O P E R A T I N G   M A N U A L

COMPOSER®

Gas Concentration Controller

IPN 074-289

INFICON

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Gas Concentration Controller

IPN 074-289L

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This is to certify that this equipment, designed and manufactured by:

INFICON Inc.
2 Technology Place
East Syracuse, NY 13057
USA

meets the essential safety requirements of the European Union and is placed on the market accordingly. It has been constructed in accordance with good engineering practice in safety matters in force in the Community and does not endanger the safety of persons, domestic animals or property when properly installed and maintained and used in applications for which it was made.

Equipment Description:	Composer Controller including cells. Not including computers.
Applicable Directives:	73/23/EEC as amended by 93/68/EEC 89/336/EEC as amended by 93/68/EEC
Applicable Standards:	EN 61010-1 : 1993/A2 : 1995 EN 55011, Group 1, Class A : 1991 EN 50082-2 : 1995
CE Implementation Date:	September 1997
Authorized Representative:	Gary W. Lewis Vice President - Quality Assurance INFICON Inc.

ANY QUESTIONS RELATIVE TO THIS DECLARATION OR TO THE SAFETY OF INFICON'S PRODUCTS SHOULD BE DIRECTED, IN WRITING, TO THE QUALITY ASSURANCE DEPARTMENT AT THE ABOVE ADDRESS.

09/24/97

Registration Card

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Title ____

Company ______________________________ Bldg./MS ______________

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Using the table below, please circle the appropriate rank for each aspect.
In the Importance column, please indicate the importance of each aspect.

Manual Title ____

Part # (see Title Page) 074-______________________________

Aspect	Very Dissatisfied	Dissatisfied	No Opinion	Satisfied	Very Satisfied	Importance (ranked from 1 to 5, where 1 is low and 5 is high)
Found everything I needed	VD	D	NO	S	VS	
Easy to read	VD	D	NO	S	VS	
Easy to use	VD	D	NO	S	VS	
Relevant to my work	VD	D	NO	S	VS	
Accurate information	VD	D	NO	S	VS	
Well-written	VD	D	NO	S	VS	
Well-organized	VD	D	NO	S	VS	
Technical Enough	VD	D	NO	S	VS	
Helped me solve problems	VD	D	NO	S	VS	

If you have additional comments, please contact INFICON®.

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Chapter 1
Getting Started

1.1 Introduction

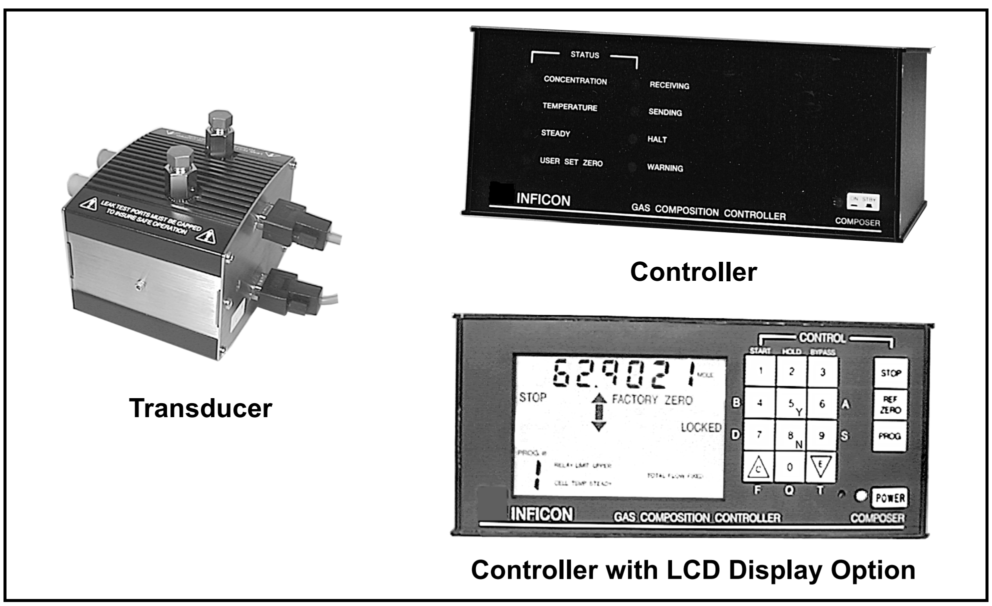
The Composer system is designed to measure and generate signals appropriate for the measurement and control of the composition of binary gasses. It is optimized for operation at pressures as low as 70 Torr (9.33 kPa) and with supply line temperatures as high as 65 °C. It has unsurpassed precision and reproducibility when measuring small concentrations of heavy molecular weight components in a low molecular weight carrier gas.

1.1.1 Description of the Instrument System

The Composer system consists of: two main hardware components, and an Interconnecting Cable. The hardware components are: (see Figure 1-1.)

- a Transducer module which interfaces to the Reactor’s gas supply line and forms the physical basis for the speed of sound measurement.
- an electronic Controller module which provides the electrical signals to the Transducer that are necessary to determine the speed of sound, provides either an LCD or LEDs for user status information, provides outputs for real time analog and digital concentration information, and feedback control for either concentration or bulk flow control.

Figure 1-1 Transducer and Controller



For the LED version of the Controller module, a software application called the Setup Tool allows the complete configuration for a single application. One of two standard lengths of Interconnect Cable is provided with the purchase of an Instrument System. There is also an optional 24 V(dc) Power Supply module.

The optional Monitor software package is a Windows™ based user interface package that has a scrolling display for historical measurement trends, means for selecting between the two measurement modes, diagnostic routines, routines for the calculation of bubbler vapor pressures and parameter setup menus for application & firmware configuration. This package may be run in multiple instances to view several instruments at once.

1.2 Using this Manual

Please take a moment to read the following.

1.2.1 Symbols and their Definitions

NOTE: Notes provide additional information about the current topic.

HINT: Hints provide insight into product usage.

CAUTION

This caution paragraph cautions against actions which may bring about a malfunction or the loss of data.

WARNING

This warning paragraph warns of actions that may result in physical injury to the user.

WARNING

This warning paragraph warns of potentially lethal voltages.

1.3 Performance Specifications

The following sections provide the Composer's performance specifications.

Transducer's swept volume

18 cc

Temperature range of transducer

0 - 65 °C, controlled from 25 to 65 °C; heating only

Temperature range of controller

0 - 50 °C

Transducer's pressure range

- 70 - 1000 Torr (9.33 - 133.3 kPa) operational range without zero shift
- 0 - 1520 Torr (0 - 202.7 kPa) recommended routine exposure range
- 0-6200 Torr (0-1655 kPa) safety range

Gas flow range

0 - 1800 sccm

Transducer's leak rate

$<1X10^{-9}$ std. cc/sec (He); primary and secondary containment vessels

Dimensions

- Transducer: 3.75" H X 5.5" W X 5.6" D (9.5 cm x 14 cm x 14.2 cm)
- Controller: 3.5" H X 8.0" W X 12.0" D (8.9 cm X 20.3 cm X 30.5 cm)

Power (optional supply)

2.0 amps at 24 V(dc)

Sensitivity

0.00011% (1.1 $X10^{-6}$ molar) TMIn (Trimethylindium) in Hydrogen equivalent

Reproducibility

$3X10^{-6}$ molar TMIn in Hydrogen equivalent

1.4 How To Contact Customer Support

If you have a question about your instrument, please read this Operating Manual before contacting Customer Support. If you can not find the answer in this manual, decide whether:

- your difficulty is with how you are using the instrument—in this case, contact Application Support.

or

- your instrument needs repair—in this case, contact Field Service and Repair Support.

When you contact Customer Support, please have this Operating Manual at hand, along with the following information:

- The serial number for your instrument.
- A description of your problem.
- An explanation of the corrective action that you may have already attempted.
- The exact wording of any error messages that you have received from the instrument.

Within the USA, you may reach Customer Support at the phone numbers shown in section 1.4.1 below. Please contact the location that is closest to you.

If you are located outside the USA please contact your sales office, or see www.inficon.com for a complete listing of Worldwide Service Centers.

1.4.1 Application Support

Syracuse, NY. . . . ph. 315-434-1128 . . . . .fax 315-437-3803

Austin, TX . . . . . . ph. 512-448-0488. . . . . .fax 512-448-0398

San Jose, CA. . . . ph. 408-361-1200 ext. 125 . . .fax 408-362-1556

1.4.2 Field Service and Repair Support

Syracuse, NY. . . . ph. 315-434-1167 . . . . .fax 315-434-2551

Austin, TX . . . . . . ph. 512-448-0488. . . . . .fax 512-448-0398

San Jose, CA. . . . ph. 408-361-1200 ext. 120 . . .fax 408-362-1556

1.4.3 Returning Your Instrument

Do not send your instrument without first speaking with a Customer Support Representative.

You must obtain an RMA (Return Material Authorization) number from the Customer Support Representative. If the delivery of a package without an RMA number is attempted, INFICON® will refuse delivery and the package will be returned to you.

You will be required to complete a Declaration Of Contamination form if your Transducer has been exposed to process materials. We will require that the Transducer be sent to a designated decontamination facility, not to the factory. Failure to follow these procedures will significantly delay the repair of your instrument.

1.5 Inventory of Supplied Items

Every Composer consists of the items shown in Table 1-1.

Table 1-1 Inventory of Supplied Items

Qty.	Part Number	Description
1	B761-600-G1or B761-600-G2	Controller LED or Controller LCD
1	B761-601-G1, G2, or 761-601-G3	Transducer - Viton, Kalrez, or metal seal respectively
1	600-1096-P5, P10, or P20	Controller to Transducer interconnect cable
Included In Ship Kit 761-606-G1		
1	074-289	User Guide
1	761-701-G1	Setup Software Kit (LED display only)
4	070-811	Feet, rubber
1	051-1143	9 Pin connector, solder cup
1	051-620	cable clamp
1	051-483	25 pin connector, solder cup
1	051-619	cable clamp
2	059-265	gasket (SS-4-VCR-2)
2	059-196	gasket (Ni-4-VCR-2)

In addition, there may have been additional items selected at the time of order, such as power supplies and rack mounting kits.

1.6 Physical Requirements

The following sections provide the physical dimensions, weight, mounting requirements, ventilation requirements, and the perimeter for maintenance access required by the Composer.

Physical dimensions

- Transducer: 3.75" H x 5.5" W x 5.6" D (9.53 cm x 14 cm x 14.2 cm)
- Controller: 3.5" H x 8.0" W x 12.0" D (8.9 cm x 20.3 cm x 30.5 cm)

Weight

- Transducer: 4.8 lb. (2.2 kg)
- Controller: 6 lb. (2.7 kg)

Mounting requirements

- Controller is designed for 19" (48.26 cm) relay rack mounting. Two units may be placed side-by-side. Or, one unit may be rack mounted with the rack filler from the optional Mounting Kit.
- The Transducer is provided with horizontal mounting surfaces and is firmly restrained by use of one or two of the mounting holes.

Ventilation requirements

None when operated within temperature limits.

Perimeter for maintenance access

- Transducer to be removed from the delivery line: Cajon™ VCR-4 zero clearance type fittings are used and require only side-to-side or top-to-bottom clearance of 6" (16 cm) for wrench rotation.
- Cable to be removed or replaced from either Transducer or Controller requires 3” (8 cm).
- Controller to be removed from rack, full 12” (30.5 cm) instrument length required.

1.7 Electrical Power Requirements

The following sections detail the electrical power requirements for the Composer as minimally required by, or supplied by the optional Power Module.

WARNING

Failure to comply with the electrical power requirements stated below may result in the unit malfunctioning or being damaged, and could result in personal bodily injury.

1.7.1 Rated Output to Composer

Voltage . . . . 24 V(dc) ±5%, isolated from ground

Ripple and Noise . . . . 1 V peak to peak max.

Overvoltage Transient Protection . 36 V

Current . . . . 2 A min. continuous at 50 °C ambient

Turn on Surge . . . . 35 A

Operational Peak Loads . . . . 2.5 A for 10 seconds max.

Short Circuit Protection . . . . Required, VFB, VIFB, PWM allowed

Short Circuit Time . . . . Indefinite

Ambient Operating Temperature . . 0 to 50 °C

Humidity . . . . 0 to 95% non condensing

24 V Connector Interface . . . . Custom Shielded Cable Assembly

- Connector . . . . 9 Pin D-Sub-Miniature Female
- Length . . . . 5 ft. ± 1ft. (1.5 m ± 0.3 m)
- Wiring Size . . . . #20 AWG
  - +24 V . . . . Pins 6, 7, 8
  - +24 V ret . . . . Pins 1, 2, 3
  - Shield Drain . . . . Pin 9
  - Shell . . . . Isolated

1.7.2 Rated Input

Operational Voltage Range . . . . . . 90 to 264 V(ac)

Overvoltage . . . . Category II (EN 61010-1, Annex J)

Frequency Range . . . . 47 to 63 Hz

Mains Connection . . . . 3 Wire L, N, G

Unit Mains Connector IEC320

Inrush Current . . . . < 30 A peak

Line Fusing . . . . Required, consistent with power rating of supply

Line Cord . . . . > 95% shielded

1.7.3 User Supplied Power Supply

If the user provides their own power supply it should minimally meet the specifications and requirements shown above and must also provide a series DC current limiting means consistent with the Composer DC current requirements. The 9 pin D-sub-miniature female power cable connector is provided in the ship kit.

1.8 Environmental Requirements

The following paragraphs detail the Composer's environmental requirements.

Use

This instrument is designed for indoor use only.

Altitude range

The Composer can be used to a maximum altitude of 2000 meters (6561 feet). For applications above this altitude, please consult the factory.

Maximum humidity

Non-condensing relative humidity at operating temperature.

Pollution degree

Category II (as defined by EN61010-1, only non-conductive pollution occurs).

Operating temperature

The maximum and minimum operating temperature is shown in the following sections.

Maximum temperature

- Controller: 50 °C
- Transducer: 65 °C

Minimum temperatures

- Controller: 0 °C
- Transducer: 0.1 °C (minimum); recommended operating is 5 °C above ambient for maximum stability.

1.9 Computer System Requirements

The Composer utilizes the Setup Tool software or the Monitor software for monitoring and storing data. See section 8.2.1 on page 8-2 for the computer system requirements.

1.10 Installation

The Composer should be installed following the guidelines presented in the following sections.

1.10.1 Physical Installation

The Transducer is connected to the Reactor's delivery tubing with Cajon™ VCR-4 fittings. Although a vertical orientation is shown, there is no restriction on mounting orientation. It is recommended that the Transducer be secured by means other than relying on the plumbing. Two 1/4"–20 holes are provided on two faces of the Transducer for this purpose. Any one of the four threaded holes will provide a ground connection.

CAUTION

Perform a thorough leak check prior to connecting the Transducer to any process gas. Many of the gasses used for film growth are toxic at very low exposure levels. The use of a highly sensitive helium mass spectrometer type leak detector is mandatory for safety. See section 5.6 on page 5-2 for the recommended procedure.

The Transducer's gas flow is restricted by the inlet and outlet tubing's 0.058" inside diameter. This restriction arises from acoustic energy conservation considerations. The penetration of the inlet and outlet at the extremes of the Resonant Chamber was chosen so the gas flow within the Resonant Chamber generally sweeps the entire volume, thereby avoiding the creation of large stagnant zones and thereby extending response times.

NOTE: Cajon™ recommends that VCR type fittings be tightened 1/8 turn past finger tight for Nickel and stainless steel gaskets. **Gaskets should not be reused.**

CAUTION

Do not allow Composer's transducer to be attached to gas tubes that can exceed 6200 Torr (1665 kPa) [8.2 atmospheres gauge]. Exposure to excess pressures can stretch the diaphragms and require on site rezeroing. See section 3.1.2 on page 3-1.

Applications of pressures in excess of 8.2 atmospheres gauge may cause catastrophic diaphragm failure. It is recommended that a certified rupture disk be installed upstream of the transducer to limit any possible over pressure to less than 8 atmospheres.

1.10.1.1 Use with Heated Delivery Lines

The Transducer may be attached to Delivery Lines heated to a maximum of 60 °C. The temperature of the Transducer's Resonant Chamber is controlled to a maximum of 65 °C. This temperature is a user determined parameter. It takes less than 15 minutes for the Resonant Chamber to reach temperature and up to 1 hour for maximum stability. Normal temperature excursions are ± 0.05 °C or less.

NOTE: It is recommended that the Resonant Chamber's temperature be set slightly higher than the temperature of the Reactor's inlet and outlet tubing and about 5 °C higher than the Ambient. This is to insure that Precursor will not condense within the Resonant Chamber or the Transducer's inlet or outlet tubing.

Operation of the Transducer at a temperature slightly higher than the Reactor's inlet and outlet tubing will not cause any problems with material condensing downstream. The reason for this is, (assuming the precursor is not already condensing in the Reactor's inlet tubing), it will become even less saturated in the slightly higher temperature of the Transducer. The only way for condensation to subsequently occur in the Reactor's line leaving the Transducer is for the temperature of the outlet tubing to be less than the temperature of the Reactor's supply tubing to the Transducer and below the gas mixture's saturation (condensation) temperature.

1.10.1.2 Rack Mounting

The Controller may be rack mounted using the optional rack adapter kit's extender if only one Controller is used. Two Controllers mount side by side in a standard 19" (48.26 cm) relay rack enclosure without the extender.

1.10.2 Electrical Installation

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Adhere to the guidelines presented in the following sections when installing the Composer.

1.10.2.1 Connection to Rear Panel

The long term performance of this instrumentation is dependent on the quality of the installation. A first rate installation includes the proper assembly of the user/OEM installed cabling. The assembly instructions for the connectors used on this instrumentation are shown in the following sections. See section 1.10 on page 1-9 and section 4.3.6 on page 4-22 for specific details.

1.10.2.1.1 The BNC Connectors

Because complete BNC cables are so common, there are no mating connectors supplied in the ship kit for the Controller's source and recorder outputs. It is recommended that completed BNC type cables be purchased locally, even if one end is cut off for connection to the external apparatus.

1.10.2.2 The D Shell Connectors

The D shell connectors use solder cup contacts that will accept solid or stranded wire with a maximum individual wire size of 20 AWG. Multiple stranded wire jumpers may equal 18 AWG, or two 22 AWG wires may be employed. The recommended wire strip length is 1/4" (6.4 mm).
See Figure 1-2 on page 1-13.

The duplex tin/lead solder cup readily accepts tinned leads and will securely strain-relieve wires when properly soldered.

The American National Standards Institute *Standards For Soldering Electronic Interconnections* (ANSI/IPC-S-815A) is recommended for establishing soldering quality guidelines.

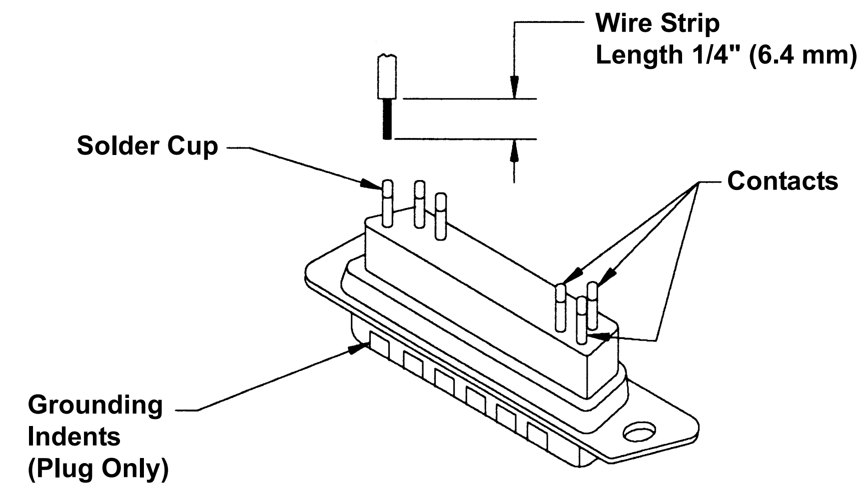
The soldering procedure is as follows:

1. Obtain a connector and wire(s) of the type and size required for your application.
2. Ensure that surfaces to be soldered are clean and free of any contaminants that may inhibit solderability.
3. Strip wire(s) to recommended strip length of 1/4" (6.4 mm). Tin the leads if required.
4. Obtain resin flux, 40/60 alloy solder, and a low-wattage soldering iron.

NOTE: It is common to use heat shrink tubing over solder joints to insulate the exposed solder connection at the cup. If using heat shrink tubing, ensure that the tubing sections are cut to proper length and placed on the wire(s) prior to soldering. After wires are terminated, slide tubing over solder connections and shrink with an appropriate heat source.

5. Coat the stripped portion of the wire(s) with the flux and insert into the solder cup of the contact until the conductor is bottomed in the cavity.
6. Heat the solder cup with the soldering iron and allow the solder to flow into the cup until the cavity is filled but not over filled.
7. Continue soldering wires until all termination's are complete.
8. Clean the soldered connections with a suitable alcohol/water rinse to remove flux and solder residue.

Figure 1-2 Solder Cup Connector



1.10.2.3 How to Connect Electrical Power to the Instrument

All external electrical power is supplied to the Controller through the DB-9 style POWER connector. It is subsequently distributed to the Transducer through the Interconnect Cable.

1.10.2.4 Isolated +24 V(dc) Supply

An isolated +24 V(dc) power supply is available to convert line power to a safe low voltage for the Controller. This optional Power Supply's output is rated for a minimum of 60 W. The pin assignments are shown in Table 1-2, below.

Table 1-2 +24 Volt Power Connector's Pin Connections

Pin	Function
1	Return
2	Return
3	Return
6	+24 Volts
7	+24 Volts
8	+24 Volts
9	Cable Shield

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1.10.2.5 Protective Grounding Requirements

The Controller and Transducer must be connected to a low impedance and reliable earth ground using a high quality solid copper conductor of the shortest possible length. It is recommended that this wire be a minimum of 16 gauge and that any connector terminals be soldered. Although the Transducer will normally be grounded by the Reactor's Delivery Line tubing, an additional ground connection to one of the 1/4"-20 mounting holes must be used for optimum results.

CAUTION

Verify that the Reactor is grounded and that the metal Delivery Line tubing makes a low impedance connection to this ground.

1.10.3 Electrical Grounding and Shielding Requirements

Careful consideration of simple electrical guidelines during installation will avoid many problems caused by electrical noise.

To maintain the required shielding and internal grounding as well as insuring safe and proper operation, the instrument must be operated with all enclosure covers and option panels in place. These must be fully secured with the screws and fasteners provided.

1.10.3.1 Verifying/Establishing Earth Ground

If local facilities engineering cannot provide a low impedance earth ground close to the instrument, the following procedure is recommended.

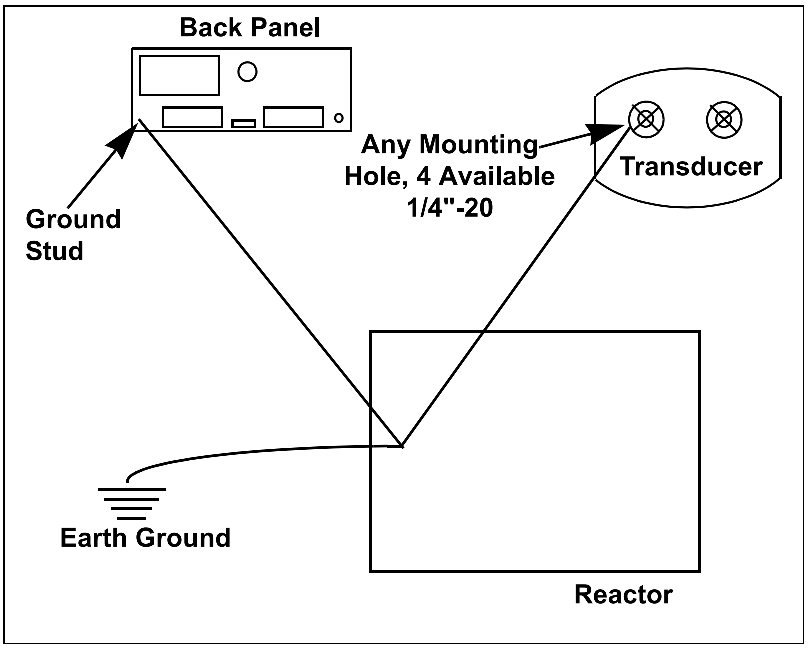
Where soil conditions allow, drive two ten foot copper clad steel rods into the ground 6 feet (2 meters) apart. Pour a copper sulfate or other salt solution around the rods to improve the soil's conduction. A near zero resistance measurement between the two rods indicates that a desirable earth ground is established. In severe cases it may take several soakings of solution over several days to reach this condition.

NOTE: Keep connections to this grounding network as short as possible. Most noise transients contain significant power at high frequencies. A long path adds to the ground circuit's inductance and thereby increases its impedance at these frequencies.

1.10.3.2 Connections To Earth Ground

The ground connection on the Controller is a threaded stud with a hex nut. It is convenient to connect a ring terminal to the ground strap, thus allowing a good connection with easy removal and installation. The ground connection to the Transducer may be made to any one of four 1/4"-20 mounting holes. See Figure 1-3 for the suggested grounding scheme. This method ensures that no ground potential may exist between the controller and the transducer. In many cases, a braided ground strap is sufficient. However, there are cases when a solid copper strap (0.030" thick X 1" wide) (0.08 cm x 2.5 cm) is more suitable because of its lower RF impedance.

Figure 1-3 System Grounding Diagram



When used with RF powered systems, the grounding scheme may have to be modified to optimize the specific situation.

CAUTION

An external ground connection is required to ensure proper operation, especially in electrically noisy environments.

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1.10.3.3 Minimizing Noise Pickup from External Cabling

When an instrument is fully integrated into a deposition system, there are many wire connections; each a potential path for noise to be conducted to the inside. The likelihood of these wires causing a problem can be greatly diminished by using the following guidelines:

- Use shielded coax cable or twisted pairs for all connections.
- Minimize cable lengths by centralizing the controller.
- Avoid routing cables near areas that have the potential to generate high levels of electrical interference. For example, large power supplies can be a source of large and rapidly changing electromagnetic fields. Placing cables as little as one foot (30 cm) from these problem areas can be a very significant improvement.
- Be sure that a good ground system and straps are in place as recommended above.
- Ensure that all instrument covers and option panels are in place and tightly secured with the provided fasteners.

1.10.3.4 Communications Connection and Software Installation

The optional Monitor software currently supports RS-232C communication only. See Chapter 7 for information concerning RS-232C communications and Chapter 8 for information on the Setup Tool and other software options installation.

1.10.4 Connections to the Reactor

When integrating this Instrument System there are three basic levels of integration to the Reactor.

- As a *Monitor*, where the measured concentration is either automatically recorded or just visually observed. Any adjustments to the system is either manually executed or the Reactor's controller makes the adjustments based on user or OEM supplied algorithms.
- As a *Concentration Controller*, where the Instrument System measures concentration (mole fraction) and then makes small adjustments to the flow (the Manipulated Variable) to maintain the target concentration without manual intervention. In addition, the reactor's flow may be maintained at a constant total flow (bubbler flow plus dilution flow equals constant total flow). This feature is set by enabling SW#5 on CFGR2; see section 4.3.6.6 on page 4-26.
- As a *Bulk Flow (Flux) Controller*, where the instrument in addition to measuring mole fraction has an input that reads the flow through the bubbler's MFC and controls the Bulk Flow. This feature requires the Analog I/O Option Card and is set by enabling SW#8 on CFGR2. See section 3.1.13 on page 3-11 for detailed operating and set-up instructions.

  Optionally, the wire harness, Bulk Flow Control Installation Kit (IPN 600-1149-P1) may be purchased to facilitate integration.

