrange the input manifold valves so that the sample gas is flowing through the analyzer, and retrim the throttle valve for an indicated flow-rate of 2.0 SCFH.

   NOTE: Analyzer accuracy is not affected by variations in sample flow rate. The recommended flow rate of 2.0 SCFH insures maximum speed or response.

6) Select the range of analysis that will provide the best possible resolution of the oxygen content of the sample gas.

7) Allow sample gas, not calibration air, to flow through the analyzer. **IMPORTANT: IT IS PARTICULARLY VITAL TO THE CONDITION OF THE A-3 CELL EMPLOYED IN FLUE GAS (OR HIGH $O_2$ CONTENT APPLICATIONS) THAT THE CELL NOT BE EXPOSED TO A $CO_2$ FREE ENVIRONMENT FOR A PROLONGED PERIOD OF TIME.**

3.5 Operational Calibration. After the equilibration period following the installation of any new cell, or whenever it is desirable to recheck the calibration of the instrument, employ the following calibration procedure:

1) Place the range selector switch on the 0-25% position.

2) Arrange the input manifold so that calibration (span) air is flowing and adjust the flowrate to 2.0 SCFH.

3) Unlock and adjust the span control until the meter pointer is in precise coincidence with the scale "CAL" mark and relock the span control.

4) Return the instrument to service by restoring sample flow at the proper rate (2.0 SCFH), and selecting the range that provides the best possible resolution of the sample oxygen.

3.5.1 Calibration of Alarm Equipped Instruments. To prevent generating ambiguous alarms during calibration, simply unlock and rotate the set point dial (or dials) until the limits of travel in the "NORMAL" (rather than "ALARM") direction have been attained. After sample flow has been reinitiated, and the proper scale of analysis selected, the alarm point can be precisely reset by simply re-dialing the set point.

3.5.2 Calibration of Converter Equipped Instruments. The current output of the converter always tracks the output of the measuring circuit amplifier. No provisions for inter-locking the converter to a particular range of analysis have been provided. If the current output is being used to operate a pneumatic control device, the customer will be required to provide whatever necessary electrical or mechanical interlocks.

## 4. MAINTENANCE

4.1 Routine Maintenance. No moving parts other than the meter movement and the relay contacts of -1 and -2 models are contained in the Series 328 analyzer; therefore, periodic service is not required. The sample flow check and infrequent calibration outlined in Section 3 should be adequate to keep the analyzer functioning throughout the life span of a given Micro-Fuel Cell.

4.2 Special Shut-down Precaution for Class A-3 Cell. When the analyzer is equipped with a Class A-3 Cell, it must be protected from prolonged exposure to high oxygen concentrat-ions (such as air). This can be accomplished by trapping $CO_2$ containing sample (flue gas) by closing the input manifold valves and sealing the vent connection with a valve, water trap or clamped-off plastic tubing.

4.3 Cell Replacement. When the Micro-Fuel Cell nears the end of its useful life, sensitivity will decline very rapidly. The initial response to this phenomenon will be to recalibrate the analyzer. If many turns of the span control are required to recalibrate the instrument, or if in fact, as most often will be the case, the control does not have sufficient range to recalibrate the analyzer, a new Micro-Fuel Cell will be required.

To offset the possibility of not having a replacement cell available when it is needed, TBE/AI recommends that a spare cell be ordered shortly after the instrument is placed in service, and each time the cell is replaced thereafter. **CAUTION: DO NOT OVER ORDER OR STOCK- PILE SPARE CELLS.** Only one cell per instrument should be in reserve.

4.4 Cell Warranty. The Micro-Fuel Cell carries a warranty that covers its normal life expectancy. Three types (or classes) of cell are employed in the Series 328. Each class carries its own warranty, and the section of the class cell employed is a function of the customer's application. The various classes of cell, the guidelines governing their use, and the applicable warranties covering each class are outlined in the following subsections.

4.4.1 Class A-3 Cell. The Class A-3 cell must be used when the instrument is a part of the Model 9502 Flue Gas Oxygen Analysis System, and for any other application where the carbon dioxide content of the sample gas is in the region of from one (1) to twenty (20) percent.

The A-3 cell is warranted for six (6) months from date of shipment.