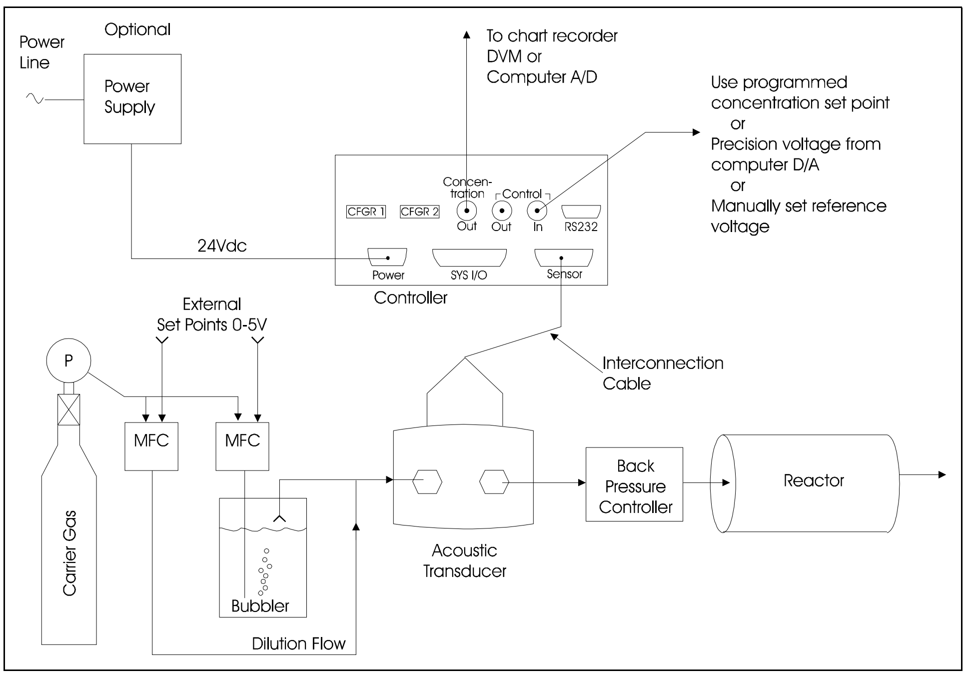
1.10.4.1 When Used as a Monitor

Concentration output is available from an analog voltage output, see section 4.3.6.8 on page 4-27. It is also available visually on a scrolling recorder screen from the optional Monitor Software package or the optional LCD display.

When used as a Monitor, it is only necessary to view the concentration as displayed on the LCD display or the Monitor Software's main screen. From this value the reactor's flows may be altered to correct the concentration.

The Concentration is also available via the precision analog voltage output, CONCENTRATION OUT; see section 4.3.6.8 on page 4-27. The concentration may then be monitored by connecting a DVM or Chart Recorder. See Figure 1-4.

Figure 1-4 Basic Integration with a Reactor



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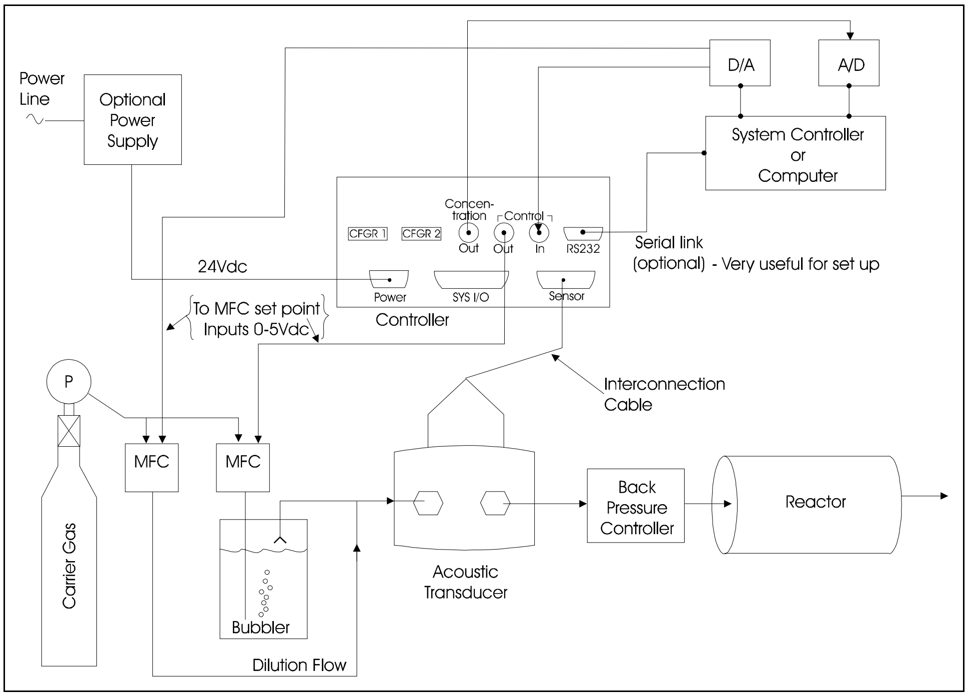
1.10.4.2 Basic Connection to a Reactor (Concentration Measuring Mode)

If a permanent connection from the Reactor’s electronics is made to the back panel’s CONCENTRATION OUT connector, the reactor’s controller may be configured to read the value of concentration and display it on the main controller interface. The reactor’s controller may then be able to independently manipulate variables to maintain or vary concentration. See Figure 1-5.

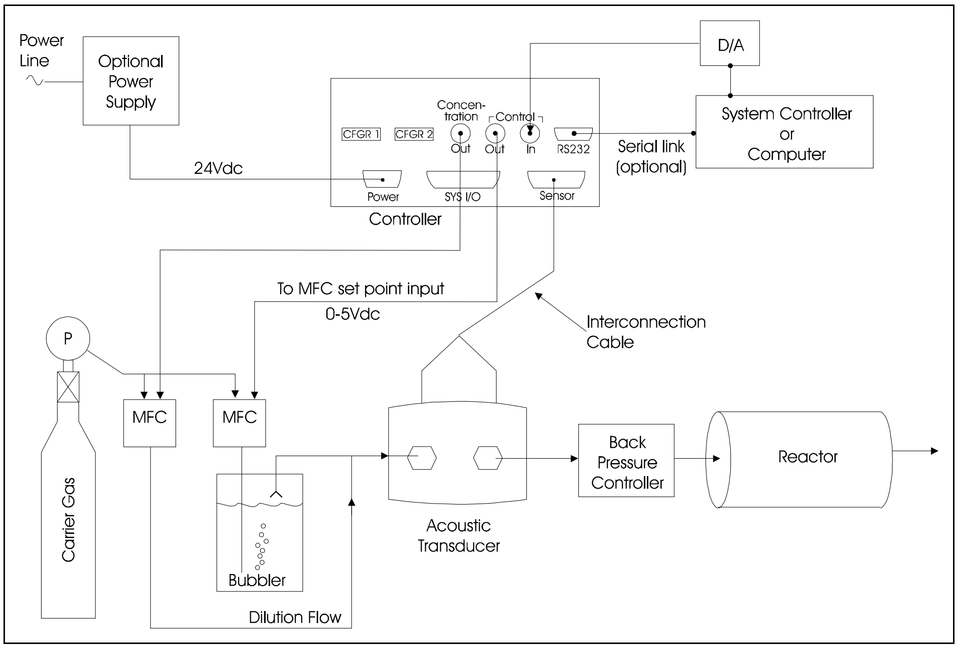
Figure 1-5 Integration with Reactor’s Controller



1.10.4.3 How to Connect the Instrument for Independent Control of the Concentration

This Instrument System is also capable of independent control of the concentration. An analog control voltage is available on the CONTROL OUT connector for this purpose. This control voltage is intended to be used as the control input voltage to a mass flow controller. A suggested control configuration is shown in Figure 1-6.

Figure 1-6 Integration with Reactor Only, Setpoints Provided by Reactor's Controller



The targeted Concentration Setpoint may be configured either by setting the appropriate parameter through the Setup Tool or Monitor software or by applying a precision analog voltage onto the CONTROL IN connector. This parameter is available for direct entry with the optional LCD display version. If DIP switch #4 on the CFGR2 switch block is set, the voltage applied to the CONTROL IN connector will be interpreted by the Instrument System as the Instrument's target Concentration Setpoint parameter (normally set through the Monitor Software or LCD display). When this feature is selected, the voltage at the CONTROL IN connector V_{in} interprets the applied input voltage so that the Target Concentration Setpoint is:

$$\min + \mathrm{diff}\left(\frac{V_{in}}{\text{Input Voltage Range}}\right) \qquad [1]$$

where:

max is the value of the max input parameter and diff is the difference between the Max Input and Min Input parameters.

See section 4.3.6.6 on page 4-26, SW#4 and SW#7.

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The parameters necessary for tuning the concentration maintaining Control Loop are readily visible and alterable through the LCD display or the optional Monitor software. In the absence of the optional software, these parameters may be configured permanently at the time the Instrument System is installed through a temporary digital setup link using the Setup software (see section 8.2 on page 8-1). There are three parameters to optimize. It is suggested that the tutorial in section 3.2.1, Control Loop Fundamentals — Concentration Control, on page 3-21, be consulted. The appropriate control parameters are available for direct entry with the optional LCD display version.

The Instrument System may be switched to active control by toggling to ground digital input #4, pin 21 on the SYSTEM I/O connector (see section 4.3.6.1 on page 4-22). When Input #2 is toggled to the ON (to ground) state, the control voltage remains at the last controlled voltage. The control voltage may also be set to zero by activating input #3, pin 20 on the SYSTEM I/O connector. In addition, instead of setting the flow to zero, the system may be set to maintain bypass flow by setting SW#5 on CFGR2 and activating input #5 on the SYSTEM I/O connector. Movement between the instrument's states is directly accessible from the LCD front panel.

1.10.4.4 Basic Connection To A Reactor—Bulk Flow Control Mode

See section 3.1.13 on page 3-11.

1.10.5 Sensor Installation

The following sections should be followed when installing the sensor.

1.10.5.1 Vacuum Considerations

This Instrument System works best when the pressure in the Reactor's Delivery Lines range from 70 to 1000 Torr (9.33 to 133.3 kPa).

NOTE: It is suggested that the Transducer be installed after any Dilution Flow gas is added and prior to any Back Pressure Controller. This creates the environment with the most stable pressure and flow conditions for best instrument stability. Positioning the Transducer after the Dilution Flow also simplifies calibration. It is now easy to flow only pure carrier gas through the Transducer and consequently very easy to set the Reference Zero.

In order to optimize performance at low pressures, the tubing directly connected to the Transducer's Resonant Chamber has an inner diameter of 0.058” (0.147cm). The balance of the Reactor's tubing may be of any other appropriate size without degrading performance.

1.10.5.2 Positioning

There is no preferred orientation for the Transducer. It is, however, best to maintain the correct inlet / outlet convention. However, if the connections to the inlet and outlet are reversed, there will be no difference in performance until the flow exceeds about 1000 sccm. The inlet tube is intentionally longer than the outlet tube so that the incoming gas more closely reaches the Resonant Chamber's temperature before entering.

1.10.5.3 Integration With The Instrument

There is a single Interconnection Cable between the Transducer and Controller. Connect this cable after physical installation of the Transducer and Controller. This cable has three standard lengths, 5' (152.4 cm),
10' (304.8 cm), and 20' (609.6 cm). Use the shorter length whenever possible. Cables over 20' (609.6 cm) are not recommended!

1.10.5.4 Maximum Pressure Considerations

Reliable measurement of concentration to pressures as low as 70 Torr (9.33 kPa) [absolute] requires relatively flexible diagrams to be used so that sufficient acoustic energy may be transmitted.

There is a possibility that diaphragms may destructively rupture if more that 8.2 atmospheres (gauge) pressure is applied. A secondary containment vessel is built into all transducers produced after July 1998, See section 5.6 on page 5-2 for proper leak check procedures, and section 5.7 on page 5-4 for performance verification procedures.

1.10.5.5 Transducer Series

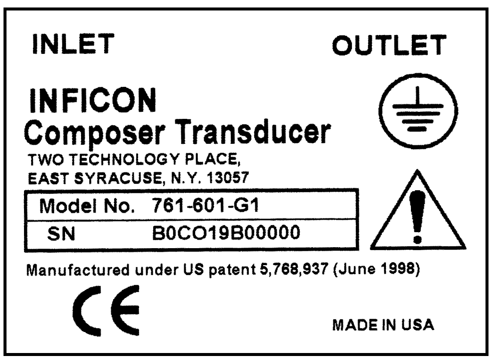
Composer transducers are divided into two series. The controller must be configured to match the transducer's series by properly setting SW#1 CFGR1. See section 4.3.6.5 on page 4-25.

The series is determined by the series designated on the transducer's serial number label. Set the switch active if the serial number's series is 18 or lower, otherwise leave the switch in the off state.

NOTE: The state of these switches is only read when power is first applied to the controller. See Table 4-3 on page 4-25 for the configuration switch number descriptions.

The series number is identified by referring to the serial number label placed on the transducer, see Figure 1-7. In the SN field the transducer's series is identified as 19 (the 5th and 6th characters from the left) and would require that SW#1 CFGR1 be left in the off position. Operation of a transducer with the configuration switch in the wrong position may lead to improper operation at very low pressures or false signals at vacuum.

Figure 1-7 Example of a Serial Number Label on the Transducer



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Chapter 2
How the Instrument Works

2.1 Speed of Sound and Gas Composition

The speed of sound, C, in an ideal gas is equal to:

$$C = \sqrt{\frac{\gamma R T}{M}} \quad [1]$$

where:

$$\gamma = \frac{C_p}{C_v} = \frac{\textit{Heat Capacity at Constant Pressure}}{\textit{Heat Capacity at Constant Volume}} = 1.4 \text{ for Air} \quad [2]$$

T = Kelvin temperature

R = Universal Gas Constant = 8.3143 x 10^7 erg/(Mole K)

M = Molecular Weight (AMU)

Equation [1] may be expanded for binary mixtures by modifying the Specific Heat Ratio and molecular weight to account for the Mole Fraction of component two, x, as follows.

$$\bar{\gamma} = 1 + \left[\frac{x}{\gamma_1 - 1} + \frac{1-x}{\gamma_2 - 1}\right]^{-1} \quad [3]$$

$$\overline{M} = xM_1 + (1-x)M_2 \quad [4]$$

So the speed of sound of the mixtures, C_M, is:

$$C_M = \sqrt{\frac{\bar{\gamma} R T}{\overline{M}}} \quad [5]$$

which holds for any ideal mixture; that is, a mixture that is formed without change in volume.

The Instrument System determines the speed of sound by precisely determining the gasses' fundamental resonant frequency in a fixed chamber of length L. At resonance, a standing half wave exists in the Resonant Chamber, so the speed of sound and frequency are related as follows:

$$f = \frac{C}{2L} \quad [6]$$

In practice, the exact value of L is unimportant. Composition is computed from knowledge of the mixture's frequency relative to the frequency of the pure gas as follows. Let:

$$m = \frac{M_1}{M_2} \quad [7]$$

$$g = \frac{\gamma_1}{\gamma_2} \quad [8]$$

$$h = \frac{1}{\gamma_2} \quad [9]$$

Applying equations 7, 8, and 9 into equations 3 and 4 yields,

$$\overline{M} = M_2\{(m-1)x+1\} \quad [10]$$

$$\bar{\gamma} = 1 + \frac{\gamma_2\{(g-h)(1-h)\}}{\{x(1-g)+(g-h)\}} \quad [11]$$

If we define the speed of sound in the majority, or carrier, gas as C_2

$$C_2 = \sqrt{\frac{\gamma_2 RT}{M_2}} \quad [12]$$

and apply equations 9 and 10 into equation 4 we get:

$$c^2 = c_2^2\left(h + \frac{(g-h)(1-h)}{x(1-g)+(g-h)}\right)[1+(m-1)x]^{-1} \quad [13]$$

Since the speed of sound in a fixed resonator is directly proportional to the frequency of resonance, we define a ratio:

$$\lambda = \left(\frac{C}{C_2}\right)^2 = \left(\frac{f}{f_2}\right)^2 \quad [14]$$

Where f and f_2 are the resonant frequencies of the mixture and pure gas, respectively.

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Combining 12, 13 and 14:

$$\lambda\{1+(m-1)x\} = \frac{[(g-h)(1-h)]}{[x(1-g)+(g-h)]}+h \quad [15]$$

Simplifying leads to,

$$Ax^2+Bx+C = 0 \quad [16]$$

where,

$$A = \lambda(m-1)(1-g) \quad [17]$$

$$B = \lambda m(g-h)+\lambda(1-2g+h)-h(1-g) \quad [18]$$

$$C = (\lambda-1)(g-h) \quad [19]$$

Since the equation is obviously a quadratic, the solutions are of the following form.

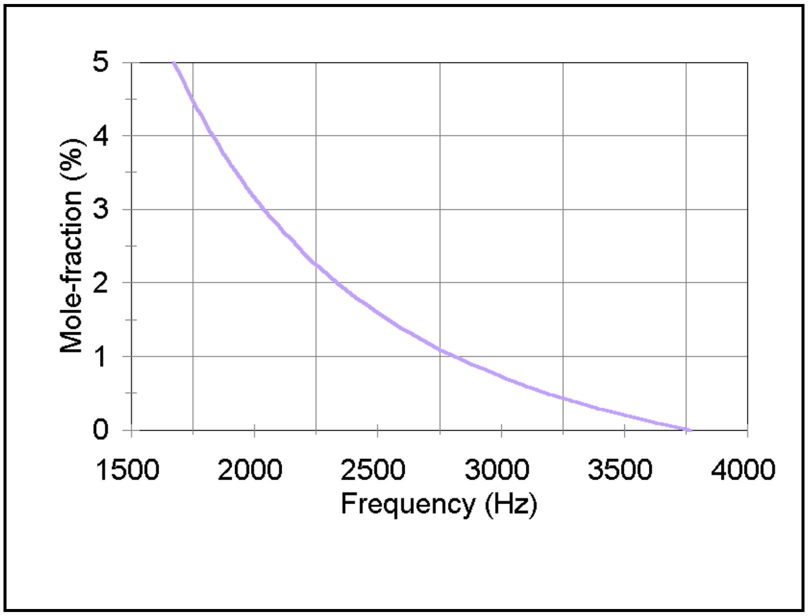
$$x_{1,2} = \frac{-B\pm\sqrt{B^2-4AC}}{2A} \quad [20]$$

Since $x_{1,2}$ represents the Mole Fraction of the gasses, acceptable solutions are,

$$0 \le x_{1,2} \le 1 \quad [21]$$

The general result of this analysis is that the technique is most sensitive to composition changes when the Molecular Weight difference between the carrier gas and the Precursor is the greatest.

Figure 2-1 Mole Fraction of Trimethylindium in H_2 vs. Instrument's Frequency



2.2 Measuring the Speed of Sound

A simple explanation of the functioning of this Instrument System is that it measures concentration by first determining the resonant frequency of the gas flowing through it and then comparing the measured resonant frequency to that of the pure carrier gas. Utilizing this frequency ratio, λ, and the physical parameters of the gasses, m and γ, the concentration is derived. The instrument determines the basic resonant frequency by varying the frequency across the operating range and then operating at the frequency where the largest amplitude of sound is transmitted. Because the composition is controlled, or varies slowly, and the Resonant Chamber has good acoustic properties, the frequency may be measured with great precision. From equation [6] on page 2-2, the speed of sound may be derived from knowledge of the Resonant Chamber's length, L. In operation, the exact length is unimportant as only the ratio of frequencies, λ, is used to determine concentration.

One critical issue confronted in the measurement of the speed of sound is the ability to correctly measure or control the temperature of the gas. The Transducer is designed to provide a user-set isothermal environment for the gas in the Resonant Chamber and to precondition the gas as it enters the Resonant Chamber. To aid in this preconditioning, the Transducer's inlet tubing is intentionally longer than is strictly necessary and is contained within the insulation of the Transducer's enclosure. This helps smooth the gasses' temperature transition from the temperature of the Reactor's supply tubing to the Resonant Chamber's carefully controlled temperature. There is a feedback loop between the temperature (Controlled Variable) as measured by a PRT, Platinum Resistance Thermometer, and the power level applied to the heaters

(Manipulated Variable). It is normal for this temperature to be controlled to +/- 0.05 °C. It is also normal for an offset between the value of the temperature parameter and the actual temperature.

Measurement of the speed of sound is also dependent on the instrument's ability to precisely measure the amplitude of sound transmission through the Resonant Chamber. This is especially difficult as the pressure in the Resonant Chamber is lowered. Because of the need to operate some Delivery Systems at low pressures, a method was needed to couple energy more efficiently from the Excitation Microphone through the target media and into the Detecting Microphone. The use of a 5 chamber Helmholtz Resonator was chosen because its careful shaping allowed relatively efficient energy coupling into the Resonant Chamber by providing a better impedance match. The Helmholtz design also provides a means of building a compact & low volume structure so that its Fundamental Resonance is at frequencies below the Self Resonance of both the Diaphragms and the Drive and Detecting Microphones.

A potential difficulty of operating at low frequencies is an apparent loss of frequency resolution (at least on a relative basis), when compared to operating at the frequencies produced by a high harmonic. But this is only an illusion. This apparent advantage is negated by modern electronics' ability to generate precision sine waves with resolutions of better than one part in 50,000. Improving the generation precision of the operating frequency to 0.1 Hz has the same affect on relative precision as operating in the tenth harmonic, without the viscous energy losses associated with the higher frequency sound waves. The basic measurement scheme employed is to generate a frequency and measure its amplitude. By intelligently varying the frequency it is easy to find the maximum amplitude, which corresponds to the Resonant Frequency. It is possible to further enhance the measurement system's resolution by methodically Curve Fitting the frequency vs. amplitude data around a Resonance peak to match a Lorentzian shape.

Another important aspect of this instrument's design is that the composition measurement does not depend on absolutes. How does this help? Think about the difficulty of measuring temperature to 0.01 °C in an absolute sense. A quick review of the equations (section 2.1, Speed of Sound and Gas Composition, on page 2-1) shows that concentration measurement by this technique is dependent only on maintaining the temperature at the same temperature at which the reference zero measurement was taken. The PRT is a sensing element that is stable to fractions of a PPM per day, and all the relative error due to temperature variation is eliminated every time the instrument is zeroed. Likewise, the speed of sound depends slightly on the pressure, very slightly on the flow rate and even slightly on the local barometric pressure changes. Daily setting of the Reference Zero minimizes the possible influence of these variables on the concentration measurement.

2.3 Control Loop Primer

The instrumental advances in measurement speed, precision and reliability would not be complete without a means of translating this improved information into improved process control. For a CVD process, this means keeping the reactor's inlet concentration as close as possible to the target concentration. The purpose of a control loop is to take the information flow from the measurement system and to make gas flow corrections that are appropriate to the characteristics of the particular precursor source. When properly operating, the control system translates small errors in the controlled parameter, or concentration, into the appropriate corrections in the manipulated parameter, flow. The controller's ability to quickly and accurately measure and then react appropriately to the small changes keeps the process from deviating very far from the target concentration.

The most commonly chosen controller model for converting error into action, is called PID. In the PID model, P stands for *proportional*, I stands for *integral* and D stands for *derivative action*. Certain aspects of this model will be examined in detail a little further on.

Knowledge of the responses of the precursor source can be found by repetitively observing the system response to a disturbance under a particular set of controller settings. After observing the response, new controller parameters are estimated and then tried again until satisfactory control is obtained. Control, when it is finally optimized, essentially matches the parameters of the controller model to the characteristics of the precursor delivery system.

In general, it is not possible to characterize all processes exactly; some approximation must be applied. The most common is to assume that the dynamic characteristics of the process can be represented by a first-order lag time plus a dead time. The Laplace transform for this model (conversion to the s domain) is approximated as:

$$\frac{Output}{Input} = \frac{K_p \exp\left(\frac{-L}{s}\right)}{T1s + 1} \qquad [22]$$

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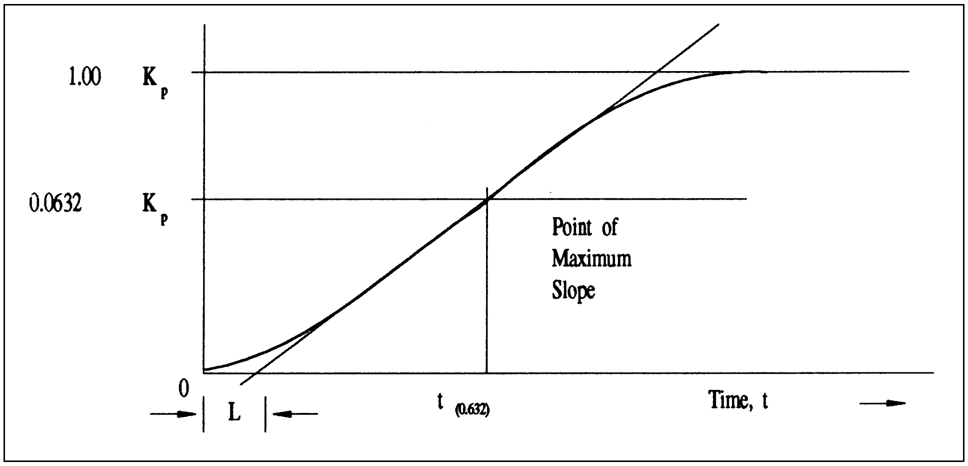
Figure 2-2 Response of process to an open loop step change at t=0 (control signal is increased)



$$T1 = t_{(0.632)} - L \quad [23]$$

$$K_p = \frac{Change\ in\ Output}{Change\ in\ Control\ Signal} \quad [24]$$

The value of three parameters are determined from the process reaction curve. They are the Steady State Process Gain, K_p, the Dead Time, L, and the Time Constant, $T1$. Several methods have been proposed to extract the required parameters from the system response as graphed in Figure 2-2. These are a one point fit at 63.2% of the transition (one time constant), a two point exponential fit, or a weighted least square exponential fit. From the above information a process is sufficiently characterized so that a controller algorithm may be optimized.

The PID controller model is shown in Laplace form in equation [25].

$$M_s = K_c\left[1 + \frac{s}{T_i} + T_d s\right]E(s) \quad [25]$$

Where

M_s = Manipulated variable or flow

K_c = controller gain (the proportional term)

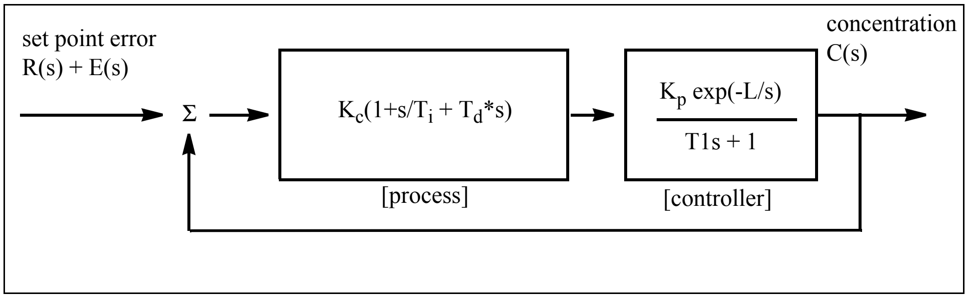
T_i = integral time

T_d = derivative time

$E(s)$ = process error

Figure 2-3 represents the controller algorithm and a process with first order Lag and Dead time. The process block implicitly includes the dynamics of the measuring devices and the final control elements, in our case the mass flow controllers. R(s) represents the concentration set point. The feedback mechanism is the error generated by the difference between the measured concentration, C(s), and the target concentration, R(s).

Figure 2-3 PID Controller Block Diagram



The key to using any control system is to choose the proper values of K_c, T_d and T_i. Optimum control is a somewhat subjective quantity as noted by the presence of several mathematical definitions as shown below.

The Integral of the Squared Error (ISE) is a commonly proposed criterion of performance for control systems. It can be described as:

$$ISE = \int_0^{\infty} e^2(t)dt \qquad [26]$$

Where error = e = target - measured concentration. The ISE measure is relatively insensitive to small errors, but large errors contribute heavily to the value of the integral. Consequently, using ISE as a criterion of performance will result in responses with small overshoots but long settling times, since small errors occurring late in time contribute little to the integral.

The integral of the absolute value of the error (IAE) has also been frequently proposed as a criterion of performance:

$$IAE = \int_0^{\infty} |e(t)|dt \qquad [27]$$

This criterion is more sensitive to small errors, but less sensitive to large errors, than ISE.

Alternately, Graham and Lathrop[1] introduced the integral of time multiplied by the absolute error (ITAE) as a criterion of performance:

1.Graham, D., and Lathrop, R .C., “The Synthesis of Optimum Transient Response: Criteria and Standard Forms, Transactions IEEE, vol. 72 pt. II, November 1953

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$$ITAE = \int_0^{\infty} t|e(t)|dt \qquad [28]$$

ITAE is insensitive to the initial and somewhat unavoidable errors, but it will weight heavily errors occurring late in time. Optimum responses defined by ITAE will consequently show short total response times and larger overshoots than with either of the other criteria.

Since the process response characteristics depend on the position of the system (that is, concentration for this discussion), the process response is best measured at the desired operating point of the system. This measured process information (that is, process gain, K_p, time constant, T_1, and dead time, L) is used to generate the best fitting PID control loop parameter values for the specific system.

2.4 Fuzzy Logic

In recent years, fuzzy logic has drawn much attention from academic researchers, and its application in the area of industrial control has gained rapid popularity. Fuzzy logic control has seen successful implementation in myriads of applications, from consumer products to large complex chemical plants. The strength of fuzzy logic is that it does not require concrete mathematical modeling of the process for effective control. Rather, it uses a number of *rules of thumb* derived from the past experience of human operators or self-learning fuzzy controller. Thus, highly nonlinear processes with many interacting parameters, which are extremely difficult to model, have greatly benefited from the application of fuzzy logic control. Even in the case of linear processes, fuzzy control rarely requires elaborate and time consuming parameter tuning required by conventional PID controllers. The ease of set up and tolerance for imprecision makes this type of controller attractive. In the Composer, we have implemented a fuzzy logic controller, in addition to a traditional PID controller. The essence of a fuzzy logic controller, specific to our application is briefly described below.

The departure of measured concentration from the set point constitutes *error* and point to point variation of *errors* constitute *change-in-error*. The *error* and the *change-in-error* are the working variables of the fuzzy engine. These variables are categorized in linguistic terms, such as large negative, negative, zero, positive, and large positive. A given magnitude of these variables can have membership functions in all of the above mentioned categories in varying degrees. The fuzzy engine itself comprises of a set of rules (wisdom of an experienced operator). For example,

- if the error is large negative (much above set point), then if the change-in-error is large negative (fast moving away from set point).

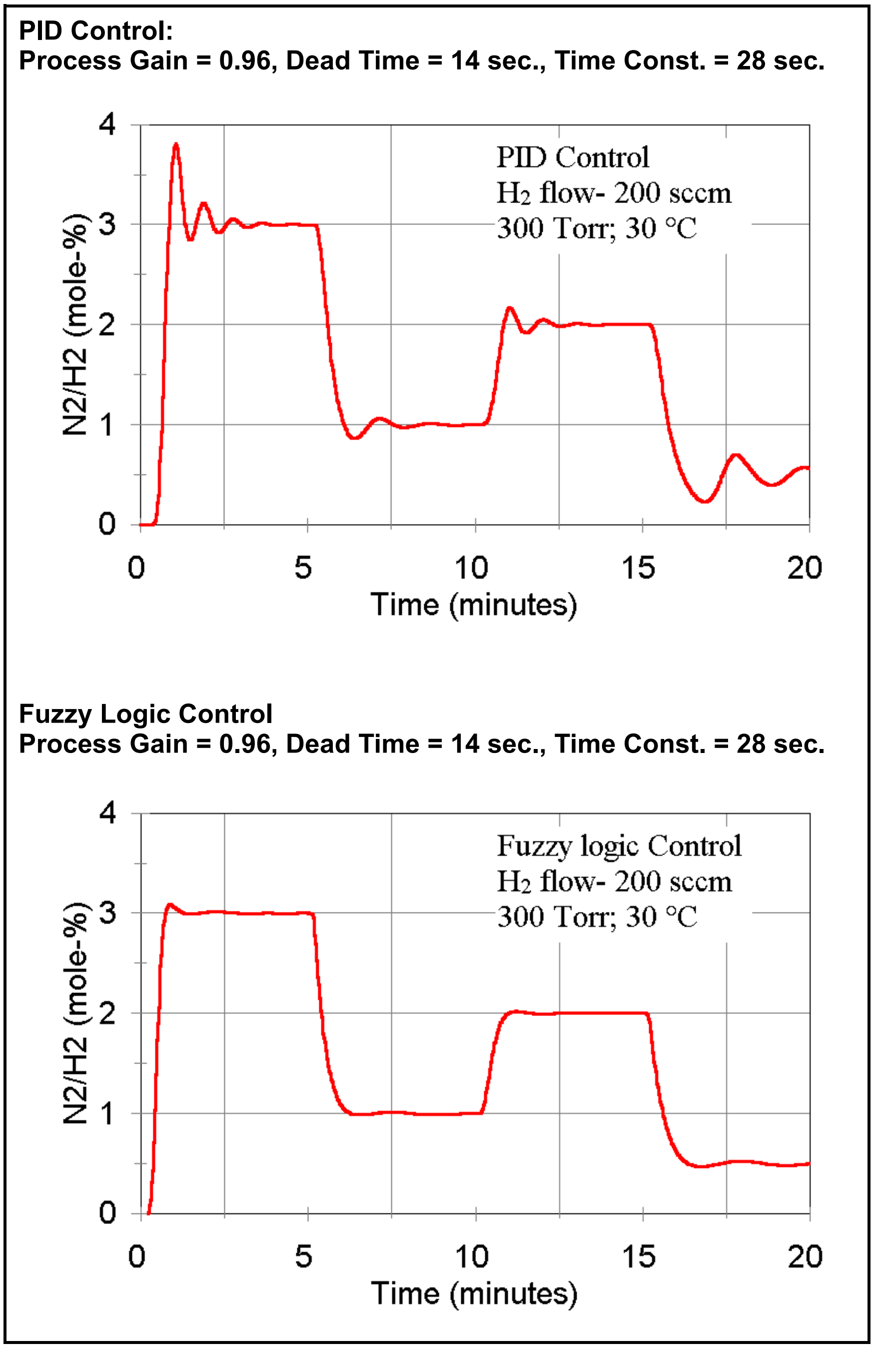
Or,

- If the change-in-error is negative (moving away from set point), then the action is large negative (reduce control power by largest allowable limit).

There are about twenty-five such rules in our controller logic. Each rule is mathematically transformed using operations of fuzzy logic. At the end, the outcome of all the rule base are combined by centroid method to yield a numerical value for action. Though the fuzzy control rules can be executed in real time, it is advantageous to precompute the control action for all possible values of *errors* and *change-in-errors*. Such actions describe the control surface and can be stored as the fuzzy *state-action table*. Thus, during actual control, the computational chore is reduced to mere table look up in real time.

In our experience, a fuzzy controller is easier to set up, approaches set point faster and settles with minimum overshoot. See Figure 2-4. These are generally conflicting requirements for a PID controller. The critics of fuzzy logic point out that the mathematical stability analysis can not be performed due to lack of a controller model. The advocates of fuzzy logic assert that stability analysis is neither necessary nor sufficient condition for robustness of an industrial plant controller. Ultimately, you will have to make the decision as to which control route is more suitable for the application at hand.

Figure 2-4 Comparison of PID and Fuzzy Logic Control



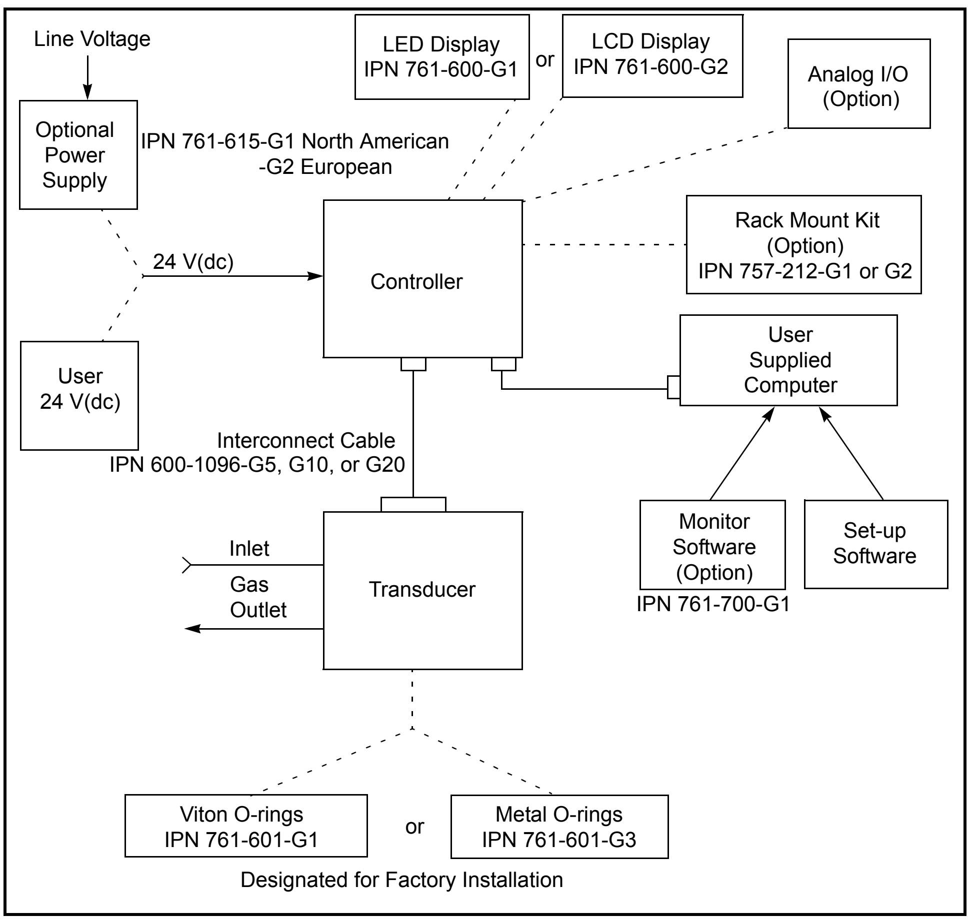
2.5 Instrument Overview

The Instrument System Block Diagram, see Figure 2-5, depicts the general layout of the complete system. Overall layout first depends on the convenient location of the Transducer within the flow of the precursor delivery system.

The controller may then be located up to twenty feet away (five feet is preferred) either in a relay rack, table top, or deployed within the reactor. Power is supplied either with an optional universal type power supply or from the reactor’s 24 volt regulated power bus. Refer to section 1.7 on page 1-7.

The controller responds to discrete digital I/O commands and analog set points. Configuration data is provided at set up through the LCD display or through a temporary computer link and Setup software. A more expansive and complete user interface is provided by the optional Monitor software package.

Figure 2-5 Instrument System Block Diagram



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2.6 Description of Subsystems

The two major components which comprise the Composer are the Transducer and the Controller.

2.6.1 Transducer

IPN 761-601

The basic Transducer element is the resonant chamber with the inlet and outlet tubes providing a means of transporting the gasses from the reactor's supply lines, through the transducer's case and finally connecting to the structure that defines the shaped resonant chamber, see Figure 2-6. Because the speed of sound of a gas is dependent on it's temperature there is a mechanism to measure and control the temperature. First, a platinum resistance thermometer, or PRT, is imbedded into the chamber body. Two low power heater elements are able to provide a "heat only" means of control. The PRT and heaters are connected in a feed back control loop that is monitored and executed by the controller portion of the instrument system. A thermo-mechanical switch (not shown) is attached to the chamber body and automatically interrupts the heaters' current should there ever be a fault that would allow the temperature to exceed 70° C. Both ends of the resonant chamber are defined by a tensioned diaphragm. This diaphragm is used to safely seal the chamber and also to provide a level of flexibility sufficient to impose an acoustic wave on one end and to allow its transport and detection outside the resonant chamber on the other end.

The function of all of the above component elements is to provide an ideal environment for transporting and measuring sound velocity through the resonant chamber.

The sending microphone cartridge provides the source of acoustic energy to excite the diaphragm. It is designed to effectively couple acoustic energy into the diaphragm yet not couple energy into the chamber body. It uses a pair of flat response electro-dynamic microphones to accomplish this. This cartridge is powered by the controller portion of the instrument system.

The receiver microphone cartridge is used for detection of the acoustic energy transported across the resonant chamber and through the diaphragm. It is a wide response electret type with a built in FET amplifier. Its signal is amplitude detected by the controller portion of the instrument system.

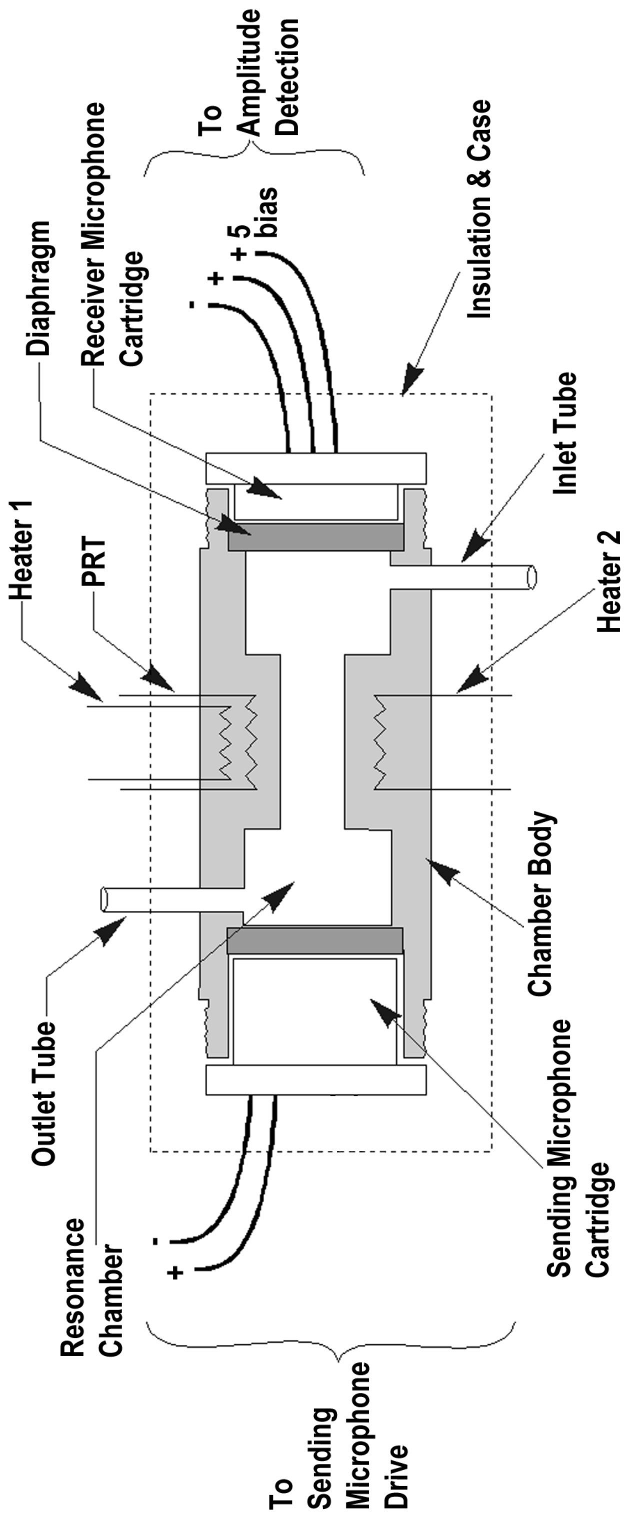

Figure 2-6 . Transducer Block Diagram

IPN 074-289L

2.6.2 Controller

IPN 761-600

The following sections describe the 761-600 controller; see the block diagram in Figure 2-7 on page 2-19.

2.6.2.1 CPU (Central Processing Unit)

U30, U26, U28

The CPU section uses an Intel 80C196KC(U30) for the controller running at 19.6608 MHz along with a DS1244Y(U26) 32X8 battery backed RAM and a PSD302(U28) for ROM and address decoding. The 80C196KC acts as the master controller and performs all the functions necessary for Composer operation except for sensor excitation and signal response functions which are left to the DSP.

2.6.2.2 DSP (Digital Signal Processor)

U31

An Analog Devices ADSP-2101 is utilized to perform digital signal processing functions to excite and analyze the acoustical response of the sensor. Its core task is to perform as a locked amplifier to the excitation frequency. The excitation is generated by a sine function approximation of the output of a 16 bit phase accumulator that has a phase increment added to it at a 16.384 KHz rate. This arrangement allows frequencies to be generated by the size of the phase increment by the following formula:

$$\text{Phase Increment} = \frac{F}{\left(\frac{16384}{65536}\right)} \quad [29]$$

The locked amplifier task also uses the output of the sine function and its cosine along with the returned signal from the sensor, and also by digital multipliers, low pass filters and math determines the phase and amplitude of the returned signal. The results can then be used to determine the acoustic resonance of the sensor.

The clock for the ADSP-2101 is generated by its internal oscillator using a 19.6608 MHz crystal. The DSP's clock output is used to generate the clocks for the rest of the system. The program code for the DSP is downloaded from the CPU after a power up reset.

2.6.2.3 FPGA

U33

The FPGA is an Actel A1010B programmed to act as an interface to the various sections of the system. It provides a bi-directional parallel port between the CPU and the DSP along with the necessary logic for handshaking and power up boot loading of the DSP by the CPU. The FPGA also performs a serial to parallel, parallel to serial conversion and handshaking to read and write the temperature A/D by either the CPU or the DSP. It also provides a second serial to parallel interface and handshaking for the A/D converter that monitors the CONTROL IN signal from the back panel that is also accessible by either the CPU or the DSP. Clocks for the rest of the system are also provided by the FPGA by dividing down the DSP clock producing 9.8304, 4.9152, and 2.4576 MHz outputs. Resets for the DSP and sensor electronics are also provided by FPGA logic allowing the CPU to individually set, clear and monitor their state.

2.6.2.4 Cell Excitation

U5, U24, U29, U8, U9

One half of a LF347(U5A,C) quad op-amp is utilized to amplify the signal from the sensor and to also convert it from single ended to differential before presenting it to a TLC320AC02(U24) CODEC (Coder/Decoder). Also U5B of the LF347 supplies the 1.25 volt microphone bias to the sensor by dividing VMID of the TLC320AC02 by two. The TLC320AC02(U24) is a 14 bit CODEC that simultaneously performs an A/D and D/A function sending and receiving data between it and the DSP via a serial link. The TLC320AC02 has eight internal registers for the purposes of controlling filters, sample rate, and attenuators for both input and output signals. A second TLC320AC02(U29) operating as a slave to U24 is used to generate a second drive signal to cancel mechanically coupled signals from the first drive signal. Two MC34119D’s (U9,U8) are used as power amplifiers for the drive and anti-drive signals to the sensor speakers.

2.6.2.5 Sensor Temperature Control

U3, U5D, U13, U14, VR1,
U19, Q2

Temperature of the sensor is measured by a Crystal Semiconductor A/D converter CS5516-AS (U13). The 16 bit converter is configured to measure a range of temperature from 0 to 80 °C thus yielding a resolution of 1.22e-3 degrees. Precision is maintained by the use of .1% resisters with low TCO (R25,26,27,32,33) and AC excitation to eliminate thermocouple effects. The AC excitation is produced by the combination of a 78L05CZ(U3), LF347(U5D), and a 7002SMT CMOS transistor and is driven by BX1 of the CS5516-AS. 10 Volts P-P excitation is produced by the LF347 acting as a unity gain inverter when Q1 conducts and as a unity gain buffer when Q1 is off. The 5 volts supplied by the 78L05CZ does not need to be precise because the A/D conversion is done ratiometrically. Data and configuration parameter values are serially communicated through the FPGA and accessible in a parallel form by either the CPU or DSP.

The heater section uses an 8-bit PWM output of the CPU to switch the raw 24 volts and apply it to the sensor heating elements. A HCPL-0201(U19) is used to isolate the PWM signal from the 24 volt supply along with a 78L15(VR1) regulator for the logic side of the HCPL-0201. C88 and D9 prevents the heater from being full on should the PWM stop and be inadvertently left in a high state. A RFD3055SM(Q2) is used as the power switching transistor and the combination of L8, C125, and D16 filters the output to the sensor.

2.6.2.6 I/O

U18, U20, U6, U17

Analog I/O uses two 16-bit AD699(U18,U20) precision D/A converters for +/- 10 volt outputs (CONCENTRATION OUT, CONTROL OUT). Pots R18,R19,R53 and R57 are provided for gain and offset trim. Data to the D/A's is via a 16-bit CPU data bus. A CS5501(U17) is used for the analog input (CONTROL IN). The CS5501 is internally calibrated for zero on power up and gain is set by a LT1019(U6) reference trimmed by R17. Data is sent by a serial bus to the FPGA where it's converted to a parallel format and made available to either the CPU or DSP.

U1, U2, U12, U16

Five relay outputs are controlled by a 74HC595(U1) serial to parallel shift register and a ULN2003D(U2) driver. Also 7 digital inputs are provided by a ULN2003D(16) driver to a 74HC165(U12) parallel to serial shift register. The serial communications are made directly by CPU I/O pins.

2.6.2.7 Power Supply

U27, U25, U23, U11,
U10, U22, U4

A LT1070(U27) is used as an 18 volt pre-regulator adjusted by R60. A UC3846(U25) is used to drive the primary of isolation transformer T1 with Q3 and Q4. Secondary winding outputs are rectified and filtered and then regulated by U23, U11, U10 and U22 to -15, +15, +5 and -5 volts. A DS1231(U4) is used to detect power fail and to provide a power up reset pulse.

2.6.2.8 Composer Connector Board

IPN 761-132

The connector board provides analog I/O and RS-232C connections and configuration setting by 16 DIP switches. Two 74HC168's(U1,U2) parallel to serial shift registers are used to read DIP switch settings with the serial communications made directly by CPU I/O pins. A MC14506(U3) is used as a level translator between the CPU UART TTL signals and RS-232C levels. The analog outputs utilize a LT1014(U4C,D) precision OP-AMP configured in such a way that loads down to 1K can be driven to +/- 10 volts with no loss of precision. Also using the LT1014(U4A) the circuit divides the input voltage of +/- 10 by four to properly scale it for the A/D converter while simultaneously allowing over voltage protection.

2.6.3 Monitor Software

IPN 761-700-G1

Optional. A more complete digital interface that includes the Setup Tool described in section 2.6.5 below. Additional functionality includes scrolling graphics, data logging, and access to additional test and diagnostic software.

2.6.4 Power Supply - External

- IPN 761-615-G1, North American
- IPN 761-615-G2, European

  Optional. A Universal input type power supply converts local line current to regulated and current limited 24 V(dc) for powering the controller.

2.6.5 Setup Tool Software

A basic Windows software application that provides a means to readout the controller's parameters and change them through an RS-232C Interface. Version 1.5 and greater is Windows 95 and Windows NT compliant.

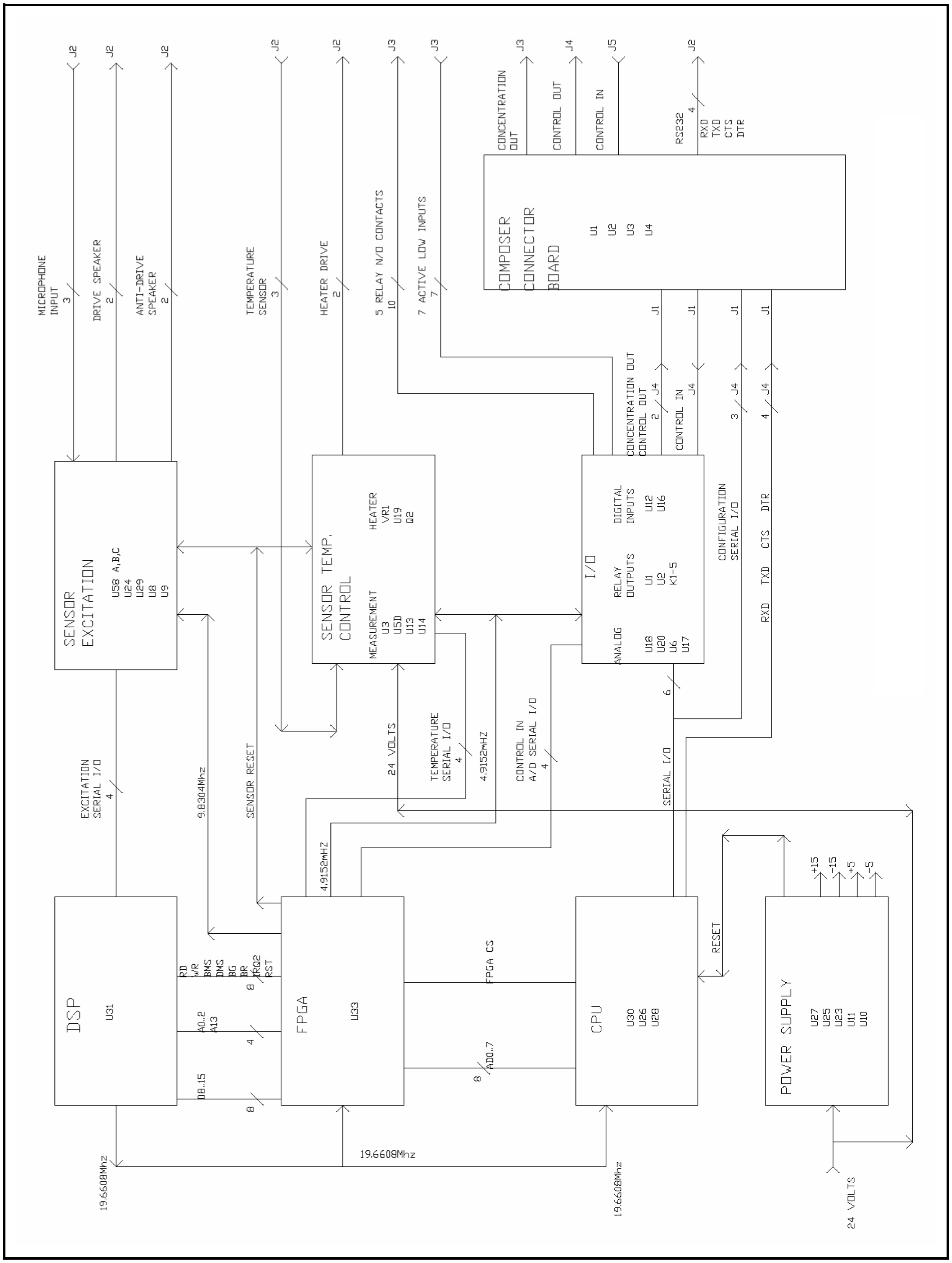

Figure 2-7 Electrical System Block Diagram

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Chapter 3
Applications Guide

3.1 Advice and Tips

The following paragraphs review many of the common questions encountered during setup and operation.

3.1.1 What is the Required Warm Up Time

Once the set point for the Transducer's temperature is altered, it will take up to 15 minutes for the temperature to settle around the operating point. It may take even more time if the temperature set point is lowered and is close to the ambient temperature. Once the set point temperature is reached, the instrument is ready to provide data. It is our experience that because of the relatively low thermal conductivity of the materials used to construct the Resonant Chamber that even after an hour there is still some small potential for further reducing temperature induced speed of sound measurement errors. It is easy to reset the Reference Zero frequency and eliminate these effects. It is also expected that the Transducer will always be operating, so day to day variations will be minimal because any long term thermal settling complications will be absent. If the Ambient temperature changes, there may be some slight variation on the temperature of the Resonant Chamber as the effective thermal load changes. This can be ignored except for the most precise measurements and over the most extreme temperature swings.

3.1.2 When and How Often to Set the Reference Zero

Normal operation will be enhanced by daily setting of the Reference Zero. This mitigates any effects of slight variations in day to day delivery line pressure and atmospheric pressure changes. If the frequency of the Reference Zero is recorded every day, a record of instrumental performance is generated. This makes it easy to determine if a mistake has been made due to careless procedure by comparison to the previously recorded values. It would be unusual for the instrument's daily zero frequency to vary by more than about 0.2 Hz for Nitrogen and 0.8 Hz for Hydrogen. The instrument should be immediately re-zeroed any time the pressure, flow rate or any other instrument subsystem such a Mass Flow Controller, Back Pressure Controller or pressure gauge is changed—even if it is the same type and uses the same settings. The correct (user set) Reference Zero is retained until a new Reference Zero is established or new carrier gas parameters are entered. User Reference Zero is locked out if SW#6 CFGR1 is set, see section 4.3.6.5 on page 4-25.