4.4.2 Class C-3 Cell. The Class C-3 Cell is employed in $CO_2$ free applications where a response time of 90% in 30 seconds can be tolerated in the interest of long cell life.

The C-3 cell is warranted for 12 months from date of shipment.

4.4.3 Class B-1 Cell. Class B-1 cells are employed in $CO_2$ free applications where fast response (90%) in 10 seconds) is of paramount concern.

The Class B-1 cell is warranted for six (6) months from date of shipment.

4.4.4 Warranty Conditions. Customers having warranty claims must return the cell in question to the factory for evaluation after obtaining an RMA. If it is determined that failure is due to faulty material or workmanship, the cell will be replaced free of charge. (CAUTION: Evidence of tampering or abuse will render the warranty null and void).

4.4.5 $CO_2$ Effect on C-3 and B-1 Cells. A graph showing the effects of different concentrations of $CO_2$ on the C-3 and B-1 cells is on the following page.
NOTE: This graph does not apply to Class A-3 cells.

## 5. TECHNICAL INFORMATION

5.1 Integral Cell Protection. A N-channel field effect transistor (FET) is incorporated in the circuitry across the cell to short circuit the cell whenever the power to the instrument is off. The FET switches to a very high resistance instantly when power is supplied to the analyzer and is essentially no longer part of the circuit.

The FET is necessary because of the characteristics of the cell and the operational amplifier. When in operation, the amplifier input circuit looks like a short to the cell (approximately one ohm). If the power were interrupted, without some means of short circuiting the cell, the amplifier would appear as an open circuit to the cell. Since the cell is a current generating device, these two circuit extremes (short circuit-open circuit) would necessitate a prolonged period of equilibration. With the incorporation of the FET in the cell circuit, the cell looks into essentially a short circuit at all times and the instrument responds immediately when power is restored to the circuit.

## 6. SPECIFICATION DATA

6.1 TBE/AI Sales Order Number:

6.2 Analyzer Model Number: 328

6.3 Analyzer Serial Number:

6.4 Measuring Cell Class:

6.5 Analyzer Range:

RANGE SWITCH POSITION "HI":
RANGE SWITCH POSITION "MED":
RANGE SWITCH POSITION "LO":

6.6 Analyzer Output Signal:

6.7 Sample Flowrate: 2.0 SCFH (or higher) as indicated on the integral flowmeter.

6.8 Response and Recovery: 90% within seconds at an indicated flowrate of 2.0 SCFH.

6.9 Accuracy: Plus or minus 1% of scale from 30 to 125°F when a recorder or indicator of comparable accuracy is used.

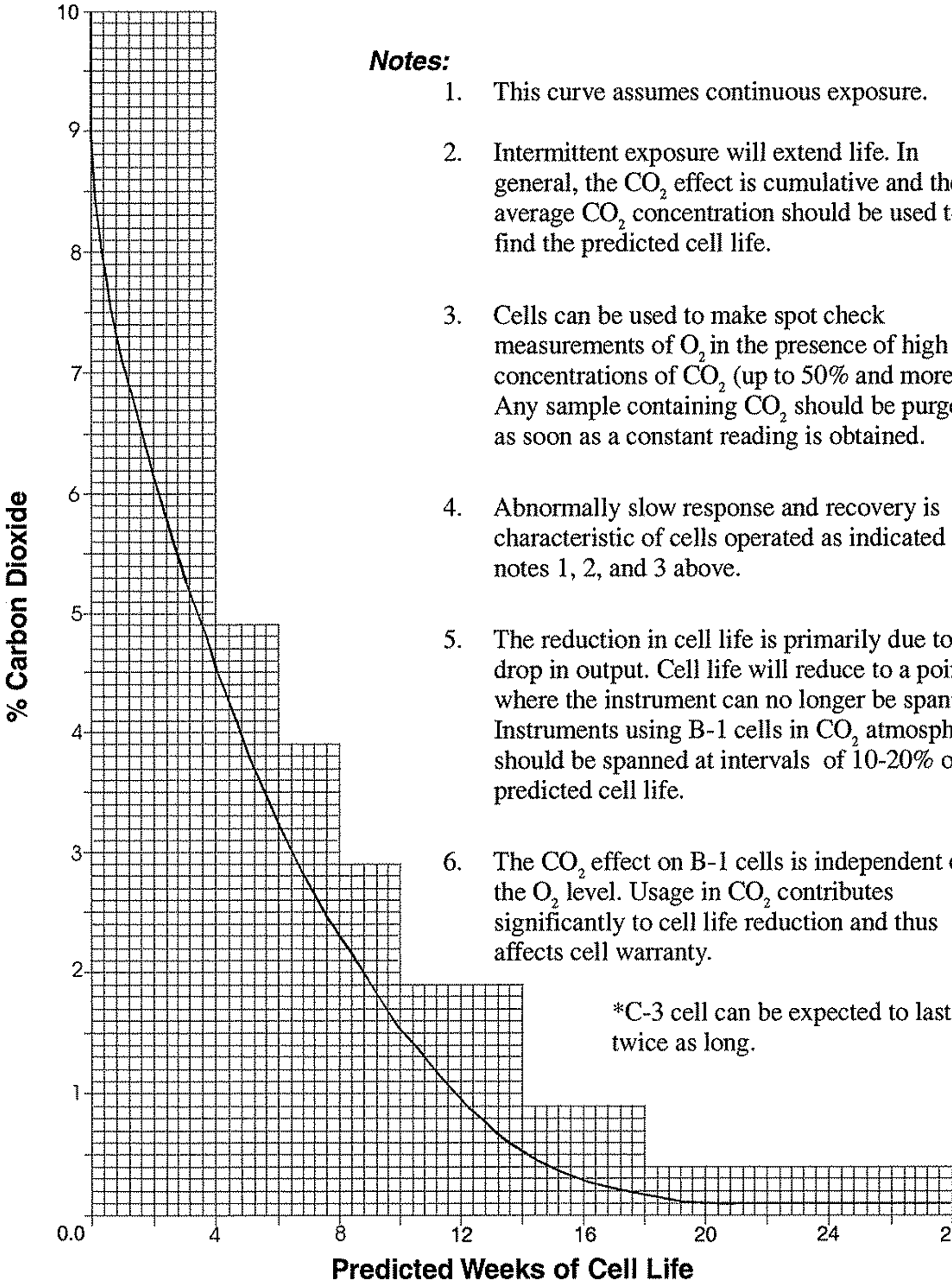
6.10 Recommended Span Gas: Compressed air (20.9% oxygen). Use the "HI" range switch position when calibrating.

6.11 Alarm

6.11.1 Set Point 1: ____________

6.11.2 Set Point 2: ____________

# Effect of $CO_2$ on B-1* Cell Life




***Notes:***

1. This curve assumes continuous exposure.
2. Intermittent exposure will extend life. In general, the $CO_2$ effect is cumulative and the average $CO_2$ concentration should be used to find the predicted cell life.
3. Cells can be used to make spot check measurements of $O_2$ in the presence of high concentrations of $CO_2$ (up to 50% and more). Any sample containing $CO_2$ should be purged as soon as a constant reading is obtained.
4. Abnormally slow response and recovery is characteristic of cells operated as indicated in notes 1, 2, and 3 above.
5. The reduction in cell life is primarily due to a drop in output. Cell life will reduce to a point where the instrument can no longer be spanned. Instruments using B-1 cells in $CO_2$ atmospheres should be spanned at intervals of 10-20% of the predicted cell life.
6. The $CO_2$ effect on B-1 cells is independent of the $O_2$ level. Usage in $CO_2$ contributes significantly to cell life reduction and thus affects cell warranty.

*C-3 cell can be expected to last at least twice as long.

# MICRO FUEL CELLS

| CELL CLASS | COLOR CODE | WARRANTED LIFE | EXPECTED LIFE | 90% RESPONSE TIME (SEC.) | OUTPUT IN AIR |
|---|---|---|---|---|---|
| A-1 | BLUE | | | 4 | 1.0 MA |
| A-2 | GOLD | 6 MONTHS | 6 MONTHS IN FLUE GAS | 7 | .56 MA |
| A-3 | BLACK | 6 MONTHS | 8 MONTHS IN FLUE GAS | 45 | .20 MA |
| A-5 | GRAY | 6 MONTHS | 8 MONTHS IN FLUE GAS OR AIR | 45 | .19 MA |
| B-1 | TAN | 6 MONTHS | 8 MONTHS IN AIR | 7 | .50 MA |
| B-2 | YELLOW | 6 MONTHS | 8 MONTHS IN TRACE $O_2$ APPL | 7 | .50 MA |
| B-3 | ORANGE | 12 MONTHS | 12 MONTHS IN AIR | 11 | .30 MA |
| C-1 | GREEN | | | 30 | .20 MA |
| C-2 | WHITE | | | 30 | .20 MA |
| C-3 | RED | 12 MONTHS | 18 MONTHS IN AIR | 30 | .20 MA |