NOTE: Always wait for the **STEADY** lamp on the Controller's front panel to illuminate before completing the Reference Zero establishment process; that is, actually pressing the switch. This indicates that the measurement conditions are stable and a relative equilibrium has been reached. It sometimes takes many minutes for the light (low molecular weight) carrier gas to clean the Resonant Chamber of any residual Precursor or other heavy gasses. Remember that some gasses may also absorb on the Resonant Chamber's walls and are slowly released, further extending the time to reach pure carrier gas as indicated by stable frequency.

CAUTION

Setting the Reference Zero before the Resonant Chamber is filled with only pure reference (carrier) gas will result in an offset and scaling error in the measured composition (until the next time the Reference Zero is set). See section 3.1.12 on page 3-10.

3.1.3 How is Performance Affected if I Use the Factory Set Reference Zero Value?

While it is most accurate to reset the Reference Zero on a daily basis, good results can be obtained for many processes by using the factory set default value for the Reference Zero. While the exact loss of reproducibility is hard to predict, it is reasonable that it will be about 2-4 times worse than the specified value when monitored over extended periods of time. This may be acceptable for the process and might also be convenient. Alternating between the factory default and carefully setting the zero occasionally will not be productive. It would be better to extend the interval between reestablishing the Reference Zero than to alternate. An example of long term stability is shown in section 3.1.10 on page 3-8.

3.1.4 What To Do when the Specific Heat Ratio for a Gas is Unknown?

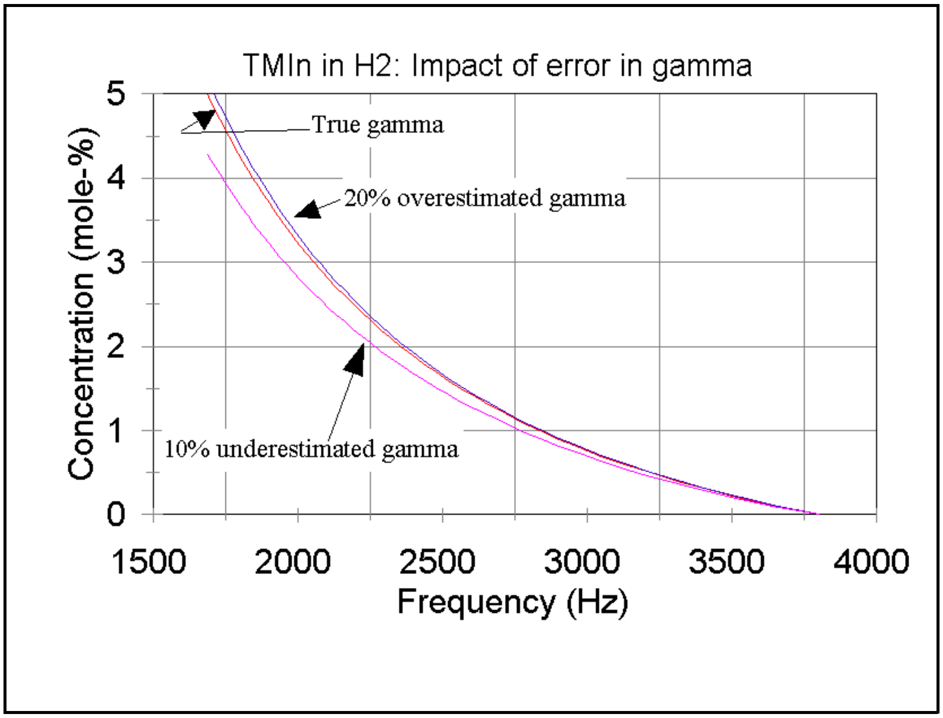
Quantitative accuracy for an acoustic measurement technique partially depends on accurate knowledge of the Specific Heat Ratio, γ, of the individual gas species. While this ratio is known for many pure common gasses, little information is available in the literature on many of the complex Precursor molecules. The information we have at the time of this printing is given in Table 3-1. Even without exact knowledge of the Specific Heat Ratio, useful information and reliable operation can still be obtained. The Specific Heat Ratio of gasses is a parameter that does not have a large range, it is literally confined to a range of about 1.1 to 1.7 for almost every known gas. Consequently, guesses that are wrong don’t make a lot of practical difference if they are reasonable guesses. It is also possible to make intelligent guesses about unknown gasses using the value of the Specific Heat Ratio for a similar gas. Interestingly, it is almost always more accurate to overestimate the Specific Heat Ratio than to underestimate by the same amount; see Table 3-1 and Figure 3-1. Consider also that in production the accuracy is not as important as the reproducibility. As long as the Specific Heat Ratio is not changed the Instrument System will reproduce the results day after day.

Table 3-1 Common Molecular Weights and Specific Heat Ratios

Gas Name	Molecular Weight	Specific Heat Ratio	Gas Name	Molecular Weight	Specific Heat Ratio
Ammonia (NH_3)	17.030	1.316	R134a	102.000	1.120
Argon	39.948	1.667	$SiBr_4$	347.702	1.094
AsH_3	77.950	1.269	$SiCl_4$	169.900	1.101
B_2H_6	27.670	1.165	SiF_6	142.080	1.127
CBr_4	331.627	1.100	$SiFH_3$	50.1	1.213
CO_2	44.010	1.288	$SiHCl_3$	135.450	1.123
Cp_2Mg	154.49	1.2	TEAM - DMZn	196.65	1.10
Cupra-select	370.830	1.052	TDEAT	336.10	1.2
DETe	185.72	1.100	TDMAT	224.0	1.2
Deuterium	4.032	1.398	TEGa	156.910	1.103
DMHy	60.10	1.16	TEOS $Si\text{-}(C_2H_5O)_4$	208.26	1.2
DMZn	95.450	1.120	TMAl	72.090	1.230
Ethyl Lactate	118.100	1.140	TMGa	114.830	1.103
$GeCl_4$	214.404	1.097	TMIn	159.930	1.120
Helium	4.003	1.630	WF6	297.830	1.075
Hydrogen	2.016	1.404			
Nitrogen	28.010	1.399			
Oxygen	32.000	1.395			
$POCl_3$	153.33	1.168			

NOTE: Long term use of the Composer with some of the materials listed in Table 3-1 may not be possible. The user is responsible for ensuring compatibility of use for all materials.

Figure 3-1 When the Specific Heat Ratio for a Gas is Unknown it is Generally Better to Overestimate the Specific Heat Ratio



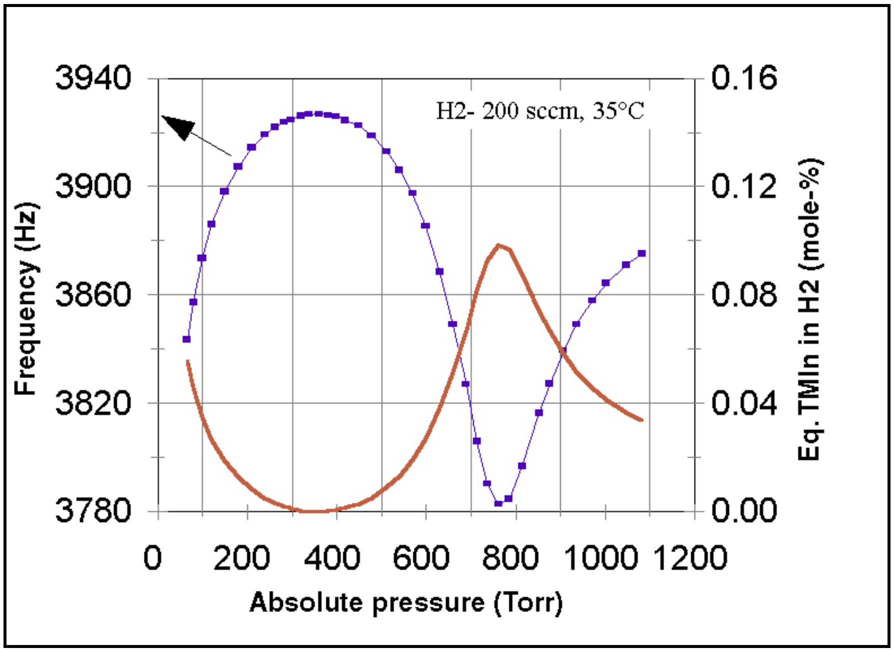
3.1.5 What is the Ideal Operating Environment?

In an ideal environment none of the parameters that influence the concentration measurement change. Most Reactors can be configured so that the pressure and flow through the Transducer are held constant by independent controllers. In this way the Precursor's Fluence into the Reactor can be maintained or changed without altering the total flow and pressure through the Transducer. This is also considered good practice for Reactor design. Leave the Instrument System on at all times; it is always ready to immediately function with best accuracy and we have not seen deterioration through continuous use. Since all Reactors are in environmentally controlled rooms, the small influences due to ambient temperature changes are of no concern.

3.1.6 What is the Effect of Pressure Variation?

Because not all mixtures are purely ideal and the use of Diaphragms to separate the toxic and corrosive gasses from the Exciting and Receiving microphones is required, this Instrument System displays a small influence from pressure changes. The effects of pressure variation on concentration are shown in Figure 3-2.

Figure 3-2 Effect of pressure on apparent concentration



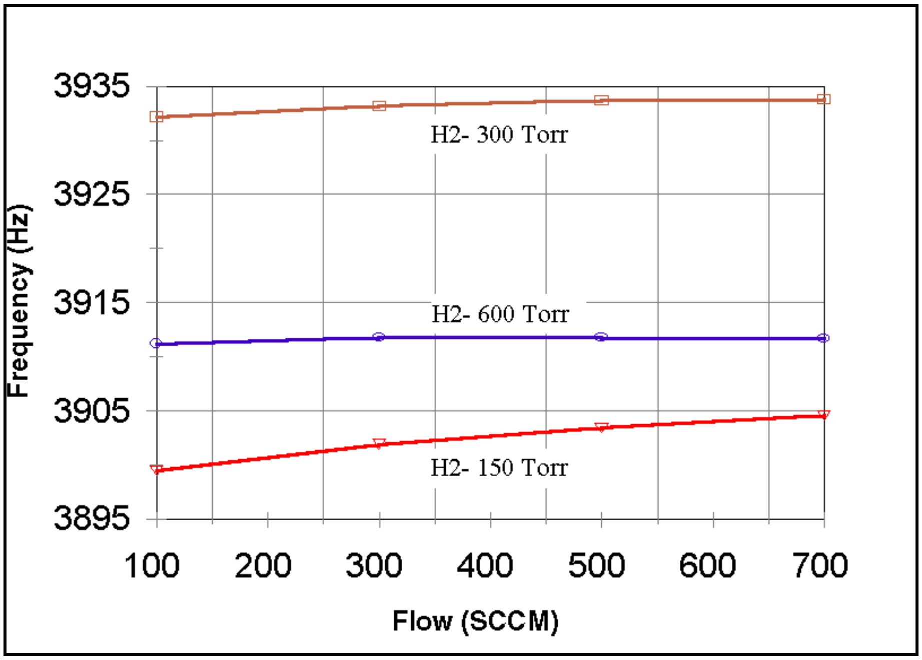
3.1.7 Should Sweep or Amplitude Track Mode Be Used?

The standard measurement mode is Amplitude Track. Sweep mode is available only with the optional Monitor software. Sweep is a diagnostic mode and is fully described in section 8.3.6 on page 8-20.

3.1.8 What is the Effect of Flow Variation?

There is virtually no flow induced effect on concentration measurement in this Instrument System except at the highest flow rates, see Figure 3-3, the pressure drop across the sensor is about 10 torr (1.33 kPa) per 500 sccm.

Figure 3-3 Effect of flow on apparent concentration



3.1.9 How Does This Instrumental Method Differ from Measuring the Speed Of Sound by Time Of Flight

The use of a low frequency Resonant Chamber has significant advantages over Time Of Flight (TOF) methods. First, it allows the constructive build up of energy within the Resonant Chamber. Secondly, sound transmission in hydrogen at low frequency is more efficient than at high frequency. These enhance the instrument's ability to measure concentration in Hydrogen mixtures at lower pressures. Finally, the careful intelligent manipulation of the applied frequency around the resonant amplitude peak allows even greater precision in the determination of the speed of sound. The resonant method does not loose accuracy because of uncertainty of guessing when the center of a low energy acoustic pulse packet precisely leaves the Sender and when the same center of energy reaches the Receiver. See Figure 3-4. For a TOF instrument to achieve the equivalent resolution as the resonant acoustic technique's 1 part in 50,000, it must achieve time measurement precision of 3 nanoseconds. This resolution is achievable for sophisticated instruments measuring photons or particles, but is approximately 40 times better than the resolution possible on the poorly defined 15 kHz ultrasonic wave pulse in hydrogen. One wavelength of a 15 kHz tone is 0.0856 meter, almost one half the length of a 0.2 meter path length instrument.

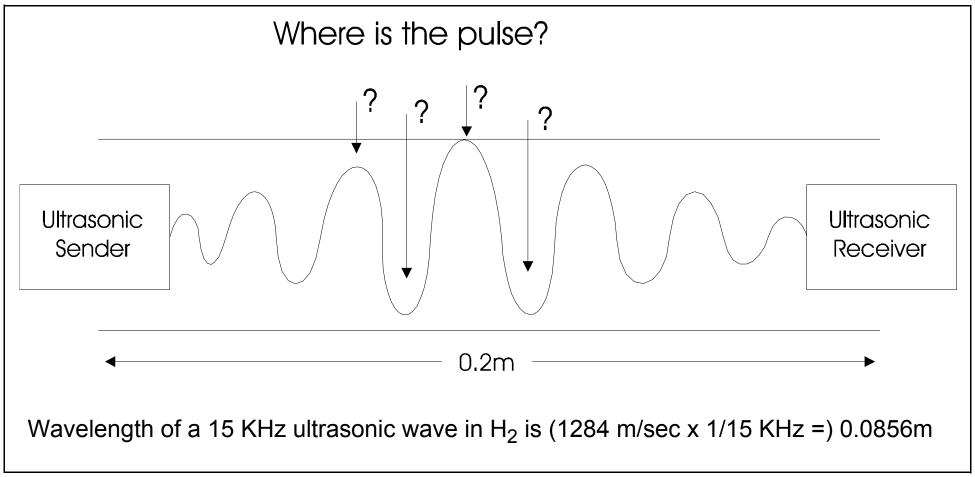
3.1.9.1 Calculation Example

The time interval for an acoustic pulse to travel 0.2 meters in hydrogen is computed as follows:

The speed of sound in hydrogen is 1284 meters/second, consequently the time of transit across the chamber is 0.2 meters / 1284 meters/sec = 1.56 E-4 seconds. See Figure 3-4.

In order to achieve equivalent resolution to this instrument's resonant technique, the TOF instrument's ability to measure the pulse must be 1/50,000 of the transit time, or: 1.56 E-4 (1/50,000) = 3.12 E-9 seconds

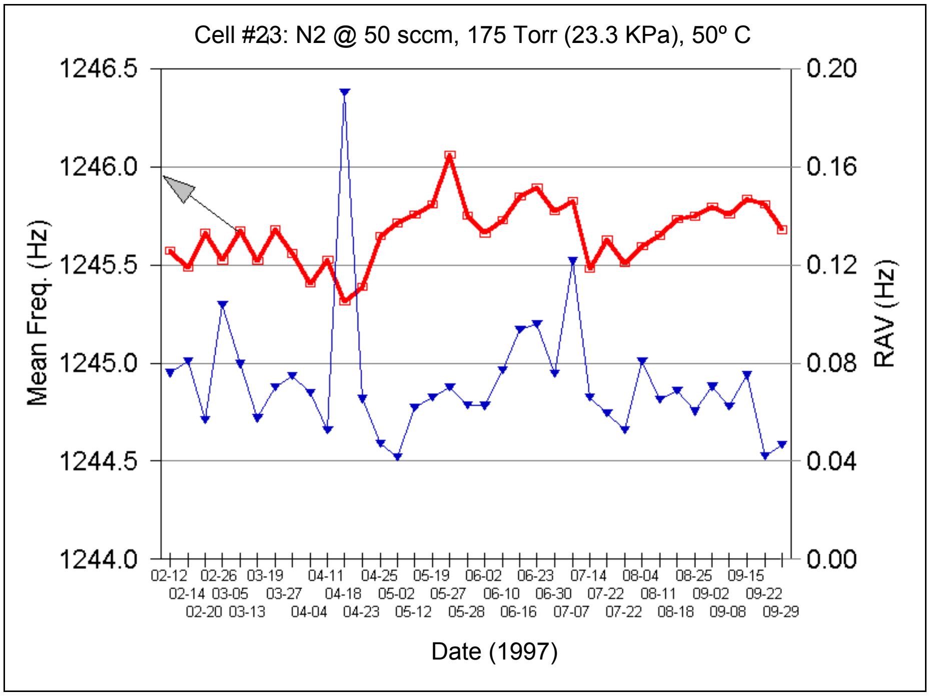
Figure 3-4 Where does the pulse begin or end?



3.1.10 What is the Long Term Stability of this Measurement System

A Composer Transducer was checked weekly for its frequency in nitrogen at 175 Torr (23.3 kPa) and 50 °C. As of this writing there does not appear to be any trend that might be construed to relate to any wear mechanism or degradation with time, see Figure 3-5. In addition, the short term measurement stability was checked at the same time and plotted as Root Allan Variance (RAV). This data is not corrected for zero off sets due to atmospheric pressure variations over the test period.

Figure 3-5 Long Term Reproducibility and Stability at Low Pressure



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3.1.11 Properties of Optional O-ring Materials

The use of some chemicals may preclude the use of Viton seals. KALREZ elastomers are factory available. These materials are somewhat more permeable than Viton, especially for small molecules.

NOTE: The high permeation rate of the optional elastomers may create some confusion when leak checking. It is possible that an apparent leak can occur long (approximately 30 seconds) after a specific joint has been probed. Unless the leak detector's response is immediate, the joint in question is leak tight; permeation is the source of the apparent leak.

Table 3-2 Permeation of gases through select elastomers

$$\textit{Permeation Rate} = \frac{(X10^{-9}Cm^{3} - Cm)}{(S - Cm^{2} - CmHg\Delta P)}$$

	KALREZ	Viton
He	2.5	1.7
H2	113	21
N2	0.05	0.031
Ar	6.1	4.1

A version of the Transducer that uses metal gaskets for the primary seal is available. Refer to Figure 2-5 on page 2-12.

WARNING

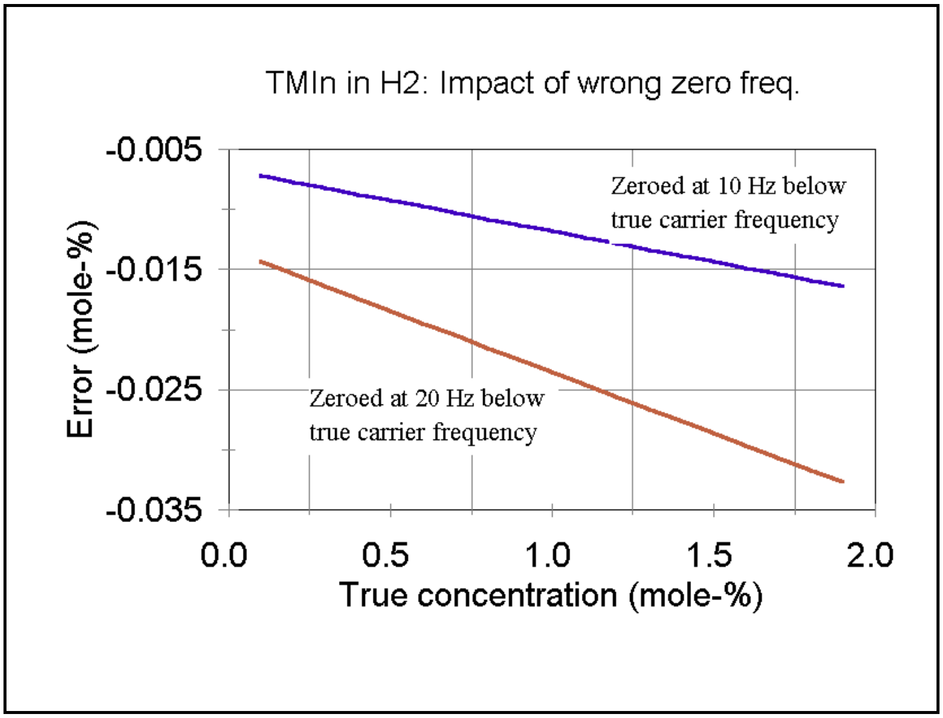
Perform a thorough leak check prior to connecting the Transducer to any process gas. Many of the gasses used for film growth are toxic at very low exposure levels. The use of a highly sensitive helium mass spectrometer leak detector is mandatory for safety.

3.1.12 What Happens if the Reference Zero is Improperly Set

If the Reference Zero is set when the conditions are wrong, i.e. not pure gas, two bad results occur.

1. A permanent concentration offset equal to the concentration at the time of zero is introduced. This is not corrected until a proper Zero Set is performed.
2. The sensitivity is altered, leading to an error proportional to the concentration.

Figure 3-6 Impact of Wrong Zero Frequency



Factory zero will be restored:

- if one of the gas parameters (molecular weight or γ) is altered.
- if the instrument is powered on with the "Always Use Factory Zero" configuration switch active, SW#6 of CFGR2.
- if selected, through the Set Up Tool or Monitor Software menu.

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3.1.13 Composer Bulk Flow Control Configuration

3.1.13.1 General

Composers with firmware version 4.00 (LED display) or 5.00 (LCD display) and higher are designed to have an alternate configuration that allows automatic feedback control of Bulk Flow, or Flux, in addition to the standard Concentration Control. Within this context, Bulk Flow is defined as the product of Concentration (mole%) and Bubbler Flow (sccm).

Bulk Flow Control manipulates only the Bubbler's MFC to maintain a constant Target Flux into the reactor, i.e., Total Flow Control is not available. This is different than Concentration Control, which may also manipulate a second MFC to provide constant precursor flux while maintaining constant total flow. In some situations Bulk Flow Control can provide faster response to changes in the Target Flux.

The Bulk Flow Control configuration is selected by activating SW#8 on CFGR2 (configuration switch bank 2). The analog I/O option board is required. This board allows the read-back of the Bubbler's MFC and also generates a 0 to 5 volt analog equivalent to the measured Concentration or other parameters, see section 4.3.6.8 on page 4-27. Internal or external control of the Bulk Flow target is electrically toggled by respectively "grounding" or "opening" pin 21 (Input #4) of the Composer's System I/O connector. A 0 to 10 volt analog signal proportional to either Concentration, Frequency or F/F2 is also available on the standard Concentration Out BNC, see section 4.3.6.8 on page 4-27.

The voltage range of the analog inputs is set by SW#7 on CFGR2. When the switch is "off" the range is 0 to 10 volts. Activating the switch reduces the range to 0 to 5 volts.

NOTE: The state of a configuration switch is only read during an initialization sequence when power is first applied to the Composer. Changing the state of the switch while the controller is "on" does not result in a change of the selected features.

3.1.13.2 Sensor Installation (Bulk Flow)

The Composer Transducer is installed downstream of the Bubbler and before any dilution or push flow additions in the Bulk flow control configuration. Other useful information is found in section 1.10.1 on page 1-10, section 1.10.1.1 on page 1-11, section 1.10.2.5 on page 1-14, section 1.10.3 on page 1-14 (all sections) and section 1.10.5 on page 1-21 (all sections).

3.1.13.3 Controller Installation (Bulk Flow)

SW#8 of CFGR2 must be activated to use Bulk flow Control. See Figure 3-7 on page 3-14 for detailed information on proper wiring of the interface. Note the presence of the 4.99 megohm resistor to ground from the common connection of relays K4 and K5 on the System I/O Connector. This resistor is necessary to avoid the Bubbler's MFC from self-generating a voltage that will drive the control to the full "on" condition if the Composer is powered off. Other useful information will be found in the Composer's Manual sections; section 1.10.1.2 on page 1-11, section 1.10.2 on page 1-11 (all sections) and section 1.10.3 on page 1-14 (all sections). The ground wires are not shown in Figure 3-7 for clarity, they must be connected to provide proper references. Be sure the grounds from the MFC's power supplies are maintained.

The balance of the interface is provided by the firmware coordinating the action of two SPST relays. Relay K4 is configured as a Normally Open relay and relay K5 is configured as Normally Closed. There is a "make before break" sequence so that the Bubbler's MFC is never allowed to drop to zero during the toggle action. The reactor's connection to Input #4 is now used to initiate a toggle between the Composer internally or the reactor externally maintaining Bulk Flow.

- During periods of externally (reactor) controlled Bulk Flow the STOP message is illuminated on the controller's LCD display and the reactor generated "CF Setpoint" is passed through relay K5 to the Control Input of the Bubbler's MFC. This voltage is also applied to the Composer's CONTROL IN connector to allow the Composer to keep track of the Bubbler's flow; which aids in quickly acquiring control when transitioning between reactor and Composer control modes.
- When the Composer is actively in control (internal control), the Composer's CONTROL OUT signal is routed through relay K4 to the Control Input of the Bubbler's MFC, and the CONTROL message is illuminated on the controller's LCD display. The Bulk Flow target is determined by the product of the Concentration Target and the flow setpoint applied to the CONTROL IN connector by the reactor.

A schematic of the pertinent aspects of a Composer configured for bulk Flow Control is shown in Figure 3-7 on page 3-14.

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The Analog I/O option card has a 9 pin D connector. The pin out is as follows:

Table 3-3 Option Card 9 Pin D Connector Pinout

pin #	function
1	ground
2	not used
3	not used
4	Concentration Read-out
5	ground
6	MFC Read-back input
7	ground
8	not used
9	not used

The System I/O connector is fully described in section 4.3.6.1 on page 4-22.

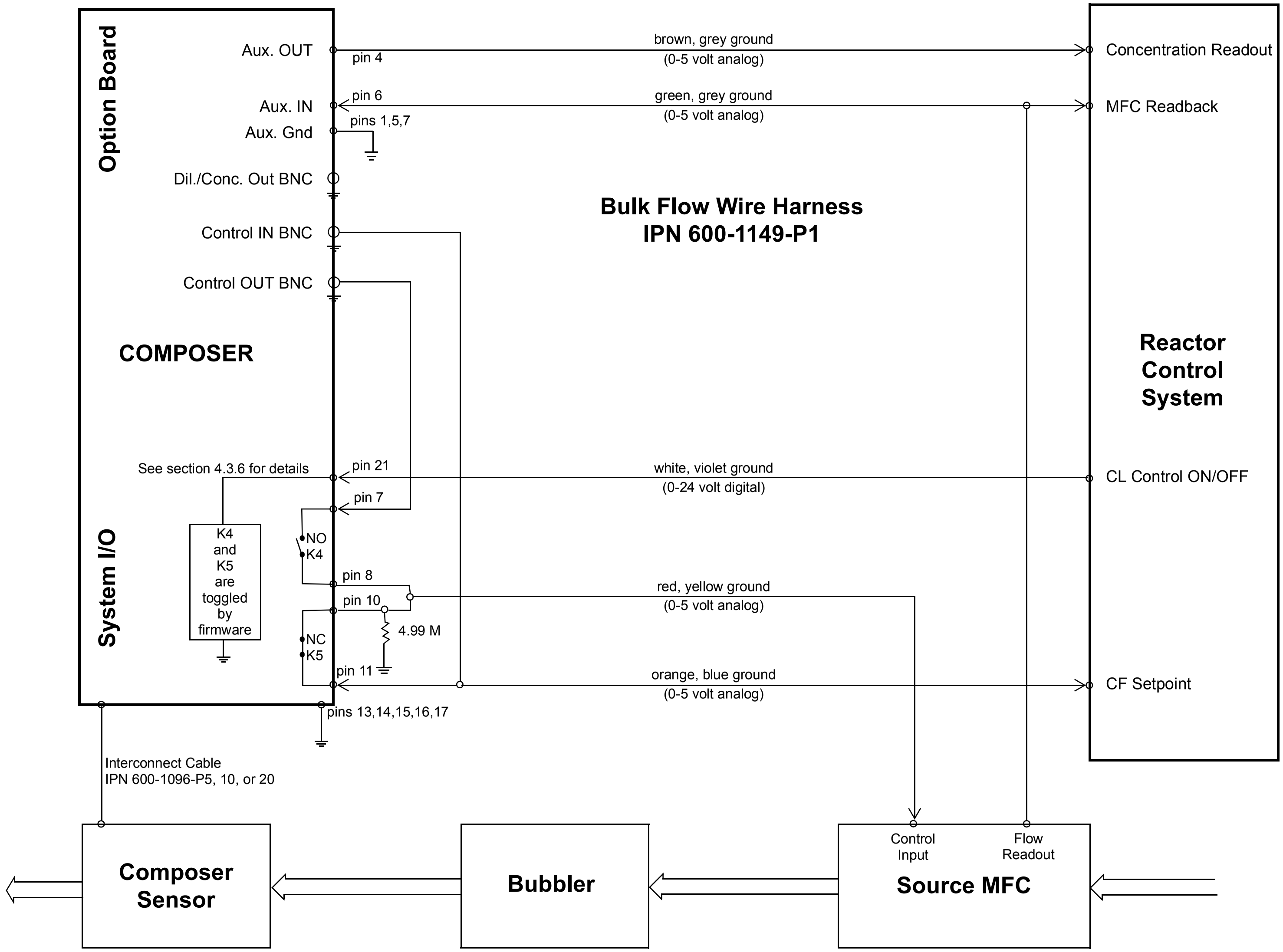


Figure 3-7 . Bulk Flow installation scheme showing optional Bulk Flow Cable's details. 4.99 megohm resistor is included within the hood of the mating system I/O connector. Wires are twisted pair; colors as shown; grounds not shown for clarity. Insure that the grounds from the MFC's power supplies are maintained or the MFCs may be damaged.

3.1.13.4 Operation (Bulk Flow)

The PROG key alternates the display between operate and program modes. In operation there is no requirement for operator involvement once the Composer's pertinent parameters are set, see section 3.1.13.5 on page 3-16.

The 7-digit numerical display normally provides the measured concentration. It is also possible to temporarily view other system and instrument parameters by pressing one of the keys on the front panel. The parameters and keys are:

Table 3-4 Parameters and Keys

Key		Parameter
A	(6)	Concentration (mole %)
S	(9)	Amplitude of the measured frequency (millivolt)
T	(E)	Temperature of Resonant Chamber (^{0}C)
Q	(0)	Resonant Frequency's quality factor
F	(C)	Current Resonant Frequency (Hz)
D	(7)	Current Bulk flow (sccm)
B	(4)	Current Bubbler Flow Read-back (sccm)
Y	(5)	Displays current warnings (if WARNING indicator is illuminated) see manual
N	(8)	Current Bulk Flow Target (sccm)

The front panel switches labeled START, HOLD, BYPASS and STOP are inactive in this configuration. Internal or external control is toggled through Input #4 as described in section 3.1.13.3 on page 3-12.

Calibration, if required, must be coordinated with the reactor's controller to establish a steady flow of pure carrier gas through the Composer Transducer. Refer to section 3.1.2 on page 3-1 and section 3.1.3 on page 3-2 for more information regarding calibration.

When operating in the Bulk Flow configuration the control algorithm uses only an Integral (I) term, unlike the PID (Proportional, Integral, Derivative) algorithm employed in the Concentration Control configuration.

If the Composer is turned on (or has lost resonance) and the reactor's controller is asking for Composer control, the output will go into Kp control until "good" measurements are obtained.

3.1.13.5 Programming the Controller’s Parameters (Bulk Flow)

When operating in the “Bulk Flow Control” configuration, the following list of parameters must be entered. See section 4.3.5.2.7 on page 4-15 for a complete description of each parameter and section 4.3.5.3 on page 4-17 (all sections) for a description of the display’s operation.

3.1.13.5.1 List of Parameters used for Describing the Bulk Flow Control Configuration

PROG # . . . . Numerical indication of program number (1-9).

Concentration Target . . . . Parameter that is used by the Composer to internally multiply the CF setpoint (as read by the composer on the Control In connector) and thereby form the Bulk Flow Target. See section 3.1.13.6 on page 3-18 for help in setting this parameter. (0.000 to 100.00%)

Process Gain . . . . Set parameter’s value per section 3.1.13.6.1 on page 3-18.

Dead Time . . . . Initially set to 2 seconds, do not set less than 1.0 second. Actual time will depend on delays in MFC read-back.

Time Constant . . . . Set to 1 second

Relay Limit. . . . . Units are sccm in Bulk flow configuration

Fuzzy Y/N

Cell Temperature

Carrier MW

Carrier γ

Precursor MW

Precursor γ

MFC Range, Bubbler

Max Flow Bubbler

IPN 074-289L

Minimum Bubbler Flow (User 3) . . Parameter used to set a minimum opening for the Bubbler's MFC, avoiding unnecessary control action on start-up and resulting unpredictable concentration profiles. This parameter is overridden during periods of external (reactor) control [when the STOP message is illuminated]. (0.000 to full MFC range.)

Max Input (User 5) . . . . Parameter sets flow corresponding to Max Voltage applied to Control In connector.

Min Input (User 6) . . . . Parameter sets flow corresponding to zero volts applied to Control In connector.

All of these parameters are also used in the "Concentration Control" configuration. Many additional parameters used in the Concentration Control configuration are not required. These parameters do not light on the display, being automatically skipped as the film's parameters are stepped through. The instrument can store up to 9 unique sets of parameters, individually indicated by a unique PROG #.

3.1.13.6 Determining Process Control Loop Parameters (Bulk Flow)

3.1.13.6.1 Gain, Kp

The most important parameter for good feedback control in the Bulk Flow Control configuration is K_p. It is an easy one or two step experimental exercise to determine this parameter.

Step 1- While in External (reactor) control, establish a “normal” flow of gas through the bubbler. When stable, note the displayed concentration. Use this value for the Concentration Target parameter and enter it into the Composer. If this value is already known for a given bubbler and system, use that value.

Step 2 – Using your knowledge of the full-scale flow for the Bubbler’s MFC, estimate its flow at 1 volt. Multiply this estimated flow by the Concentration Target to determine the K_p for the delivery system.

NOTE: Most MFCs provide full flow at 5 volts.

Example

Bubbler’s MFC full-scale flow is 200 SCCM

Full-scale flow is 5 volts

Concentration reading was 0.8500%

Calculate:

K_p = [200 sccm / 5 V] * 0.85 = 34.00 sccm / V

3.1.13.6.2 Dead Time

For Bulk Flow Control set this parameter to 2 seconds initially, but never less than 1.0 seconds.

3.1.13.6.3 Time Constant

For Bulk Flow Control set this parameter to 1 second.

3.1.14 Analog I/O Option — Concentration Control Configuration

In addition to its use enabling the Bulk Flow Control configuration, refer to section 3.1.13 on page 3-11, the Analog I/O option provides the following features in the Concentration Control configuration.

- A second analog output that:
  - When dilution control is not used, duplicates all of the functionality of the standard Concentration Out BNC, see section 4.3.6.8 on page 4-27.
  - When dilution control is used, maintains all of the functionality normally provided by the Concentration Out BNC (which is now providing control to the Dilution MFC), see section 4.3.6.8 on page 4-27.
- A second analog input is present but not used in Concentration Control configuration.

The pin-out arrangement for this option is shown in Table 3-5.

Table 3-5 Pin outs

pin #	function
1	ground
2	not used
3	not used
4	Analog Output (0 to 10 V)
5	ground
6	Analog Input (0 to 5 or 10 V, see section 4.3.6.6 on page 4-26, SW7 of CFGR2)
7	ground
8	not used
9	not used

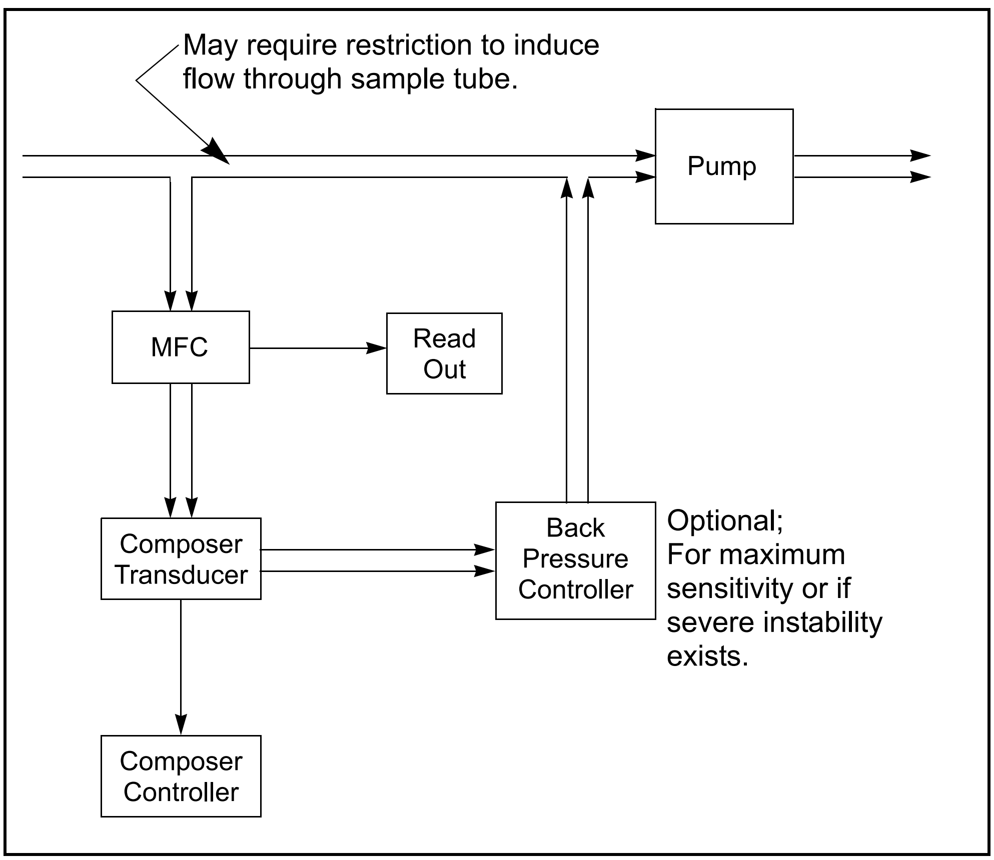
3.1.15 How to Sample Flow with a Composer

When the flow through a pipe exceeds the Transducer's 1800 sccm limit, sampling of the process is required. In our experience simply bypassing some of the process gas through the Transducer can compromise the Composer's precision, long term accuracy and add noise due to pressure and flow fluctuations.

Our recommendation is to "buffer" the flow through the transducer by adding a Mass Flow Controller (MFC) upstream of the Transducer in the sample line. This device will stabilize the flow and in most cases restore the instrument's full measurement capability. In some extreme cases it may be necessary to also add downstream buffering with a Back Pressure Controller. Try to maintain at least 100 Torr in the Transducer for best operation. It may be necessary to slightly restrict the process tubing in order to induce flow through the sample tube. See Figure 3-8.

An added benefit of adding the MFC to the sample tube is that flow through the Transducer is made visible and easily verified.

Figure 3-8 Flow Sampling



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3.2 Tutorials

The following information is available:

- Control Loop Fundamentals — Concentration Control, see section 3.2.1 on page 3-21.
- Computing the System's Time Constant, see section 3.2.1.5 on page 3-25 for Concentration Control or section 3.1.13 on page 3-11 for Bulk Flow.
- How to Determine Process Parameters, see section 3.2.3 on page 3-28.
- What if the NOVRAM's Battery Fails and I Lose All My Stored Parameters?, see section 3.2.4 on page 3-32.
- Why is a Digital Connection to the System Controller Preferred?, see section 3.2.5 on page 3-33.

3.2.1 Control Loop Fundamentals — Concentration Control

NOTE: Control in the Bulk Flow mode is best described in section 3.1.13 on page 3-11.

The function of the control loop parameters is to match the instrument's reaction to an error (between the measured concentration and the desired concentration) to the time related characteristics of the reactor. There are three adjustable parameters; **PROCESS GAIN**, **TIME CONSTANT** and **DEAD TIME** used to accomplish this. It is convenient to think of Delivery Systems as falling into two categories: slow or fast.

- A slow delivery system, for the purpose of this discussion, has more than a one second delay (lag) between the control voltage change (into the Bubbler's MFC) and the measurement system's ability to sense that change has taken place. Most delivery systems have this characteristic. See section 3.2.1.1, Tuning a Slow Delivery System, on page 3-22.
- A fast system, for the purpose of this discussion, is a system that has not more than a one second dead time between the control voltage change (into the MFC's set point) and the measurement system's ability to sense that change has taken place. See section 3.2.1.2, Tuning a Fast Delivery System, on page 3-23.

Fast systems effectively use an integrating type controller while slow systems are better controlled with a PID type. The tuning parameters are affected by liquid source level, flow rate, delivery system volume, and solid source condition.

Because the volume to flow rate ratio is typically quite large in current delivery systems, it is expected that most will be characterized as slow.

NOTE: The use of a chart recorder, especially when beginning a new application, is highly recommended. Connect the recorder output to the Controller's output and use it to monitor the response to small changes in the **TARGET CONCENTRATION**.

If you do not know if the system is fast or slow, it is straight forward to measure the delay using the chart recorder. Using manual flow control, establish a flow rate and allow the measured concentration to become steady. When the chart recorder pen crosses some convenient reference point, increase the flow rate a few percent (~5% if possible). Allow the source to again stabilize. Graph the delay time to determine if the system is fast or slow. Run the recorder at a chart speed sufficiently fast to accurately measure time. Dead times greater than 1 second characterize the source as slow.

3.2.1.1 Tuning a Slow Delivery System

If the response has been characterized as slow (Dead Time is greater than 1 second), review section 2.3, Control Loop Primer, on page 2-6 and then set the PID control parameters as follows:

PROCESS GAIN. . . . . K_P, enter this value into the parameter

TIME CONSTANT. . . . . T_1, enter this value into the parameter

DEAD TIME . . . . L, enter this value into the parameter

As illustrated in Figure 2-2 on page 2-7, the control dead time, L, is the time delay between a change in the Bubbler's flow setting and a noticeable change in concentration. The time constant, T_1 is ($T_{0.632}$ - L) where $T_{0.632}$ is the time between a change in the Bubbler's flow setting and the time to achieve 63.2% of the new equilibrium concentration.

K_P is then the ratio of the change in concentration divided by the change in flow setting.

$$K_p = \frac{(\textit{change in output})}{(\textit{change in control signal})} = \frac{\textit{concentration (mole\%)}}{\textit{controller output (volt)}} \qquad [30]$$

These values may be adjusted slightly in use to optimize the tuning. The tuning may change because of process variations. Once determined, **TIME CONSTANT** and **DEAD TIME** usually do not need to be changed unless flow rates or operating pressure are altered. At higher flow rates, the gas mix turns over quicker; at higher operating pressures it is slower for the same flow rate.

NOTE: Remember that increasing the value of **PROCESS GAIN** reduces the controller's change for a given concentration error, that is, the system responds more slowly.

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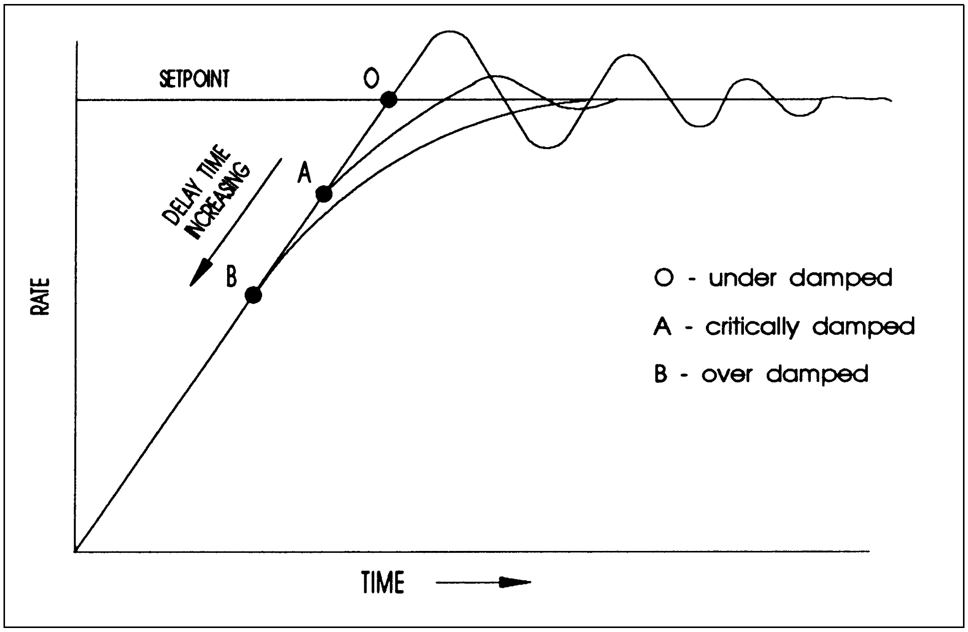
Figure 3-9 Examples of Delay, or Deadtime Settings



3.2.1.2 Tuning a Fast Delivery System

If the source response has been characterized as fast (Dead Time is less than 1 second), set the **INTEGRATING TYPE** control parameters as follows:

DEAD TIME . . . . since this is a fast source, set this parameter's value to 0.1 and leave it there.

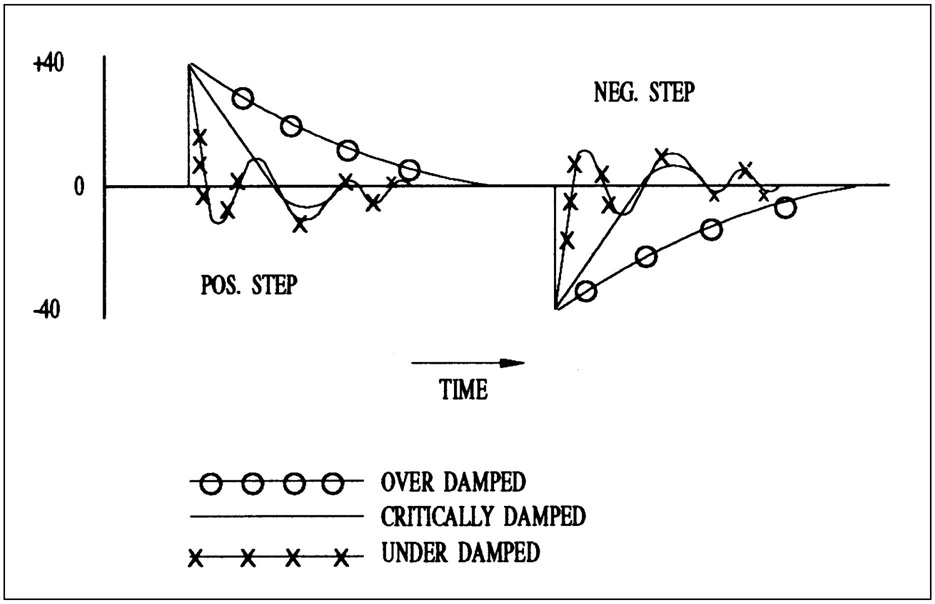
TIME CONSTANT. . . . . set this parameter's value to 0.1 and leave it there.

PROCESS GAIN . . . . approximate the process gain by dividing the increase in concentration (%) by the increase in Bubbler flow rate (sccm). Set this parameter to this computed value. Optimize this value by changing the value in use. Remember that increasing the value of this parameter reduces the controller change for a given error in the measured concentration. That is, the system responds more slowly with higher values of process gain.

NOTE: If satisfactory control cannot be established using only **PROCESS GAIN** the system is probably not a fast system.

The response of a system with too little controller gain (its **PROCESS GAIN** value is too large) is characterized as over damped as shown in Figure 3-10. Decrease the **PROCESS GAIN** value until the system oscillates as is shown by the under damped curve. Proper control is established by an intermediate value that approximates the critically damped curve.

Figure 3-10 Examples of Damped Curves



3.2.1.3 Typical Parameter Values

Some values that have performed well in our delivery system are: **PROCESS GAIN = 0.95**, **TIME CONSTANT = 23 sec.**, and **DEAD TIME = 8 sec**. The parameter values computed by ITAE Criteria were tried and then somewhat optimized by increasing the **DEAD TIME** slightly as shown in Figure 3-10. A longer **DEAD TIME** makes for a very slow response.

3.2.1.4 Setting Total Flow

When SW#5 on CFGR2 is set, the CONCENTRATION OUTput is used as a slaved controller output. Specifically, it is used to maintain CHANNEL FLOW as (Total Flow minus Bubbler Flow) equals Dilution Flow. Refer to section 1.10.4.3, How to Connect the Instrument for Independent Control of the Concentration, on page 1-20 for further descriptions.

3.2.1.5 Computing the System's Time Constant

This Instrument System operates at 1 Hz in the Amplitude Track Mode; that is, it provides a new measurement of concentration every second. Now, how fast does the Reactor respond to a change? It is determined by the gas flow rate through the Reactor's Delivery Line and the volume of the Reactor's gas Delivery System between where the change is induced and its entry into the Reactor's chamber. The volume within the Reactor's Chamber will also extend this basic time constant but is complexly affected by the reactor's flow design. Keep this basic time response in mind as you set the system's time constant and remember that nothing will happen faster than this basic response time; see section 3.2.1.6 for a quick calculation.

3.2.1.6 Calculation Example

A TMI delivery line has a flow rate of 150 sccm. The volume of the Delivery System is defined by 2 meters of 1/4" (6.35 mm) tubing and 100 cc of empty "head space" above the Bubbler. The 2 meters of tubing has an internal volume of about 40 cc, combined with the head space gives a total volume of 140 cc. In addition, the Transducer's Swept Volume is about 18 cc for a total volume of 158 cc. The basic time constant is then calculated: 158 cc/ 150 sccm = 1.053 minute = 63.2 seconds.

3.2.2 How to Precisely Tune a Control Loop

Here is a method to precisely determine process parameters for the Composer's control loop. This method is robust in systems with fairly wide range of dead time and time constants and is quite accurate. The method requires data logging and off-line calculations. The Monitor software, with its data logging and manual gas control capabilities, would be a very convenient interface. A simplified but less accurate method is later described in section 3.2.3, How to Determine Process Parameters, on page 3-28.

1. Start Monitor software in Amp Track mode.
2. Select **Show Advanced Data** in **Setup >> Data Display** menu.
3. From the **Setup >> Process Parameters** menu option, set appropriate MFC parameters, gas parameters and total gas flow.
4. If total flow is to be conserved, the DIP SW#5 on CFGR2 must be set. Connect MFC control cables to the back of the instrument.
5. Evacuate the system.
6. Press **BYPASS** button to start dilution gas flow at predetermined rate and wait until pressure stabilizes.

7 Start data gathering.

NOTE: Zeroing the instrument is not essential, but the concentration reading should be steady.

8 Start data logging. Wait about half a minute.

9 Press the **MANUAL** button to bring forth a pop up window.

10 Set bubbler gas flow and adjust dilution flow if total flow is to be conserved.

11 Press the **SET FLOW** button on the pop up. Since, full scale output of the bubbler MFC corresponds to 5 volts, the control voltage to the bubbler MFC can be readily estimated as (*5.0 V * bubbler flow /bubbler full scale)*. Let's call this value *volts*.

12 The concentration will start to increase and then settle down to a steady value. After the concentration becomes steady, wait for about a minute and then press the **BYPASS** button to terminate bubbler gas flow.

13 Stop data logging when the concentration is within 10% of its initial value (near 0, if the instrument was zeroed).

14 Press **STOP** button to terminate all gas flows.

15 Now is the time for data analysis. When the logged data is plotted, it will be similar to Figure 3-11 on page 3-27.

16 Use fifteen data points (about 15 sec) from the initial section to calculate average and standard deviation. The average, *Vo*, is the initial concentration baseline and twice the standard deviation will be called error band, *Err*.

17 After the concentration has become steady (within *Err*) at the higher value, calculate the average concentration over fifteen seconds. This average, *Vf*, is the final concentration reading.

18 Compute the process gain, *Kp = (Vf - Vo) / volts*.

19 Now enumerate time, *t,* from the moment the bubbler flow is reset to zero. Pick a number of data points at approximately uniform intervals, covering the range from immediately after the concentration begins to drop off (beyond *Err*) to slightly beyond halfway between *Vo* and *Vf*. We will call this data set *V(t)*. In this regime, as seen in Figure 3-11 and Figure 3-12 on page 3-28, the following relationship holds, where *Td* and *Tc* are process dead time and time constant respectively;

$$V(t) = Vo + (Vf - Vo) \exp -(t - Td)/Tc$$

20 Define a variable *Y(t)*, such that,

$$Y(t) = \ln(Vf - Vo) - \ln(V(t) - Vo) = t/Tc - Td/Tc$$

21 Use linear regression technique to fit data to *Y(t) = A + Bt*. Then, by comparing with the above equation, we get *Tc = 1/B* and *Td = -A/B*. Thus, *Kp*, *Tc* and *Td* completely characterize the process under consideration.

The same technique can be used to extract these parameters at an expected set point, slightly above and slightly below the set point. The average of these parameters will then be more representative of the dynamics of the process. It is noteworthy that, in a solid source bubbler like TMIn, the process gain will gradually diminish with increased flow. The entire procedure of tuning may take 5-30 minutes, depending upon the process. The following table shows some representative results (nitrogen in hydrogen gas).

Table 3-6 Tuning Representative Results (Nitrogen in Hydrogen Gas)

Total Flow (sccm)	Pressure (Torr)	Flow conserved	Process Gain Kp (mole-%/volt)	Dead Time Td (sec)	Time Constant Tc (sec)
400	120	Yes	0.49	2.2	11.3
300	150	Yes	0.65	4.2	14.8
100	200	No	0.95	8.1	22.8
200	300	Yes	0.96	9.8	34.8
200	600	Yes	0.95	17.1	68.8
100	600	Yes	1.89	38.4	113.5

Figure 3-11 Concentration transitions during the tuning process. Data points for process characterization are taken from the decay portion of the cycle.