NOTE: SPECIFICATIONS AT 25°C

## ON-OFF TEMPERATURE CONTROL PRINTED CIRCUIT BOARD

SCHEMATIC NO. A-33973 - PC BOARD ASSEMBLY NO. A-9730

The temperature control circuit is contained on this printed circuit board, which interfaces directly with the instrument's operating voltage and delivers power to a heating element as a deficiency (from a preset control point) is detected by a thermistor located in the compartment to be regulated (along with the heater).

The temperature control board utilizes a bridge network comprised of three resistors and a thermistor (used as feedback in the comparator circuit). A proper combination of R-1 and thermistor resistance must be used in order to maintain the desired temperature control point. The combination of 16.5 k-ohms for R-1 and 16 k-ohms @ 25°C for the thermistor yields a control point of 129°F. (See the chart below).

The bridge network works in conjunction with comparator Q-1, which turns SCR-1 ON (low Q-1 output) or OFF (high Q-1 output). The SCR delivers power to the heater only when turned ON by Q-1. As the temperature drops, the resistance of the thermistor becomes larger, and the output of Q-1 goes low, switching ON the power to the heater. As the temperature rises, the thermistor resistance becomes smaller, and the output of Q-1 goes high, switching OFF the power to the heater when the crossover threshold of the comparator is reached.

Selection of the R-1 value is made at the factory, according to the control point required. The following chart lists a few representative values:

| CONTROL TEMP. (APPROX.) | R-1 VALUE | THERMISTOR VALUE |
|---|---|---|
| 70°F (21.1°C) | 60.4 K | 16 K @25°C |
| 129°F (53.9°C) | 16.5 K | 16 K @25°C |
| 125°F (51.7°C) | 14 K | 10 K @25°C |

## PROPORTIONAL TEMPERATURE CONTROLLER PRINTED CIRCUIT BOARD

SCHEMATIC NO. B-30974
ASSEMBLY DWG. NO. B-30868

The temperature of the chamber to be controlled is regulated by a thermistor-directed electronic circuit. The thermistor and heating element are located in the chamber, and the balance of the circuit components are mounted on the Temperature Controller printed circuit board, which plugs into a connector on the "Mother Board".

The control temperature is determined by the value of resistor R3 on the Temperature Controller Printed Circuit Board, selected (at the time of manufacture) from the chart on Schematic B-30974 to provide the desired control point.

The thermistor used in the circuit is a "Negative Temperature Coefficient" (NTC) device; as the chamber temperature increases the resistance of the thermistor decreases, and vice versa.

The resistance of the thermistor in the circuit is compared with the value of resistor R3; when their resistance is equal, or when the resistance of R3 is less than that of the thermistor, the heating circuit is activated.

When a temperature deficiency is sensed by the thermistor, integrated circuit A1, acting as a zero-crossing switch, applies a pulsed signal to triac Q1, which in turn applies full wave power to the heating element.

IC A1 employs a diode limiter, a zero-crossing (threshold) detector, an on-off sensing amplifier (differential comparator), and a Darlington output driver (thyristor gating circuit) to provide the basic switching action. The DC operating voltages for these stages are provided by an internal power supply, with only capacitor C4 added externally.

The on-off sensing amplifier in this circuit is configured as a free-running multivibrator. This scheme adds proportional control, which takes over when the comparator inputs are at the design differential voltage.

Initially, when cold, the thermistor resistance is large, and the voltage at pin 13 is larger than that at pin 9. As the temperature of the controlled chamber begins to rise, the resistance of the thermistor decreases, thus reducing the voltage at pin 13. During this warmup time the thyristor gating circuit is continuously delivering gate current from pin 4, thus maintaining constant fullwave AC power to the heater.