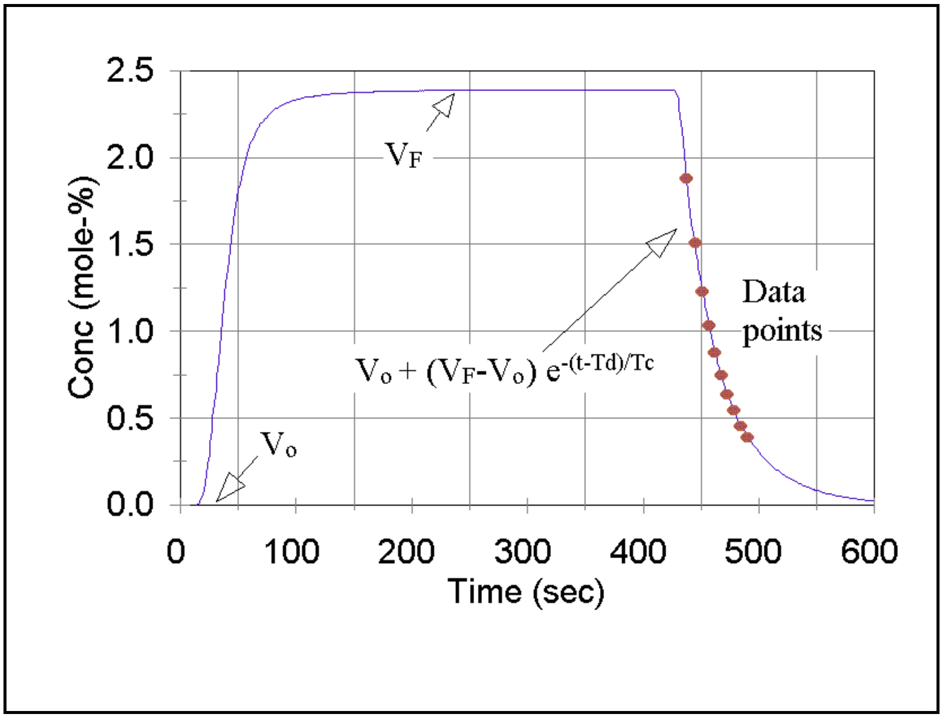
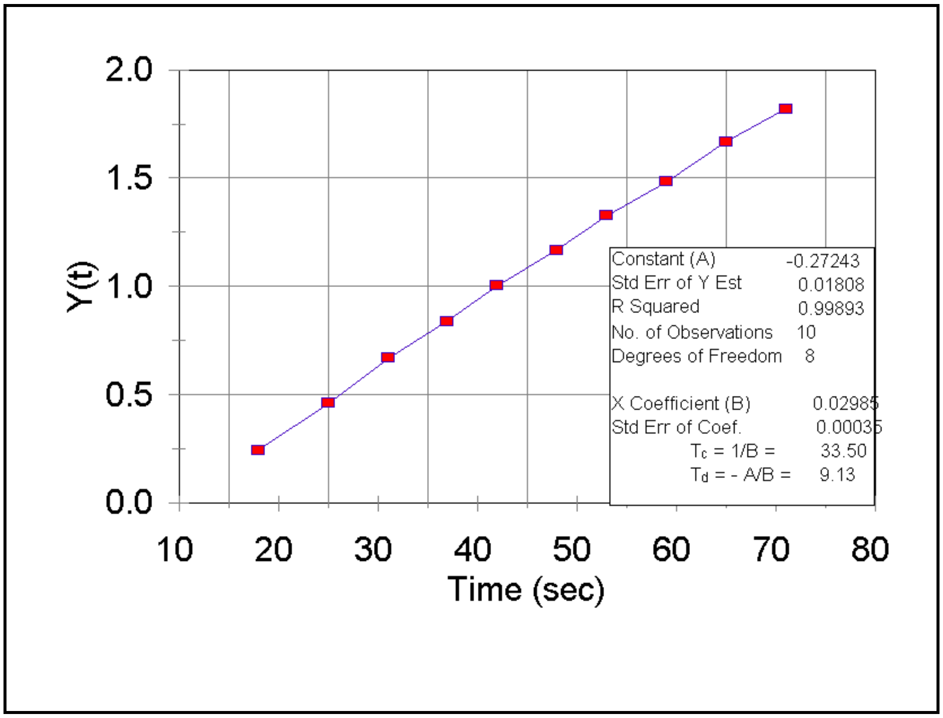


Figure 3-12 Linear regression fit of data points taken in Figure 3-11. In this particular process, the time constant and dead time are 33.5 sec and 9.1 sec respectively.



3.2.3 How to Determine Process Parameters

Whether one uses the PID controller or the Fuzzy Logic controller, knowledge of the process to be controlled is essential, because the control parameters are ultimately derived from process parameters. The process parameters can be effectively determined by using either the Composer Setup Tool software, or the Monitor software, or the Composer's system I/O interface, or the front panel keypad (for unit with LCD display). The following sub-sections describe step-by-step the procedure for deriving these parameters using each of the aforementioned interfaces. The values determined in this manner are not precise, but result in adequate functioning of the control loop. A more precise method for determining process parameters has been elaborated in section 3.2.2, How to Precisely Tune a Control Loop, on page 3-25.

3.2.3.1 Using Composer Monitor Software / Setup Tool

1 From the **Setup >> Process Parameters** menu option (or its icon on the Toolbar), set appropriate MFC parameters, gas parameters and total gas flow.

2 If total flow is to be conserved, the DIP SW#5 on CFGR2 must be set.

3 Connect MFC control cables to the back of the instrument.

4 Evacuate the cell and gas line.

5 Press the **BYPASS** button in Amp Track mode to start dilution gas flow.

6 Once the flow starts, press the **MANUAL** button. This will bring up a window for manually setting gas flows. It should display 0 in the bubbler flow box and previously chosen total flow in the dilution flow box.

7 Press menu item **Actions >> Start Collection** (or the play button on the ribbon bar) to display the graph of measured concentrations. When line pressure stabilizes, the steady light (or concentration steady sign on the unit with LCD display) will be illuminated.

8 Press menu item **Calibration >> Set User Zero** to establish pure carrier gas frequency.

9 Press the **Clear Graph** button.

10 Now enter a small value (i.e., 10) in the bubbler flow box. Subtract equal amount from the dilution flow if total flow is to be conserved.

11 Press the **SET FLOW** button. This will initiate bubbler flow. Watch the displayed concentration graph and wait until it levels off. In this manner, keep adjusting the bubbler flow and the dilution flow until the concentration reaches a steady value in the neighborhood of your desired operating point.

12 When the steady light (or the concentration steady sign) illuminates, note the bubbler flow and the displayed mole-%. Compute:

- bubbler control output as (5.0 volt)*(bubbler flow)/(bubbler full scale)
- Process Gain as (displayed mole-%)/ (bubbler control output).

13 Compute 1/e of the steady state concentration value as (displayed mole-%)* 0.37.

14 For this step, use the monitor timer on the panel (one on the left). Reset the timer by double clicking on it. Immediately press the **BYPASS** button. Observe the displayed concentration graph. Note the time at which the concentration starts to fall. This is approximately the dead time. Note the time at which the displayed mole-% reaches 37% of its original value. This time is the sum of the dead time and the process time constant. Thus, all three process parameters are known.

15 Enter these values through the menu **Setup >> Process Parameters**. Also, select the control loop type of your choice.

16 Press the **SEND** button on the pop up window. Now is the time to verify the control loop's actions with the new found process parameters.

17 Wait until the mole-% returns to zero and steady light is illuminated. Press the **START** button to initiate control loop action. This should verify that the loop parameter values are reasonable. When satisfied, press **BYPASS** to terminate bubbler flow. In the same manner, verify that the other control loop type also works with the same set of process parameters.

18 When finished, press **STOP** button to terminate all gas flows.

3.2.3.2 Using Composer's System I/O Interface

The standard system I/O interface contains electrical connections for all instrument required operating commands (see section 4.3.6.1, Description and Purpose of SYSTEM I/O Connector, on page 4-22). A simple user interface may be built with momentary contact push button switches and status LEDs.

Using the Setup software, configure the instrument for control with appropriate gas flow parameters. Use reasonable guesses for control parameters (such as, **PROCESS GAIN = 2.0**, **DEAD TIME = 5 sec**, **TIME CONSTANT = 10** sec).

If the reactor is configured with bypass or dilution plumbing, use the BYPASS input to start carrier gas flow. When stable conditions are achieved, zero the instrument using SET ZERO input.

Enter the control mode by using the START CONTROL input. The bubbler gas flow will slowly increase. When reasonable gas flow is achieved, activate the HOLD input to maintain fixed gas flow rates.

Wait until the measured concentration ceases to increase. Compute process gain from the knowledge of concentration and the bubbler flow rate. For example, if the stable concentration reading is 0.2 mole-% and the bubbler flow rate is 20 sccm through a mass flow controller of 200 sccm capacity, then the controller output is 0.5 volt (5 volt * 20 sccm / 200 sccm). Consequently, the process gain, Kp, is 0.4 (0.2 mole-% / 0.5 volt).

Activate the BYPASS input again to stop the bubbler flow. Use a stopwatch or timer to determine the dead time (time interval between the stopping of bubbler flow and a noticeable change in the concentration reading). In the same manner, determine the time constant, by measuring the time interval between the start of concentration change and its falling to 37% of the original concentration reading.

3.2.3.3 Using Composer's Front Panel Keypad (LCD Display Option)

1. Press the **PROG** button on the keypad to enter programming mode. Set appropriate MFC parameters, gas parameters and total gas flow. Choose reasonable values for target concentration, process gain, dead time and time constant parameters. These are temporary values which will be modified later.
2. If total flow is to be conserved, the DIP SW#5 on CFGR2 must be set.
3. Connect MFC control cables to the back of the instrument. Press **PROG** button again to end programming mode.
4. Evacuate the cell and gas line.
5. Press the **BYPASS** button on the keypad to start dilution gas flow. When line pressure stabilizes, the concentration steady sign illuminates.
6. Press **REF ZERO** on the keypad to establish pure carrier gas frequency.
7. Now press the **START** button on the keypad. This will activate the control loop, thus initiating bubbler gas flow.
8. Watch the displayed concentration. If the response is too slow, enter the programming mode again, reduce the process gain value and then exit programming mode. In this manner, keep adjusting the gas flows until the concentration is in the neighborhood of your desired operating point.
9. Press the **HOLD** button to maintain gas flows at the present rate and wait until the concentration stable sign is on.
10. When the concentration steady sign illuminates, note the bubbler flow by pressing the **B** button on the keypad. Also note the displayed mole-%.
11. Compute:
    - bubbler control output as (5.0 volt)*(bubbler flow)/(bubbler full scale)
    - Process Gain as (displayed mole-%)/(bubbler control output).
12. Compute 1/e of the steady state concentration value as (displayed mole-%)* 0.37.
13. For this step, use an external timer/stop watch. Reset the timer. Immediately press the **BYPASS** button on the keypad. Observe the displayed concentration. Note the time at which the concentration starts to fall. This is approximately the dead time. Note the time at which the displayed mole-% reaches approximately 37% of its original value. This time is the sum of the dead time and the process time constant. Thus, all three process parameters are known.

14 Enter the programming mode again. Modify the process parameters with newly found values. Also, select the control loop type of your choice. Exit programming mode. Now is the time to verify the control loop's actions with the new found process parameters.

15 Wait until the mole-% returns to zero and steady light illuminates.

16 Press the **START** button to initiate control loop action. This should verify that the loop parameter values are reasonable. When satisfied, press **BYPASS** to terminate the bubbler flow. In the same manner, verify that the other control loop type also works with the same set of process parameters.

17 When finished, press **STOP** button to terminate all gas flows.

3.2.3.4 An Example of Computation

This example applies to all the cases described above. Suppose, the bubbler MFC's full scale is 500 sccm and is flowing 100 sccm in steady state. If the displayed concentration is 2 mole-%, then the control output is (5 V*100/ 500) = 1.0 volt. The process gain = (2 mole-% / 1.0 V) = 2 mole-%/volt.

When the concentration reaches 1/e of its steady state value, it will be (2 mole-% * 0.37) = 0.74 mole-%.

Let us assume that, after the bubbler flow is stopped it takes 7 seconds for the concentration to start to fall. So, the dead time is 7 seconds. If it takes 28 seconds for it to reach 0.74 mole-%, then the time constant is (28 sec - 7 sec) = 21 seconds.

3.2.4 What if the NOVRAM's Battery Fails and I Lose All My Stored Parameters?

The expected life for the nonvolatile memory used in the Controller is in excess of 10 years. Therefore, failure shouldn't happen very soon; but when it does, be prepared. It is much easier to restart if you have a copy of all of the parameter values for each Controller. This can be a record saved on a floppy disk or on paper, preferably stored in several places. Replacement of the NOVRAM should be done by a factory representative. Refer to section 1.4.2, Field Service and Repair Support, on page 1-4 for information on how to get help.

3.2.5 Why is a Digital Connection to the System Controller Preferred?

Digital information is not corrupted or distorted by small changes in amplifier gain or offset that is often induced by temperature changes or grounding problems. The high precision concentration information available from this Instrument System requires that any analog instrumentation connected to it be able to measure and generate voltages with accuracy and reproducibility to less than 1 mV in 10 V in order to not lose available precision. Careful selection of the analog ranges, see section 4.3.6.8, CONCENTRATION OUT Connector, on page 4-27 and section 4.3.6.10, CONTROL IN Connector, on page 4-28, will help optimize performance.

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Chapter 4
Operation

NOTE: If you are experienced with operating this instrument, Chapter 12, Quick Use Guide, may provide you a quicker means to find the help you need.

4.1 Initialization and Setup

Although the same information must be entered into the instrument, the process varies slightly depending on if the standard or optional display is available.

Application-specific parameter values must be entered or downloaded in order to customize the Instrument System for the application and provide the correct interface to the system. The parameters normally affected include the gasses' Specific Heat Ratios and Molecular Weights. Application-specific parameters include the concentration's target set point value, CONTROL OUT voltage range and the control loop's parameters; Gain, Time Constant and Control Dead Time. A list of good starting values for the control loop parameters may be found in section 3.2.1.3, Typical Parameter Values, on page 3-24 and in section 3.2.3, How to Determine Process Parameters, on page 3-28.

4.1.1 Standard LED Display

Application specific parameters may be downloaded three possible ways:

1. When the optional Monitor program is used, parameter value customizing is readily accomplished within the setup window for each Instrument System. See Chapter 8, Software Guide for information concerning the Composer Monitor software.
2. Installations without the optional Monitor software require use of the Setup software for downloading application parameters from a temporary digital link. This link is also Windows based and is most easily run on a RS-232C link from a portable PC (see Table 4-3 on page 4-25).
3. Through a user or OEM generated file, see Chapter 7, External Communications, for command structures.

Once downloaded, the parameters are permanently stored in battery-backed RAM. See Chapter 8 for information concerning external communications.

NOTE: The expected life of battery-backed RAM is approximately 10 years. Refer to section 3.2.4, What if the NOVRAM's Battery Fails and I Lose All My Stored Parameters?, on page 3-32.

4.1.2 Optional LCD Display

The parameter set may be downloaded to the instrument in any of the methods listed in section 4.1.1 above or manually using the controller's keyboard.

Manual entry requires placing the instrument in the Program mode by pressing the **PROG** key on the front panel; see section 4.3.5.3 on page 4-17. The Program mode will be identified by the presence of a blinking cursor, adjacent to the highlighted parameter. There are no cursors in the Operate mode. Parameter data is entered by pressing the appropriate numerical or **Y-N** key to define the parameter followed by the **E** key which enters the data into memory and simultaneously highlights the next parameter.

There are nine possible sets of this information that can be stored. These data sets are called programs and are identified on the display as **PROG#** (where # is the data set being modified). Control and target parameters may be modified while the instrument is operating (controlling), but only on the current parameter set. The instrument must be in **STOP** mode to modify any other parameters. When returning to Operate mode, the last parameter set displayed will be used.

4.2 Calibration

Calibration is an optional procedure for this Instrument System. The purpose of calibration is to obtain the exact frequency (speed of sound) for the carrier gas (or one component of a mixture) for the particular instrument's operating conditions. This is called Reference Zero. For many applications, the Factory Zero may be sufficient to provide the needed levels of accuracy and reproducibility (refer to section 3.1.3, How is Performance Affected if I Use the Factory Set Reference Zero Value?, on page 3-2).

4.2.1 Frequency of Calibration

Applications requiring the highest degree of reproducibility should have the Reference Zero reset daily. Experience will determine if less frequent calibrations are appropriate. Refer to section 3.1.2 on page 3-1, section 3.1.3 on page 3-2, and section 3.1.12 on page 3-10 for additional information on this topic.

4.2.2 Special Tools and Materials

A means of flowing a pure gas through the Transducer at the processes' pressure and flow rate is required for setting the Reference Zero.

For guaranteed safe operation, a calibrated high performance mass spectrometer leak detector should be used whenever the Transducer has been removed and reinstalled.

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4.2.3 How to Calibrate

Flow the calibration gas (usually pure carrier gas) through the Transducer at the normal operating pressure and flow rate. Allow sufficient time for the calibration gas to cleanse any mixed gasses out of the Resonant Chamber. The carrier gas has displaced all of the formerly contained gas mixes when the concentration stops changing. This condition is verified by the front panel **STEADY** indicator (⇳) being illuminated. The new value for the Reference Zero is then established by pressing the **Set User Zero** switch in the optional Composer Monitor software package, pressing the **Ref Zero** key on the optional LCD Display, or momentarily pressing a switch (customer supplied) connected to the **SET ZERO** input located on the SYSTEM I/O connector's pin #18. Refer to section 3.1.2 on page 3-1 and section 3.1.3 on page 3-2. Note also that the transducers temperature must also be at set point to complete calibration. The user zero is retained until a new user zero is set or the gas parameters are changed. It is not possible to calibrate when a non-zero value for the minimum flow parameter has been set. If SW#6 of CFGR1 is set, only factory zero is used, see section 4.3.6.5 on page 4-25.

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4.2.4 How To Revert To Factory Default Settings

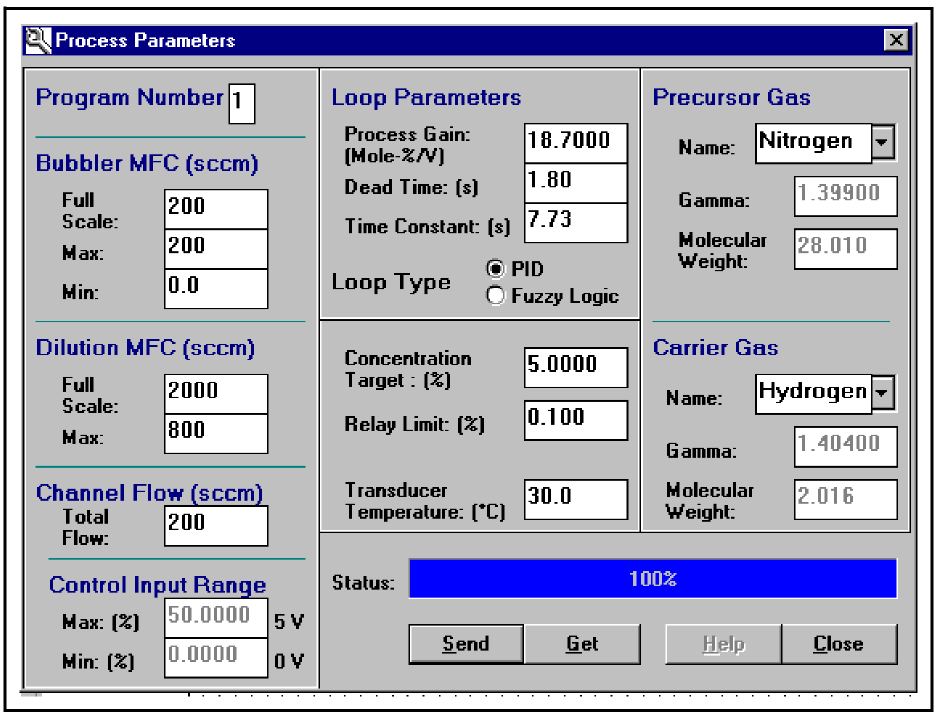
The factory set Reference Zero is re-established by changing any (concentration measurement effecting) parameter value such as Transducer Temperature, Carrier Gas Species, Specific Heat Ratio or Molecular Weight. The Controller's **USER SET ZERO** LED will be illuminated only if a user set Reference Zero is being used for calculating Concentration. All other parameter values must be altered through the digital link. Certain configuration information is set with the placement of SW#7 and SW#8 on the CFGR2 switch block, see section 4.3.6.6, CFGR2, on page 4-26. Refer to section 3.1.12 on page 3-10 for additional methods of re-establishing factory zero.

The optional Monitor Software allows the instrument to be reset to Factory Zero directly from the Calibration menu.

The optional LCD display controller may be reset to the default parameters by holding the **C** key down through two power "on" cycles.

The factory default settings are shown in Figure 4-1.

Figure 4-1 Factory Default Settings



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4.3 How To Use The Instrument

The following sections explain how to start, stop, and shut down the instrument. A description and purpose of the operating modes, displays, and system I/O connectors is also provided.

4.3.1 How To Start The Instrument

Operating the instrument requires a 24 V power connection and the **POWER** switch in the on position (**POWER** LED illuminated).

NOTE: The proper operation of all LED displays may be visually verified when the **POWER** switch is cycled on. All LEDs are illuminated for approximately two seconds after the power switch is activated.

4.3.1.1 Concentration Control Configuration

This Instrument System will attempt to measure concentration whenever power is applied and the green **POWER** indicator is illuminated on the Controller. It will give correct answers when the pressure is within the specified range and correct values for the gasses Molecular Weights and Specific Heat Ratios have been entered (refer to Table 3-1 on page 3-3) and the factory set Reference Zero is used. In addition, if a new Reference Zero is set, the proper procedure for the establishment of the Reference Zero with the correct pure calibration gas must be followed or incorrect concentration values will be output (refer to section 4.2.3, How to Calibrate, on page 4-3). Control of precursor concentration requires that the control loop parameter value be set as described in section 3.2.1, Control Loop Fundamentals — Concentration Control, on page 3-21 and in section 3.2.1.5, Computing the System's Time Constant, on page 3-25.

4.3.1.2 Bulk Flow Control Configuration

All instrument function is controlled externally through Input #4 of the system I/O connector. Refer to section 3.1.13 on page 3-11.

4.3.2 How To Stop The Instrument

4.3.2.1 Concentration Control Configuration

The Instrument will stop controlling concentration by pressing the **STOP** key on the optional LCD display, applying a closure to pin #20 (STOP) on the SYSTEM I/O connector, or pressing the **STOP** function in the optional Monitor software. The control function may be restored by applying a closure to pin #21 (START) or pressing the **START** function key in the Composer Monitor Software.

NOTE: **HOLD**, **STOP**, **BYPASS**, and **START** are mutually exclusive functions and the function will be dictated by the last command executed.

4.3.2.2 Bulk Flow Control Configuration

All instrument function is controlled externally through Input #4 of the system I/O connector. Refer to section 3.1.13 on page 3-11.

4.3.3 How To Shut Down The Instrument

Press the **POWER** switch on the front panel of the Controller. The green color of the Power LED will quickly extinguish. It is recommended that any auxiliary communication applications such as the optional Monitor Software or Setup Tool be closed first.

4.3.4 Description and Purpose of Operating Modes

4.3.4.1 Measuring Mode — Amplitude Track

Presently, the only measuring mode is Amplitude Track. The Diagnostic Sweep mode is only accessible with the optional Monitor Software.

4.3.4.2 Control Configuration — Concentration and Bulk Flow

There are two control configurations: Concentration and Bulk Flow

4.3.4.2.1 Concentration Control Configuration

STOP, BYPASS, and CONTROL are the primary states of the Composer that are useful for controlling and setting up a delivery system in the Concentration Control mode.

START . . . . Initiates the control state which manipulates the bubbler and dilution flows to maintain the target concentration.

STOP. . . . . Terminates the controlled manipulation of the bubbler and dilution outputs and sets them to zero.

BYPASS . . . . Sets the bubbler flow to zero (or MIN FLOW, if used) and manipulates the dilution flow to provide the total delivery system’s flow.

MANUAL . . . . Allows the user [through the Monitor software or the communications interface] to individually set the bubbler and dilution flows as desired.

These states, except Manual, are accessible through the front panel LCD version as well as the external I/O and external communications for all versions.

4.3.4.2.2 Bulk Flow Control Configuration

Refer to section 3.1.13 on page 3-11 for Bulk Flow Control specifics.

4.3.5 Description and Purpose of Displays

The following display types are available:

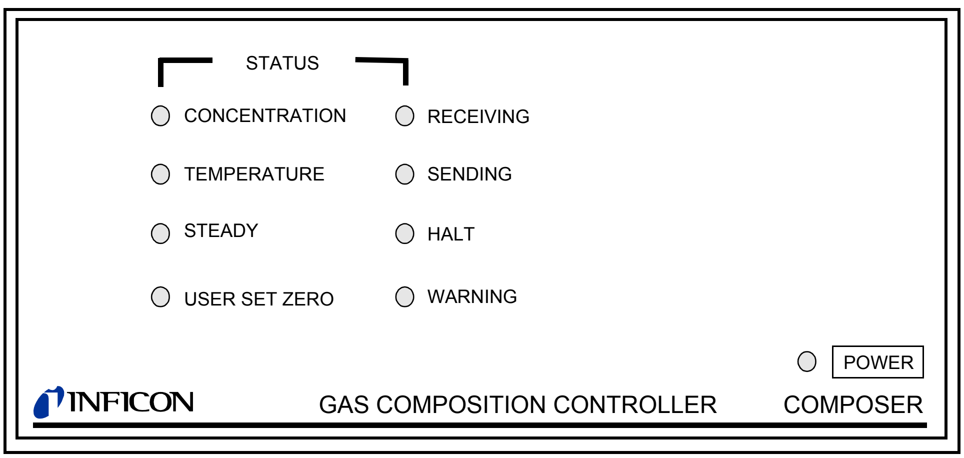
- Standard Display Description, see section 4.3.5.1 on page 4-7
- Optional - Composer LCD Display Description, see section 4.3.5.2 on page 4-9

4.3.5.1 Standard Display Description

There are nine high-intensity status LEDs on the front panel of the Controller. See Figure 4-2.

NOTE: All LEDs are illuminated for approximately two seconds after the power switch is cycled on to allow operational verification.

Figure 4-2 Composer front panel



CONCENTRATION . . . . A green LED that is illuminated when the Instrument System is actively controlling and modifying the voltage on the CONTROL OUT connector and the measured concentration is within the Concentration Window parameter's value. The default value of concentration tolerance is 0.01%

TEMPERATURE . . . . A green LED that is steadily illuminated whenever the Transducer's temperature is within +0.1 °C to -0.2 °C of the set point. It flashes slowly when the temperature is below the range and rapidly when above.

STEADY . . . . A green LED that is illuminated when the measured concentration value has been steady for 10 seconds. Its presence indicates that the Instrument System's Reference Zero may be successfully set. The particular criteria used to light this LED is that the frequency has been within +/- 2.0 Hz for 10 seconds.

USER SET ZERO . . . . A green LED that is illuminated when the Instrument System has been calibrated and no longer is using the factory set Reference Zero. The Instrument System automatically reverts to the factory set Reference Zero when any of the gas related parameter values or Transducer's temperature are modified.

RECEIVING . . . . A green LED that is illuminated whenever data is arriving on the digital link.

SENDING . . . . A green LED that is illuminated whenever the controller is transmitting data on the digital link.

HALT . . . . A red LED that is illuminated when the CPU is not properly executing code and the watchdog timer has not been reset. The instrument is not measuring or controlling when this light is illuminated. This indicator should not illuminate. If it does, push the Controller's **POWER** switch off and then on. If the indicator illuminates after this **POWER** off/on sequence, return the controller to the Service Center (refer to section 1.4 on page 1-4).

WARNING . . . . A red LED that illuminates in various repetitive blinking patterns to indicate improper operation. See section 6.5, User Diagnostics, on page 6-7 for patterns and error code extraction.

Power LED . . . . A green LED located next to the Controller's **POWER** switch that illuminates when the Controller is connected to a 24 V power source, power is applied and the Controller's **POWER** switch is on.

4.3.5.2 Optional - Composer LCD Display Description

The LCD display's layout is shown in Figure 4-3. The display has three modes.

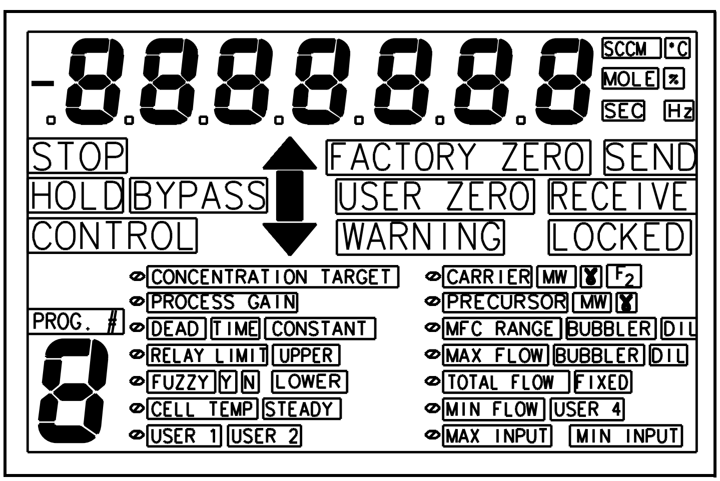
1. The first is the normal operate mode where digital composition information and various instrument status and state annunciators are visible.
2. The second mode is the program mode where the various instrument parameters are selected and the parameter values that tailor the instrument are entered.
3. The third mode is an auxiliary operate mode where various instrument performance data is temporarily displayed after the appropriate front panel key is pressed, see section 4.3.5.3 on page 4-17.

For concentration control there are annunciators for the four mutually exclusive machine states; **STOP**, **CONTROL**, **HOLD** and **BYPASS**. One of these is always illuminated. If remote communications has placed the instrument into the **MANUAL** state, no state indicator is shown. The optional Monitor Software has placed the instrument into the diagnostic Sweep mode, then the numerical display will show **SWEEP**.

CONTROL and **STOP** are the only states available in Bulk Flow Control configuration.

It is possible to check the complete function of the display during the power on sequence. All display segments will be on for several seconds. The installed firmware version will also be displayed for a few seconds immediately following the display test as **ver x.xx** on the numerical display.

Figure 4-3 Optional - Composer LCD Display



4.3.5.2.1 Numerical Display and Units Indicators

-.8.8.8.8.8.8.8 . . . . Numerical display for measured composition in the operate mode. Provides all numerical indication for the various parameter's values in the program and auxiliary display modes. Indicates the various user diagnostic modes and error conditions, see section 6.5, User Diagnostics, on page 6-7, in conjunction with **WARNING** indicator described in section 4.3.5.2.5 on page 4-12. The allowable range and resolution of individual parameters are described in section 8.3.5, Setup Process Parameters, on page 8-14.

sccm . . . . Illuminates in the program mode when the parameter value to be entered is a flow rate. Illuminates in the auxiliary display mode when the parameter to be displayed is either the bubbler (B) or the dilution (D) flow.

°C . . . . Illuminates in the program mode when the parameter value to be entered is a temperature. Illuminates in the auxiliary display mode when the parameter to be displayed is cell temperature (T).

MOLE % . . . . Illuminates in the normal operate mode, Illuminates in the program mode when the parameter value to be entered is a concentration (mole fraction percent).

% . . . . Normally part of the MOLE % message in the operate mode. Illuminates in the program mode when the parameter value to be entered is a percent (RELAY LIMIT).

SEC . . . . Illuminates in the program mode when the parameter value to be entered is a time (DEAD TIME & TIME CONSTANT)

Hz . . . . Illuminates in the auxiliary display mode when the parameter value to be viewed in the numerical display is the resonant frequency (F).

4.3.5.2.2 State Indicators

STOP . . . . Illuminates when the instrument's current state is STOP. All flows are zero in Concentration Control.
♦ Means the Reactor is in control if Bulk Flow configuration is selected.

HOLD . . . . Illuminates when the instrument's current state is HOLD. Flow outputs stay at the last (10 second average) flows output from the state just exited.

BYPASS . . . . Illuminates when the instrument's current state is BYPASS. Flow is 100% through the Dilution circuit.

CONTROL . . . . Illuminates when the instrument's current state is CONTROL. Flows are automatically adjusted to maintain Target Concentration in a closed loop manner. Flow is automatically conserved if the "Conserve Flow" configuration switch is set

SWEEP . . . . Illuminates the numerical display when the instrument's current state is sweep. This diagnostic state is only accessible through the optional Monitor Software.

MANUAL . . . . All state indicators are missing. Flows may be set manually from the Set Up Tool or optional Monitor Software.

CONTROL - WARNING . . . . A specialized state that the instrument automatically enters when errors (non-fatal) are encountered. The instrument, upon encountering certain errors dealing with the loss of signal or poor peak shape, transitions into a state which is like Hold, but will automatically return to the Control state if the error can be corrected.

4.3.5.2.3 Instrument Zero Indicators

FACTORY ZERO . . . . Illuminates when the instrument is first powered on and indicates that the reference zero is still at factory settings for the chosen carrier gas (controlled by the molecular weight and gamma parameters of the carrier gas) and temperature.

USER ZERO . . . . Illuminates when the user has set the reference zero (which overrides the Factory Zero). See ⇳ below, and section 4.2 on page 4-2 for procedures.

4.3.5.2.4 Communication Indicators

SEND . . . . Illuminates whenever the instrument is transmitting digital data.

RECEIVE. Illuminates whenever the instrument is receiving digital data.

4.3.5.2.5 Instrument and Process Status Indicators

WARNING . . . . Illuminates when various warning conditions are present. Specific conditions causing this indicator will be displayed in the numeric area if an error, or by pressing **5** if a warning. See section 7.4.4, Error Codes, on page 7-10, for meanings of the codes.

LOCKED . . . . Illuminates when the “parameter lock” dip switch is activated, see section 4.3.6.5, CFGR1, on page 4-25, or when the remote communications “remote lock” command has been given, see section 7.4.3, List of Commands with their Subcommands, Data, and Response Data., on page 7-5.

⇑ . . . . Illuminates when the concentration or bulk flow is increasing.

⇓ . . . . Illuminates when the concentration or bulk flow is decreasing.

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⇳ . . . . Illuminates when the concentration meets the condition for “steady" and the **STEADY** relay is closed, see section 4.3.6.1, Description and Purpose of SYSTEM I/O Connector, on page 4-22. You may press the **ZERO** switch to alter the Reference Zero when this indicator is illuminated.

CONCENTRATION TARGET . . . . Illuminates when the measured concentration or bulk flow is within the defined upper and lower relay limits of the target concentration.

RELAY LIMIT UPPER. . . . . Illuminates when the concentration or bulk flow has exceeded the upper limit and the @ CONCENTRATION relay is open.

RELAY LIMIT LOWER . . . . Illuminates when the concentration or bulk flow is less than the lower limit and the @ CONCENTRATION relay is open.

CELL TEMPERATURE. . . . . Illuminates when the transducer’s measurement chamber is at the value programmed for CELL TEMPERATURE +0.1 °C / -0.2 °C.

CELL TEMPERATURE STEADY . Illuminates when the transducer’s measurement chamber is at the value programmed for CELL TEMPERATURE and has been stable for 10 seconds.

TOTAL FLOW FIXED . . . . Illuminates when the “Control Dilution Flow” configuration switch has been activated, see section 4.3.6.6, CFGR2, on page 4-26.

FUZZY . . . . Illuminates when the fuzzy logic control choice has been selected for the selected film program.

4.3.5.2.6 *Film Number Indicator*

PROG # . . . . Always illuminated. Indicates function of 7 segment display below it.

8 . . . . Seven segment display that indicates which of the nine program descriptions is currently active or being modified. All programs may be entered and altered when the instrument is in the **STOP** state. When the instrument is in any of its other states, the only program which may be viewed and altered is the active process as the cursor will skip this parameter. When the display mode is switched from **PROGRAM** to **OPERATE**, the program currently displayed becomes the active program.

4.3.5.2.7 Program Parameter Indicators

Table 4-1 Composer Parameters Range and Type

Parameter	Allowed Entries Min	Max	Default	Type	Format
Concentration Target	0.0	100.0	5.0000	Float	xxx.xxxx
Process Gain	0.0001	999.9999	18.7000	Float	xxx.xxxx
Dead Time	0.01	1000.00	1.80	Float	xxxx.xx
Time Constant	0.01	1000.00	7.73	Float	xxxx.xx
Relay Limit	0.0	100.000	0.100	Float	xxx.xxx
Fuzzy	No	Yes	No		
Cell Temperature	0.1	65.0	30.0	Float	xx.x
Carrier Molecular Weight	1.000	1000.00	2.01600	Float	xxxx.xxx
Carrier Gamma	1.0	2.0	1.404	Float	x.xxxxx
Precursor Molecular Weight	1.000	1000.00	28.01000	Float	xxxx.xxx
Precursor Gamma	1.0	2.0	1.399	Float	x.xxxxx
Bubbler Range	0	5000	200	Integer	xxxx
Bubbler Max Flow	0	2000	200	Integer	xxxx
Dilution Range	0	5000	2000	Integer	xxxx
Dilution Max Flow	0	2000	800	Integer	xxxx
Total Channel Flow	0	2000	200	Integer	xxxx
Bubbler Minimum Flow	0	2000	0	Float	xxxx.x
Control Input Range Max	0	100.0000	50.0000	Float	xxx.xxxx
Control Input Range Min	0	100.0	0.0	Float	xxx.xxxx

Table 4-1 is also useful for the range and limits set by the Setup Tool software and the optional Monitorware communications software.

CONCENTRATION TARGET . . . . . The desired concentration of precursor in terms of mole %. Also used to multiply the flow read on the CONTROL IN connector to form the Bulk Flow Target.

PROCESS GAIN . . . . The numerical value of the Processes' gain (change in the concentration (mole %) divided by the change in the manipulated variable (volts).

DEAD TIME . . . . The numerical value of the processes' dead time (sec).

TIME CONSTANT . . . . The numerical value of the processes' time constant (sec).

RELAY LIMIT . . . . A parameter that defines a tolerance band around the Concentration Target or Bulk Flow Target in terms of an absolute concentration or flow. Works in conjunction with the @CONCENTRATION relay

FUZZY . . . . If set to yes (Y) the "fuzzy logic" control loop is activated, otherwise normal PID control is executed.

CELL TEMPERATURE . . . . The parameter that allows the user to set the transducer's resonant chamber's temperature (°C). Allowable range is 25 to 65 °C.

CARRIER MW . . . . The parameter representing the molecular weight of the lighter (or carrier) gas. Allowable range
is 1 - 1000.

CARRIER γ . . . . The parameter representing the specific heat ratio of the lighter (or carrier) gas.

PRECURSOR MW . . . . The parameter representing the molecular weight of the heavier (or precursor) gas. Allowable range is 1-1000.0.

PRECURSOR γ . . . . The parameter representing the specific heat ratio of the heavier (or precursor) gas.

MFC RANGE BUBBLER . . . . The parameter representing the full flow range of the mass flow controller that regulates the flow through the bubbler (sccm).

MFC RANGE DIL . . . . The parameter representing the full flow range of the mass flow controller that regulates the flow through the dilution circuit (sccm).

MAX FLOW BUBBLER . . . . The parameter representing the maximum flow desired through the bubbler (sccm). This must be equal to or less than the MFC RANGE BUBBLER parameter's value.

MAX FLOW DIL . . . . The parameter representing the maximum flow desired through the dilution (sccm). This must be equal to or less than the MFC RANGE DIL parameter's value.

TOTAL FLOW. . . . . The parameter representing the total flow desired (sccm) from both the bubbler and dilution flows.

USER # . . . . Indicators reserved for future features. Visible only during Controller's power up sequence.

MIN FLOW (USER #3) . . . . The parameter that sets the minimum allowed flow of the bubbler MFC. It avoids the erratic control that can take place due to the MFC's valve sticking at close.

MAX INPUT (USER #5) . . . . The parameter that sets the maximum concentration represented by the full range voltage applied to the Control In BNC. Requires SW#4 CFGR2 to be active.

MIN INPUT (USER #6) . . . . The parameter that sets the minimum flow when 0 volts is applied to Control In. Requires SW#4 CFGR2 to be active.

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4.3.5.3 Optional - LCD Front Panel Description

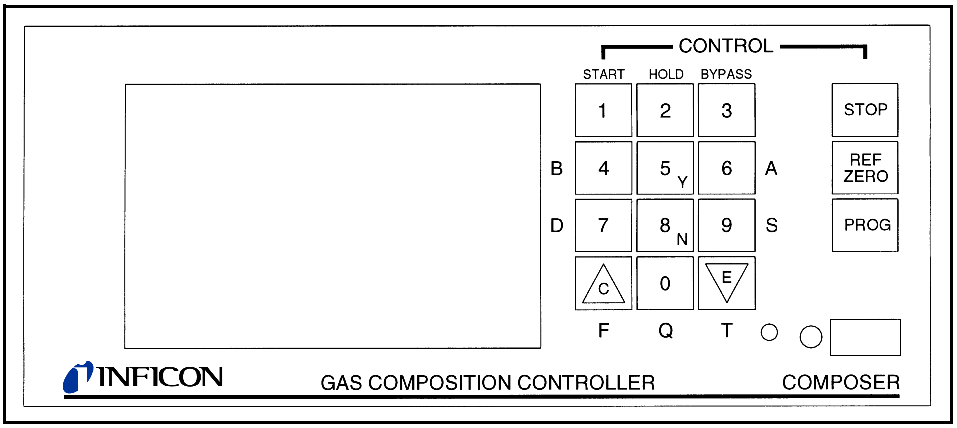
The LCD style front panel, see Figure 4-4, is composed of a power control and display adjustment portion, a display portion, see section 4.3.5.2, Optional - Composer LCD Display Description, on page 4-9, and a portion for data entry with a limited keyboard.

The power control and display adjustment portion is in the lower right corner and consists of a push-push type mechanical power switch and associated "power on" indicator which is illuminated green when the controller is connected to a 24 volt power source, power is applied and the Controller's Power Switch is on. A small opening to the left of the "power on" indicator is used to provide access to a variable potentiometer to maximize the view and contrast of the

LCD display for the specific location's lighting and instrument position, see section 5.8, LCD Contrast Adjustment — (LCD Display Option Only), on page 5-6.

The display portion occupies the entire left side of the instrument and is described separately in section 4.3.5.2, Optional - Composer LCD Display Description, on page 4-9.

Figure 4-4 Optional - LCD Front Panel



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4.3.5.3.1 Function and Numeric Keys

The data entry and process control portion occupies the upper right portion of the front panel and consists of a numeric keypad and special function keys described below.

STOP . . . . In Concentration Control mode pressing this key halts all process control activities, lights the **STOP** state indicator and sets all flows to zero. This key is active in both the operate and programming modes. This key is not operative in Bulk Flow Control configuration.

REF ZERO . . . . Pressing this key replaces the factory zero with the current resonant frequency and lights the display's "User Zero" message. The actuation of this key will be ignored unless the display's **STEADY** indicator, ⇳, is illuminated. The reference zero is used as the basis of calibration and concentration calculation. Pressing this key when other than pure carrier gas is present in the transducer will result in a concentration offset and improper concentration values, refer to section 3.1.2 on page 3-1.

This function is inoperative when a non-zero MIN FLOW value is used, refer to section 4.3.5.2.7 on page 4-15.

PROG. . . . . Pressing this key switches the display function between the operate modes and the programming modes.

C△, E ▽ . . . . After satisfactorily entering the parameter's value, pressing the **E**▽ key will place the displayed value into memory and erase the previous value, moving the cursor to the next parameter. Pressing the **C**△ key will erase the newly constructed value for that parameter and display the previous value, the cursor will remain at the current parameter.

NOTE: Holding the **C**△ key during a "power on" will unlock parameters if they have been locked by the monitor software. Holding the **C**△ key for a second cycle will set all parameters to their default settings.

0-9 . . . . Pressing these keys in the program mode will enter into the display buffer the appropriate decimal value. Should more digits be entered than the parameter requires, only the most current keystrokes will be retained.

4.3.5.3.2 Alternate Functions

When the display is in the operate mode, the numeric keypad has an alternate function which is indicated by words or letters printed around the periphery of the keypad.

START. . . . . *(Concentration Control only.)* Pressing this key will place the instrument into the CONTROL state and consequently initiates operation of the control loop to maintain the measured concentration at the CONCENTRATION TARGET parameter's value. Illuminates the display's CONTROL state indicator.

HOLD . . . . *(Concentration Control only.)* Pressing this key places the instrument into the HOLD state which maintains the bubbler flow (and dilution flow if so configured) at the value(s) current at the time of the actuation. Illuminates the display's HOLD state indicator.

BYPASS . . . . *(Concentration Control only.)* Pressing this key places the instrument into the BYPASS state which diverts all flow through the dilution circuit, reducing the bubbler circuit's flow to zero. Illuminates the display's BYPASS state indicator.

A . . . . *Concentration Control configuration:* Pressing this key will temporarily convert the numerical display's function to showing the drive level (0, 6, 12 dB) and amplifier range (1-5)

S . . . . Pressing this key will temporarily convert the numerical display's function to showing the measured resonant frequency's amplitude (millivolt RMS @ 1 V RMS drive).

T . . . . Pressing this key will temporarily convert the numerical display's function to showing the resonant chamber's temperature (°C).

Q . . . . Pressing this key will temporarily convert the numerical display's function to showing the measured resonant frequency's quality factor.

F . . . . Pressing this key will temporarily convert the numerical display's function to showing the current measured resonant frequency (Hz).

D . . . . *Concentration Control configuration:* pressing this key will temporarily convert the numerical display's function to showing the current dilution flow (sccm).

Bulk Flow Control configuration: temporarily displays bulk flow.

B . . . . Pressing this key will temporarily convert the numerical display's function to showing the bubbler flow readback.

5 . . . . Pressing this key will temporarily convert the numerical display's function to show the current warnings. (Only active if the WARNING indicator is illuminated.)

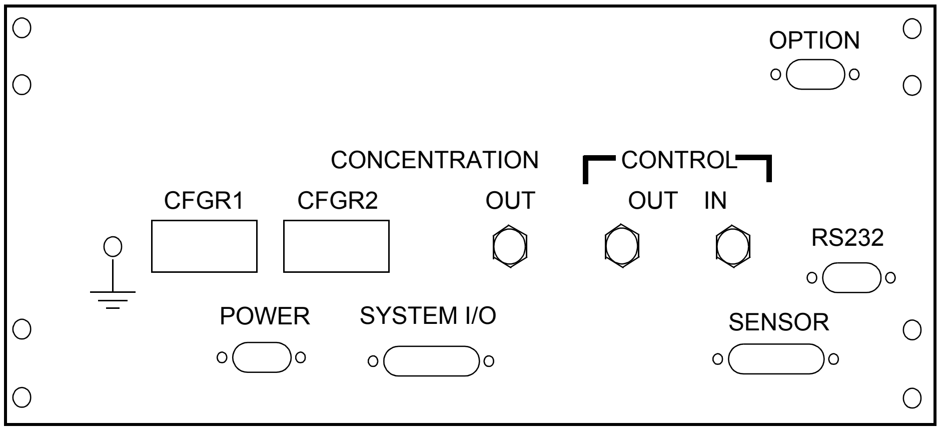
8 . . . . *Concentration Control configuration:* pressing this key temporarily displays the current target Concentration as interpreted from the applied voltage on the CONTROL IN connector.

Bulk Flow Control configuration: pressing this key temporarily displays the target Bulk Flow as interpreted from the applied voltage on the CONTROL IN connector.

4.3.6 Description of Rear Panel

The rear panel of the Composer is shown in Figure 4-5. The rear panel is the same for both front panel types.

Figure 4-5 Rear Panel of the Composer



4.3.6.1 Description and Purpose of SYSTEM I/O Connector

WARNING

The relay, relay circuit, and associated pins in the I/O connector(s) have a maximum voltage of 30 V(dc) or 30 V(ac) RMS or 42 V(peak). The maximum current rating per connector pin or relay contact is given below.

CAUTION

The current rating for the contacts for K5 is less than the current rating for the contacts K1 to K4. Please see the information below for the correct current rating.

A DB-25 connector that contains the discrete input ports and the relay outputs used for hardware interfacing with other system instrumentation and the main system controller. Relays K1-K4 are SPST type with normally open contacts rated up to 2.5 A, 30 V(dc) or 30 V(ac) RMS or 42 V(peak) max..

NOTE: K5 has slightly different electrical specifications: SPDT, 2 A @ 30 V(dc), 0.6 A @ 30 V(ac) RMS or 42 V(peak) max. K5 is a normally closed type to insure pass through of the Bulk Flux signal when the instrument is powered off.

The eight inputs are active when the specific input's terminal is pulled to ground (common) (<0.8 V) through a contact closure or with TTL/CMOS logic having current sink capability of 2 ma. (1 low power TTL load). The input ports are protected to +/- 30 V with respect to chassis ground. See Table 4-2.

NOTE: These ports are updated every 200 milliseconds; signals must be present during a read cycle. All inputs are leading edge detected and executed.

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Table 4-2 System I/O Connector Function

Relay I/O #	**FUNCTION**	**PIN #s**	**Comment**
K1	@ TEMPERATURE	1,2	Closed when the Resonant Chamber is within +0.1 °C to -0.2 °C of set point
K2	ERROR	3,4	Opens when the instrument is in an error. See Table 6-7 on page 6-7.
K3	@ CONCENTRATION	5,6	Closed when concentration is within programmed target band
K4	STEADY	7,8	*Concentration Control configuration:* closed when front panel **STEADY** light is illuminated. *Bulk Flow Control mode:* used to pass control voltage from Control Out of Composer to bubbler's MFC when in external control.
K5	user set Reference Zero	9,10 NO 10,11 NC	*Concentration Control configuration:* closed when factory Reference Zero has been overridden *Bulk Flow Control mode:* used to pass control voltage from reactor to bubbler's MFC when in external control. Use pins 10,11 to insure continuity if instrument is powered off.

Table 4-2 System I/O Connector Function (continued)

Relay I/O #	FUNCTION	PIN #s	Comment
IN#1	SET reference zero	18	Sets a new value of Reference Zero—will not take action unless: (a) steady condition is met (see K4 above), (b) the Transducer is at temperature set point, and (c) a zero value for the MIN FLOW parameter has been set.
IN#2 **	**HOLD** CONTROL OUTput	19	Holds CONTROL OUTput at present voltage value **
IN#3 **	**STOP** CONTROL OUTput	20	Sets CONTROL OUTput to zero volts**
IN#4 **	**START** CONTROL OUTput	21	Initiates feedback control to maintain target concentration set point (or value on CONCENTRATION INput)**
IN#5 **	BYPASS	22	Initiates full flow through dilution line (requires SW#5 of CFGR2 be set)** See Table 4-5 on page 4-26.
IN#6	spare 1	23	
IN#7	spare 2	24	
GND	system chassis ground	13, 14, 15, 16, 17	
** Inputs 2, 3, 4, and 5 are mutually exclusive in Concentration Control mode. The last command to change state from off to on will be operative. Certain transitions are not allowed: (a) Stop to Hold, (b) Bypass to Hold. Inputs 2, 3, and 5 are inoperative in Bulk Flow mode.			

4.3.6.2 SENSOR Connector

A DB-15 connector used for connecting the Controller to the Transducer. There are no user connections on this connector.

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4.3.6.3 POWER Connector

A DB-9 connector used for connection to a 24 volt power supply. Refer to section 1.7 on page 1-7 for a full description of the power supply requirements and pin connections.

4.3.6.4 Option Connector

A DB-9 connector used for:

- *Bulk Flow Control configuration:* for providing Concentration read back output and MFC read-back input.
- *Concentration Control configuration:* to provide concentration output for a Composer using dilution flow in the concentration control mode.

4.3.6.5 CFGR1

The first of 2 eight contact binary switch blocks used for activating various features. The state of these switches is only read when power is first applied to the Controller. See Table 4-3 for the configuration switch number descriptions and Table 4-4 for the baud rates.

NOTE: Changing the state of a switch while the Controller is powered on does not result in a change of the selected features. Switch status is only read during the Controller's power on sequence.

Table 4-3 Configuration Switch #1 Descriptions

SW#	FUNCTION	Details
1	transducer type refer to section 1.10.5.5 on page 1-23	0 = off - series 19 and higher 1 = on - series 18 and lower
2	communications configuration	(see note below)
3	communications configuration	(see note below)
4	communications configuration	(see note below)
5	spare	
6	always use factory set Reference Zero	(0=off, 1=on) When on, Reference Zero may not be user set.
7	parameter lock	(0=off, 1=on) When on, parameters may not be altered from the front panel. However, all parameters may be changed through communications.
8	spare	
NOTE: The supported communication is RS-232C.		

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Table 4-4 RS-232C Communication Baud Rates

SW#4	SW#3	SW#2	RS-232C (Baud Rate)
0	0	0	4800
0	0	1	9600
0	1	0	19200
0	1	1	38400
1	0	0	57600
1	0	1	9600
1	1	0	9600
1	1	1	9600

4.3.6.6 CFGR2

The second eight contact binary encoded switch block that is used for activating various instrument features. The state of these switches is only read when power is first applied to the Controller. Changing the state of the switch while the unit is powered on does not result in a change of the selected features. See Table 4-5.

Table 4-5 Configuration SW#2 Descriptions

SW	Function	Details
1	CONCENTRATION OUTput (MSB)	See section 4.3.6.8 on page 4-27 & also SW#5
2	CONCENTRATION OUTput	See section 4.3.6.8 on page 4-27 & also SW#5
3	CONCENTRATION OUTput (LSB)	See section 4.3.6.8 on page 4-27 & also SW#5

Table 4-5 Configuration SW#2 Descriptions (continued)

SW	Function	Details
4	CONCENTRATION INput function	0 = ignore, 1 = control to target concentration equals $\text{min input} + \text{diff}\left(\frac{V_{in}}{\text{input voltage range}}\right)$ where: input voltage range is set by SW-7 max = value of parameter MAX INPUT (USER#5) min = value of parameter MIN INPUT (USER#6) diff = (max-min)
5	Control Dilution Flow	0 = ignore 1 = maintain Dilution Flow as (Total Flow - Bubbler Flow) any time the controller is on and the Control or Bypass command has been given, unless Input #3 (STOP) of the system I/O is active. Used in Concentration Control configuration only.
6	spare	
7	Input Voltage Range	0 = 0-10 volts 1 = 0-5 volts Selects input voltage range for both CONTROL INput BNC (see section 4.3.6.10 on page 4-28) and the optional Analog I/O accessory's input; see section Table 3-3 on page 3-13 for Bulk Flow or section Table 3-5 on page 3-19 for Concentration.
8	Control Mode	0 = Concentration Control configuration (standard) 1 = Bulk Flow Control configuration; requires optional Analog I/O card.

4.3.6.7 RS-232C

See Chapter 7 for information regarding RS-232C.

4.3.6.8 CONCENTRATION OUT Connector

A BNC female connector that provides a precision analog voltage from 0 to 10.000 V into a 2 KΩ load that is proportional to either the concentration or frequency shift. It operates with 15 bit equivalent resolution, monotonic to 1 LSB and is updated every 200 milliseconds. It is intended for driving a chart recorder or being read by a system controller or other precision electronic measuring device. Its normal functionality is tailored by switch settings 1, 2 and 3 on the CFGR2 switch block as shown in Table 4-6. The Analog option card is configured at the same time to the same function, only 0-5 volts.

Table 4-6 Concentration Output Configuration Switch Settings, CFGR2

SW#1	SW#2	SW#3	FUNCTION
0	0	0	$V_{out} = 40[1 - F/F_2]$
0	1	0	0-500 Hz = $F-F_2$
0	0	1	0-1000 Hz = $F-F_2$
0	1	1	0-5000 Hz = $F-F_2$
1	0	0	0 - 0.1% Concentration
1	1	0	0-1% = Concentration
1	0	1	0-10% = Concentration
1	1	1	0-100% = Concentration

NOTE: If SW#5 of CFGR2 is set, this output is used as a 0-5 V control input to the Dilution Flow MFC and the settings of SW#1, SW#2 and SW#3 are ignored in Concentration Control mode.

4.3.6.9 CONTROL OUT Connector

A female BNC connector that outputs a precision analog voltage from 0-5.0 V into a 2KΩ load that is based on a controller algorithm for maintaining the target concentration set point. The particular target concentration used is coordinated with the setting of SW#4 on CFGR2. It operates with 15 bit equivalent resolution, is monotonic to 1 LSB and is updated every 1.1 seconds in Amplitude Track mode.

4.3.6.10 CONTROL IN Connector

A female BNC connector accepting a precision voltage that is interpreted as the target set point if SW#4 on CFGR2 is set. Otherwise it is ignored. It is protected to +/- 35 V continuous. The input voltage is read with a resolution of 14 bits and an accuracy to 0.01% +/- 1 LSB and an internal linearity of 1 LSB. The A-to-D converter’s gain drift is +/- 25 PPM/°C maximum and the zero drift is +/- 10 PPM/°C maximum.

4.3.6.11 Analog I/O Option

An optional Analog I/O card is available to support the Bulk Flow Control configuration and other features such as full time concentration read out. Refer to section 4.3.6.4 on page 4-25.

4.3.6.12 Safety Ground

Refer to section 1.10.3, Electrical Grounding and Shielding Requirements, on page 1-14.

- A 10-32 stud and nut used for establishing an electrical safety ground to the Controller.
- One of the Transducer's four 1/4"-20 mounting holes is used as an electrical safety ground.

NOTE: It is recommended that both the Controller and Transducer be grounded for safety and performance reasons.

4.3.7 Parameter Entry

Parameter values may be changed through the external communications interface or through the front panel of the optional LCD interface.