When the temperature reaches the selected control point, pin 13 voltage is about the same as pin 9 voltage, and proportional control takes over. The rate at which thyristor (triac) Q1 conducts and allows power to be delivered to the heater is determined by the combination of components R2 & R3, R4, C3, R5, and the thermistor resistance at the control temperature. Consequently, the balance point of the bridge formed by this combination of components can be altered by the selection of R3, causing the circuit to seek a temperature at which the thermistor resistance balances the bridge.

Because IC A1 triggers the thyristor at zero-voltage points in the in the supply voltage cycle, transient load current surges and Radio-Frequency-Interference (RFI) are substantially reduced. In addition, use of the zero-voltage-switch reduces the rate of change of on-state current (di/dt) in the thyristor.

## REGULATED DIFFERENTIAL POWER SUPPLY PRINTED CIRCUIT BOARD

SCHEMATIC NO. B-33129
ASSEMBLY DWG. NO. A-9306

The purpose of this power supply circuit is to provide the DC voltage requirements of the various electronic circuits within the analyzer or system. An input voltage of 40-50 VAC at card pins 8 and 10 (center-tapped to ground at pin 14) is converted to a non-regulated +24 VDC at pin 12, -24 VDC (non-regulated) at pin 4, regulated +15 VDC at pin 15, and regulated -15 VDC at pin 1.

The circuit board can be easily tested (by verifying the voltages while in operation) as follows:

REGULATED ±15 VOLTS:

a. Connect the negative voltmeter lead to the common (pin 2) and the positive lead to pin 15 of the card connector. The measured voltage should be 15 ±0.5 volt.
b. Then connect the positive DVM lead to pin 1 of the card connector. Measured voltage should be -15 ±0.5 volt.

NON-REGULATED ±24 VOLTS:

a. With the negative lead of the DVM still connected to pin 2 (ground), connect the positive lead to pin 12, and verify 24 volts (nominal).
b. Then connect the positive lead to pin 4 and verify -24 volts (nominal).

INPUT VOLTAGE - 40-50 VAC:

Using a voltmeter set to measure at least 50 VAC, test the voltage at circuit card pins 8 and 10; voltage should measure ca. 40-50 volts. Voltage from either pin 8 or pin 10 to ground should measure half the voltage found across pins 8 and 10.

## RECOMMENDED SPARE PARTS LIST

## MODEL 328R

| QTY. | P/N | DESCRIPTION |
|---|---|---|
| 1* | B-29600 | PC BOARD - E TO I CONVERTER, ISOLATED ("O" OPTION) |
| 1* | B-14702 | PC BOARD - E TO I CONVERTER, NEG. GROUND ("I" OPTION) |
| 1* | A-10045 | PC BOARD - ALARM COMPARATOR (SINGLE: -1 OPTION) |
| 1* | A-9309 | PC BOARD - ALARM COMPARATOR (DUAL: -2 OPTION) |
| 1 | A-9306 | PC BOARD - POWER SUPPLY (USED W/ANY OF THE ABOVE OPTIONS) |
| 1 | B-30868 | PC BOARD - TEMP. CONTROLLER |
| 1 | A-9348 | PC BOARD - OXYGEN AMPLIFIER |
| 5 | F-10 | FUSE - 3AG-2 AMP (220V USE F-9) |
| 1 | H-28 | HEATER (110, 220V) |
| 1 | C-6689 | MICRO-FUEL CELL: CLASS_____ |
| 1 | A-7023 | CELL CONTACT SPRING |
| 1 | A-6544 | CELL CONTACT PIN |
| 1 | A-33748 | THERMISTOR ASSEMBLY |

* - THESE ITEMS ARE OPTIONS TO THE STANDARD INSTRUMENT, AND UNLESS ORDERED, WILL NOT BE PRESENT.

A MINIMUM CHARGE IS APPLICABLE TO SPARE PARTS ORDERS.

**IMPORTANT:** Orders for replacement parts should include the part number (if available) and the model and serial number of the system for which the parts are intended.

SEND ORDERS TO:

TELEDYNE ANALYTICAL INSTRUMENTS
16830 CHESTNUT STREET
CITY OF INDUSTRY, CALIF. 91749
TELEPHONE: (626) 934-1500
FAX: (626) 961-2538
TWX: (910) 584-1887 TDYANYL COID
OR YOUR LOCAL REPRESENTATIVE