All parameters may be changed while in the **STOP** state. The parameters that define the instrument's operating environment, such as Bubbler MFC Full Scale and the Gas Constants, can only be changed in the **STOP** state. Parameters such as Control Loop Parameters and Target Setpoint can be changed at any time. Nine sets of parameters may be defined and stored as **PROG #** for use at a later time.

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Chapter 5
Maintenance

5.1 Safety Considerations

WARNING

Many of the complex chemicals that will be flowed through the Transducer are either toxic or possibly pyrophoric (spontaneously ignite in air). Complete knowledge of the chemical history and appropriate handling procedures must be followed by skilled personnel. None of the materials used in the construction of the Transducer are known to be hazardous. Refer to the Transducer's pressure range on page 1-3 for the maximum recommended pressures.

5.2 Scheduled [Preventative] Maintenance

There are no components or assemblies that have wear or anticipated failure characteristics.

5.3 Fuses

A 3.15 amp Type T fuse is located in the Controller. To replace the fuse, contact Repair Support (refer to section 1.4.2 on page 1-4).

5.4 Cleaning

Procedures appropriate for the chemicals used and compatible with the wetted materials of the Transducer (SS316L and Inconel® X-750) must be adhered to. The diaphragms are made from 0.0006 in. (0.0015 cm) Inconel X-750 and cannot be etched by any cleaner or acid without potential damage.

5.5 Inspecting the Transducer

If the Transducer is disassembled, all components should be visually inspected during reassembly and any damaged components discarded in a safe and environmentally sound manner. Upon completion of reassembly, but prior to the installation of the insulation and transducer housing, the assembly should be carefully leak tested using a high performance Helium mass spectrometer capable of sensitivity in excess of $1x10^{-9}$ std cc/sec. If the transducer has been configured with the optional elastomer seals, refer to section 3.1.11, Properties of Optional O-ring Materials, on page 3-9 before leak checking.

5.6 Leak Detection Procedures

The Composer Transducer is constructed in a manner which provides both primary and secondary containment of process gasses. Because of this construction, a special leak detection procedure is required to verify the leak integrity of both containment vessels. See section 5.6.1 below and section 5.6.2 on page 5-3.

5.6.1 Leak Testing the Primary Containment Vessel

This transducer may be tested for leaks while "in place", that is; with the process piping connected. To verify the diaphragm's and the diaphragm seal's integrity:

CAUTION

Do not allow pressure of process piping to exceed 1 atmosphere gauge, be especially careful on repressurization of the piping.

1. Remove the caps and gaskets from the two VCR-4 leak Detection ports. Simultaneously use two wrenches to avoid excessive stress and damage to the port.
2. Connect the Leak Detector and evacuate the process pipes by following the Leak Detector and system manufacturer's recommended procedures.
3. Probe with very small amounts of helium into the open Leak Test Ports.
4. Verify leak integrity, or replace and retest until leaks are eliminated. It is recommended that leaking modules be returned to the factory for service (refer to section 1.4, How To Contact Customer Support, on page 1-4 for more information).

5 Close the Leak Test Ports with a copper gasket following the manufacturer's suggested tightening procedure or proceed to section 5.6.2 on page 5-3 to verify Secondary Containment Vessel's leak integrity.

CAUTION

The use of a copper gasket is recommended because of the ease of obtaining seal integrity compared to harder gasket materials.

5.6.2 Leak Detection of the Secondary Containment Vessel

CAUTION

Do not evacuate and attach a leak detector to the Leak Detector Port until the Transducer's temperature drops below 30 °C.

CAUTION

It is recommended that the leak integrity of the Secondary Containment Vessel be verified upon installation, and at least annually thereafter.

CAUTION

Do not allow pressure of process piping to exceed 1 atmosphere gauge, be especially careful on repressurization of the piping.

Testing the integrity of the Secondary Containment Vessel requires attaching a Leak Detector to each Leak Test Port; one at a time. In order to verify the Secondary Containment's integrity:

1 If necessary, remove the caps and gaskets from the VCR-4 Leak Test Ports. Simultaneously use two wrenches to avoid excessive stress and damage to the port.

2 Attach the leak Detector to the first Leak Test Port and evacuate the Secondary Containment Vessel following the leak Detector manufacturer's procedures.

3 Probe with a very small amount of helium into the appropriate end of the transducer. Small openings are provided on each of the transducer's enclosure end plates for this purpose. A probe with a small tube or hypodermic needle will easily penetrate the insulation. Helium will readily diffuse through the insulation.

4 Verify leak integrity, replace or repair and retest until leaks are eliminated.

5 Repeat steps 3 and 4 with the second Leak Test Port.

6 Close the Leak Test Ports with a copper gasket following the manufacturer's suggested tightening procedure. Simultaneously use two wrenches to avoid excessive stress and damage to the port.

CAUTION

The use of a copper gasket is recommended because of the ease of obtaining seal integrity compared to harder gasket materials.

5.7 Verification of Transducer Performance

If the Instrument appears to be behaving abnormally or if it may have been damaged (by Transducer overpressure Etc.), it is possible to verify operational performance *in-situ* in many cases. Performance is best evaluated with the optional Composer Monitor software and the Transducer filled with carrier gas to near atmospheric pressure. It is also possible, but less convenient, to have a self evaluation performed without the Composer Monitor software.

5.7.1 Verification of Performance with Monitor Software

Fill the cell with hydrogen to about 750 Torr (100 kPa). In the Composer Monitor software initiate the sweep mode (see section 8.2.3.4.2, Sweep Mode, on page 8-5). Set Start Frequency at 2,000 Hz and step size at 4 Hz. Start sweep. If the screen looks like Figure 5-1, the unit is, most likely, OK. If it looks like either Figure 5-2 or Figure 5-3, then one or both diaphragms have suffered damage, even though they may be leak tight. In this case, the unit will require rework.

Similar procedures may be followed for other carrier gasses, consult the factory for help, if necessary.

If you are unsure as to how to interpret you results, record the screen data and e-mail the data file to us for evaluation. Screen data can be captured by:

- **File >> Save Graph As**.
-  clicking the **Save Graph** icon on the ribbon bar (see Table 8-2 on page 8-6).

The screen data is stored either as text file or as an image file in the Composer's native subdirectory on the host computer.

Figure 5-1 Correctly operating

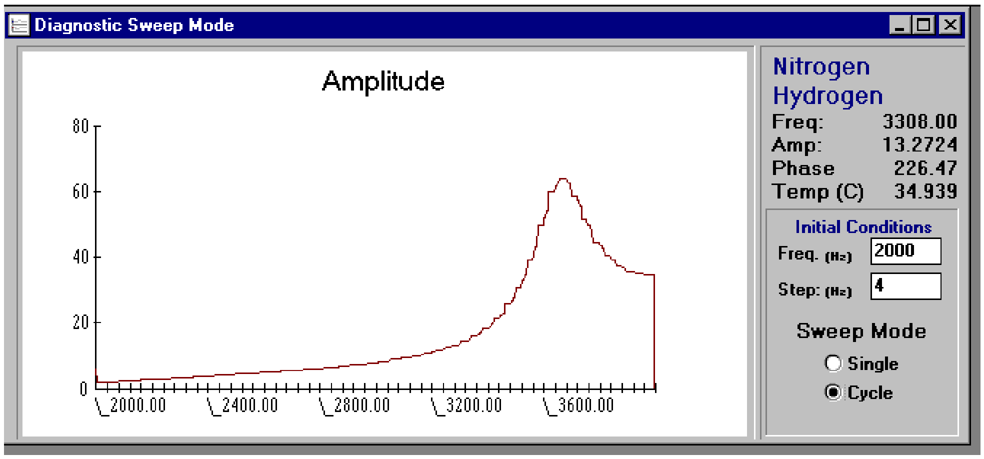


Figure 5-2 Possible diaphragm damage

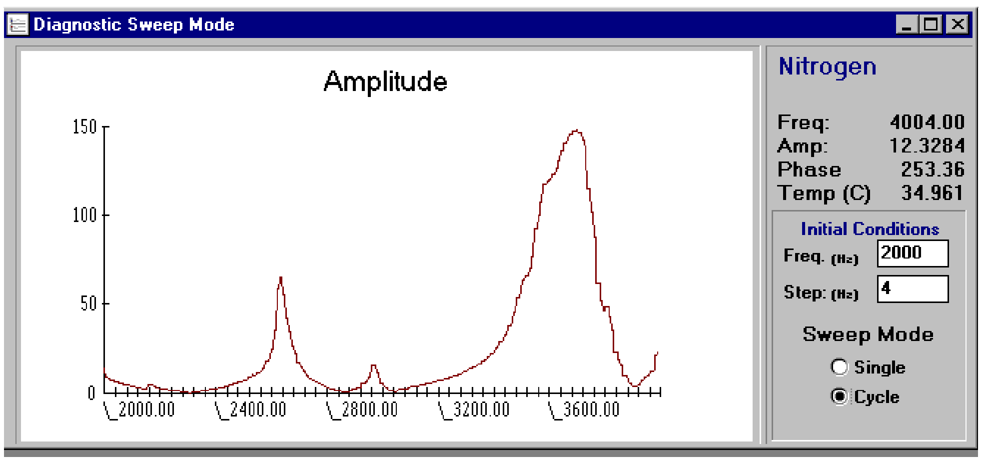
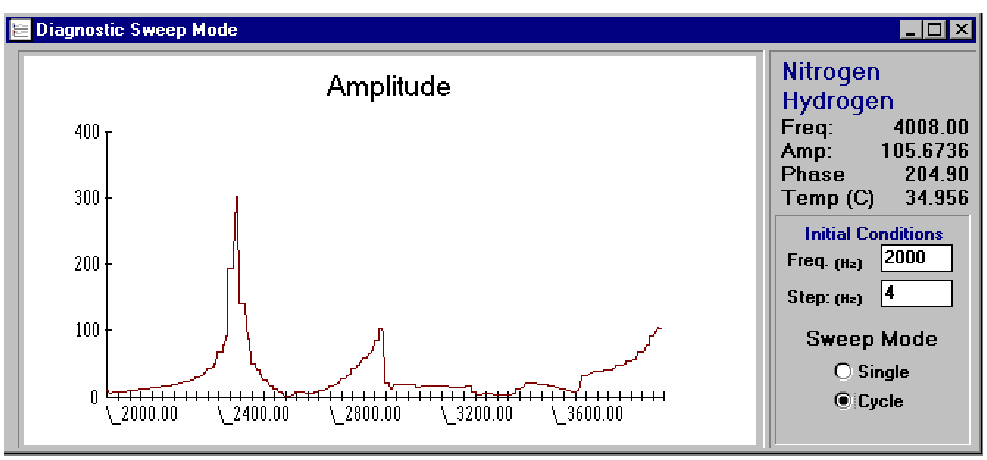


Figure 5-3 Possible diaphragm damage



5.8 LCD Contrast Adjustment — (LCD Display Option Only)

The LCD contrast is optimized for "above the display" viewing angles at the factory. It may be better optimized on site for use in positions that place the instrument in other viewing positions.

To adjust for best possible contrast in the installed position, use a potentiometer adjustment tool or a small common flat blade screwdriver carefully inserted through the front panel (refer to section Figure 4-4, Optional - LCD Front Panel, on page 4-18) and rotate the screw for an optimum setting.

NOTE: The potentiometer is a 10-turn type and is not harmed by rotating continuously in either direction.

Chapter 6
Diagnosing Problems

6.1 Introduction

There are many built in checks and diagnostics in the firmware. There are additional diagnostics available when using the optional Monitor software package. Many of the operational diagnostics are indicated on the controller's front panel (refer to section 4.3.5, Description and Purpose of Displays, on page 4-7 and also see section 6.5, User Diagnostics, on page 6-7). It is important to know that these LEDs are operative. This can be verified when the power switch is cycled from off to on. There is a short (approximately 2 seconds) period when all of the LEDs are illuminated.

Similar information is available with the optional LCD DIsplay. There is a several second period during the initial power-up period where all LCD segments are illuminated. Occasionally verify that all segments are on by referring to Figure 4-3 on page 4-9.

6.2 Failure Effects Mode Analysis (FEMA)

NOTE: In the following tables, PRT stands for Platinum Resistance Thermometer, μP stands for microphone, and C stands for concentration.

6.2.1 Category 1; Temperature Related

Table 6-1 Category 1; Temperature Related

Failure	Symptom Visibility	Effect on Accuracy
PRT ages	None	None, when recommended re-zero interval is followed
PRT opens	temperature LED extinguishes, temperature relay opens	N/A
Heater Power "Full on" failure	temperature LED extinguishes, temperature relay opens, transducers's over-temperature safety switch opens (not visible)	N/A
Temperature out of desired set-point control range	temperature LED extinguishes,* temperature relay opens	N/A
Transducer interconnect cable opens a) All wires b) PRT lead(s) c) Heater lead (s) d) Ground	a, b & c) Same as PRT open or temperature out of control range d) Noise on C signal	a, b & c) N/A d) Noise on C signal
Temperature measurement circuit a) fails, or b) gain drifts	a) temperature LED extinguishes, temperature relay opens b) None	a) N/A b) None, when recommended re-zero interval is followed
Transducer is located in a place that has a temperature higher than the set point.	a) Rapidly blinking temperature LED b) Temperature relay opens.	Proportional to temperature discrepancy.

*Temperature LED flashes rapidly when the cell’s temperature is more than 0.1 °C over the set point and slowly flashes when the cell’s temperature is more than 0.2 °C under the set point. Temperature may be read directly from the optional LCD instrument or with the optional Monitor Software.

6.2.2 Category 2; Acoustic Generator Related

Table 6-2 Category 2; Acoustic Generator Related

Failure	Symptom Visibility	Effect on Accuracy
Drive µP fails/not connected	Low amplitude, Noisy C signal	Noise on C signal
Both µPs fail/not connected	Control and Warning LEDs blink, HALT LED illuminated	N/A
Unbalanced µP assembly	Low amplitude or Noisy C signal	Noise on C signal

NOTE: PRT stand for Platinum Resistance Thermometer, C stands for concentration, µP stands for microphone.

6.2.3 Category 3; Acoustic Receiver Related

Table 6-3 Category 3; Acoustic Receiver Related

Failure	Symptom Visibility	Effect on Accuracy
Receiver µP fails/not connected	Control and Warning LEDs blink, Error relay opens	N/A
Receiver µP loses sensitivity	Noisy C signal at low P	Noise on C signal
Receiver µP loses bias	No signal, Error relay opens	N/A
Receiver µP has unstable bias	Noisy C signal	Noise on C signal

6.2.4 Category 4; Installation Related

Table 6-4 Category 4; Installation Related

Failure	Symptom Visibility	Effect on Accuracy
Acoustically noisy environment	Noisy C signal	Noise on C signal
Electrically noisy environment	Noisy C signal	Noise on C signal
Maximum flow rate exceeded	Noisy C signal	Noise on C signal
Inlet and outlet reversed	None	None
Ambient temperature exceeds setpoint	Temperature and Warning LEDs blink, Error relay opens	N/A
Low line voltage	HALT lamp illuminates	N/A
Analog output's load <2K ohm	None	Nonlinear response of control and C outputs
Noise on or variability of the analog input	None, (control hunting not visible without Monitor software for viewing)	Proportional to input variation

6.2.5 Category 5; User Related

Table 6-5 Category 5; User Related

Failure	Symptom Visibility	Effect On Accuracy
Wrong M and/or γ entered	None	Relative to error. Refer to section 3.1.4 on page 3-2.
M and γ are identical for carrier and precursor	Warning illuminates	No results given.
Reference Zero set at inappropriate time	None	Relative to delta F_2 from true zero. Maximum discrepancy restricted by limits associated with designated carrier gas.
Reference Zero left at factory default	Zero LED off	Minimal
Cell's end caps loosened	Facility toxic gas alarms	Various
Change of process pressure without re-zero	None	See dF/dP charts, refer to section 3.1.6 on page 3-5.
Large barometric pressure change without re-zero	None	Up to 0.5 Hz
Change of cell's temperature without re-zero	Zero LED off if T_0 is changed	Proportional to delta T

6.2.6 Category 6; Miscellaneous

Table 6-6 Category 6; Miscellaneous

Failure	Symptom Visibility	Effect on Accuracy
Small Diaphragm leak	Facility toxic gas alarms	Probably minor
System pressure out of specified range	a) Over-signal clipping and Error relay opens b) Under - Noisy C Signal c) >1 atmosphere gauge - subsequent Noisy C signal @ or near atmospheric pressures.	a) N/A b) Noise on C signal c) loss of exact zero reference
Loss of power (Controller only)	All relays open, C output = 0	N/A

6.3 How To Revert To Factory Default Values

Refer to section 4.2.4, How To Revert To Factory Default Settings, located on page see page 4-4.

6.4 If You Can Not Resolve Your Problem

Refer to section 1.4, How To Contact Customer Support, on page 1-4.

6.5 User Diagnostics

Various failure modes can be identified by (1) carefully watching the **WARNING** LED located on the front panel of LED display units, or (2) decoding the err value displayed on LCD units. Various failure modes can be identified. See Table 6-7. There are three types of failure modes:

fatal errors . . . . no instrument function takes place. Some communications are operative, except for remote commands. The Error relay is open.

errors . . . . the instrument continues to function and enters Stop or Bypass. Control cannot be entered until the error has been corrected. The Error relay is open.

warnings . . . . a temporary condition that causes one bad reading will either correct itself or result in an error being indicated, or certain gas parameter values may lead to ambiguous concentration calculations.

Table 6-7 User Diagnostics

Error Designation/ Type	Meaning	Warning LED Priority/ Pattern	Indication	Actions	Retry/Clear	Display and Communications Error Code (hex)
NOVRAM checksum failure/ Fatal	The battery backed RAM checksum test failed. The parameters stored in memory have been set to default values.	Double Medium Blink	Warning LED Error Relay opens	Set NOVRAM to defaults. Place into error/idle mode.*	Clear with Reset	0x8000
TI Init fail/ Fatal	The settings sent to the AtoD / DtoA chips that are connected to the driver and receiver did not match the settings query.	Full On	Warning LED Error Relay opens	Place into error/idle mode.	Clear with reset	0x4000
Temp. Init fail/ Fatal	The settings received from the temperature AtoD converter chip, do not match what was sent.	Full On	Warning LED Error Relay opens	Place into error/idle mode.*	Clear with Reset	0x2000
DSP Boot fail/ Fatal	The DSP checksum test failed. If DSP truly failed to boot the TI initialization will also fail.	Full On	Warning LED Error Relay opens	Place into error/idle mode.*	Clear with Reset	0x1000
Temp. Control failure/ Fatal	The heater is off and the temperature has been rising for 10 seconds.	Rapid Blink (~3.5 Hz, 50% duty)	Warning LED Error Relay opens	Place into error/idle mode.*	Clear with Reset	0x0800

* - error/idle mode - only limited communications operative. No measurement or control functions operative. Heater is off. Error relay opens, all other relays open.

Table 6-7 User Diagnostics (continued)

Error Designation/ Type	Meaning	Warning LED Priority/ Pattern	Indication	Actions	Retry/Clear	Display and Communications Error Code (hex)
Heater failure/ Fatal	The temperature has been dropping for 10 seconds but the heaters are on full.	Rapid Blink (~3.5 Hz, 50% duty)	Warning LED Error Relay opens	Place into error/idle mode.*	Clear with Reset	0x0400
Temperature range error/ Fatal	The temperature is below 10 or above 65 degrees (C)	Rapid Blink (~3.5 Hz, 50% duty)	Warning LED Error Relay opens	Place into error/idle mode.*	Clear with Reset	0x0200
Temperature AtoD failure/ Warning/Fatal	The temperature AtoD chip received an input that exceeded the allowable input range. Will indicate Warning unless repeated 10 times, then becomes Fatal error.	Rapid Blink (~3.5 Hz, 50% duty)	Warning LED Error Relay opens, if error	None if Warning. Error/idle if error.	Clear with Reset	0x0100
No signal/ Error	No measurable signal found.	Single Brief Blink	Warning LED Error Relay opens	Restart coarse sweep to find peak. If in Control, will go to Stop or Bypass	Clear when peak found	0x0080
Concentration Error/Warning	Invalid value returned from concentration calculation	Slow Blink	Warning LED. Turns off control. Error Relay opens, if error	Begins as Warning. Restarts coarse sweep to find peak. If still a problem, becomes an Error and will remove from control to stop or Bypass.	May be caused by wrong gas parameters. These should be checked. Clear when peak found.	0x0040
Peak not found/ Error	No peak above .002V was found over the target range.	Slow Blink	Warning LED Error Relay opens	If in dilution mode, put into BYPASS; if not, turn control off.	Clear when peak found	0x0020
Identical gases/ Error	Carrier and Precursor gas parameters indicate identical gases.	Slow Blink	Warning LED Error Relay opens	Will remove from Control to Stop or Bypass.	Cleared when valid gas parameters are entered,	0x0010
* - error/idle mode - only limited communications operative. No measurement or control functions operative. Heater is off. Error relay opens, all other relays open.						

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Table 6-7 User Diagnostics (continued)

Error Designation/ Type	Meaning	Warning LED Priority/ Pattern	Indication	Actions	Retry/Clear	Display and Communications Error Code (hex)
Bad peak shape/ Warning	The R2 of the Lorentzian fit was less than .8 or greater than 1 (while testing peak before tracking), or the Q was less than 2 (while tracking).	Slow Blink	Warning LED	Restart coarse sweep to find peak.	Clear when peak found.	0x0008
Ambiguous gases/ Warning	Parameters entered for gases could lead to ambiguous results, depending on concentration.	Slow Blink	Warning LED	No immediate action. If the system started running in ambiguous region, a concentration error would occur.	Cleared when non-ambiguous gas parameters are entered.	0x0004
DSP Timeout/ Error	Temporarily unable to speak to the DSP.	Slow Blink	Warning LED Error Relay opens	None. If problem persists, will show up as No Signal error or No Peak Found error.	On reset.	0x0002
* - error/idle mode - only limited communications operative. No measurement or control functions operative. Heater is off. Error relay opens, all other relays open.						

6.5.1 How To Start User Diagnostics

The User Diagnostics built into the controller operate automatically. The User Diagnostics associated with the software modules are covered in Chapter Chapter 8.

6.5.2 How To Exit User Diagnostics

Controller diagnostics are automatically exited.

Diagnostics invoked by the Monitor Software require that the **Stop** button on the **Sweep Mode** ribbon bar be pressed, pressing the **Amp Track** button on the **Main** tool bar, and finally pressing the **Start** button on the **Amplitude Track** ribbon bar.

6.6 Error Detection

Specific errors can be detected in one of the following ways:

1. Observing the blink pattern on the Warning LED, refer to Table 6-7 on page 6-7 for a complete list of error or warning indicated.
2. On the optional LCD Display. When an error occurs, an error code will replace the concentration output. If there is a warning (less serious problem) the "Warning" annunciator will be displayed; by pressing key 5 a warning code will be displayed. For example, if there is no gas in the transducer the display will show "ER 80", because no measurable signal was found. A complete listing of errors/warnings is given in Table 6-7 on page 6-7.
3. Via RS-232C; read the error log.
4. Via the Monitor Software pop up window.

6.6.1 LED Blink Patterns

Refer to Table 6-7 on page 6-7.

6.6.2 Error Codes

On the LCD and in the error log, errors are uniquely coded in hexadecimal with each bit representing a different error. This way, multiple errors can be recorded. Refer to Table 6-7 on page 6-7 for error codes. Multiple errors are decoded as follows:

Example 1:

There are two errors present.

The displayed error is 0x0084

It is caused by:

Ambiguous Gas Warning	0x0004
No Signal Error	0x0080
Error Code summed	0x0084

Example 2:

There are three errors present.

The displayed error is 0x001C

It is caused by:

Identical Gasses	0x0010
Bad Peak Shape	0x0008
Ambiguous Gasses	0x0004
Error code summed	0x001C

Chapter 7
External Communications

7.1 Introduction

The Composer supports RS-232C with Checksum.

7.2 Communications Connection

The Instrument System currently supports RS-232C communication only.

An industry standard 9-pin D-sub-miniature connector is required to connect to the Controller. The length of the cable is limited to fifty feet according to published standards. The communications interface operates using the DTE (Data Terminal Equipment) configuration. See Figure 7-1 and Table 7-1 for the RS-232C connector's pin assignments.

Figure 7-1 19-Pin Type "D" Female Connector

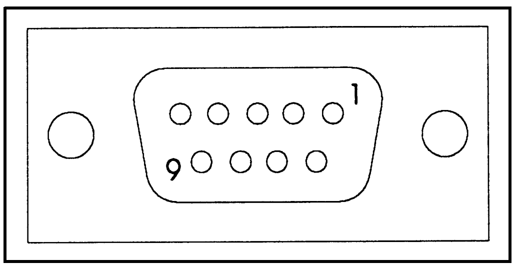

Table 7-1 RS-232C Connector's Pin Connections

Pin#	Description	DB9*	DB25**
1	Not Used.	1	-
2 TXD	Data transmitted from controller.	2	3
3 RXD	Data received by controller.	3	2
4 DSR	Not Used.	4	-
5 GND	Signal ground.	5	7
6 DTR	Output from controller indicating ready for transmit.	6	6
7 CTS	Input to controller indicating stop transmitting.	7	4
8 RTS	Not used.	8	-
9 GND	Shield Ground.	9	-

*Host **IBM compatible computer connector

7.3 Communication Settings

Serial communications baud rates between 4800 and 57600 are supported and selected on the CFGR2 switch block. Refer to section 4.3.6.6, CFGR2, on page 4-26<Default Paragraph Font> and to Table 4-4 on page 4-26. The communication initialization settings use baud rate,N,8,1 for the RS-232C port.

7.4 Basic Command Structure

Commands are always initiated from an external computer. The Composer will always send a response to commands sent, and will never initiate commands.

The following commands are available via the computer communications. Also see section 7.4.3, List of Commands with their Subcommands, Data, and Response Data., on page 7-5.

E . . . . Echo. Returns the sent message.

H . . . . Hello. Returns the model and software version number.

Q . . . . Query. Interrogates the programmable parameters and returns the value of parameter requested.

U . . . . Update. Replaces the particular parameter value with the value sent.

S . . . . Status. Sends back pertinent information based on the specific request made.

R . . . . Remote. Perform an action based on the specific command given. Many of these mimic front panel keystrokes.

7.4.1 Structure of a Command Sent to Composer

Length Command [Subcommand] [Program Number] [Data] Checksum

Length is one byte, and does not include the checksum, or the length itself.

Command is one character and represents the major categories of commands. Many commands are further delimited by sub-commands. See section 7.4.3 on page 7-5.

Subcommand is a further delimiter of some of the commands. Subcommands are one character. See section 7.4.3 on page 7-5.

Program Number is required for all Query and Update commands except Q 17 and U 17. This is a number between 1 and 9 that indicates which of the data sets is being referred to.

Data are required for some commands. The format of the data is determined by the specific command. See section 7.4.3 on page 7-5.

Checksum is a one byte sum of all the bytes in the command, not including the length or the checksum itself.

7.4.2 Structure of a Response Sent from Composer

Length Status Data Checksum

Length is one byte, and does not include the checksum or the length itself.

Status gives information about the command and the status of the instrument.

- **Bit 7** (MSB) is set if the command sent was successful. If it is clear, the command was not successful, and the data is the error code. See section 7.4.4 on page 7-10.
- **Bit 6** is set if there has been a power cycle since the last communication.
- **Bit 3** is set if there has been a change in the status of warnings in the instrument. The state of the warnings can be found (along with the errors) by doing an S 07 command. Bit 3 will remain set until an S 07 command has been done.
- **Bit 2** is set if the concentration is steady.
- **Bit 1** is set if there has been a change in the measurement mode (amp track, sweep, etc.) or a change in control state (control, stop, bypass, hold). These states can be determined by the S 10 command. Bit 1 will remain set until an S 10 command has read the current states.
- **Bit 0** is set if there has been a change in the status of errors in the instrument. The specific error can be found by doing an S 07 command. Bit 0 will remain set until an S 07 command has read the error status.

Data are returned for some commands. The format of the data is determined by the specific command. See section 7.4.3 on page 7-5.

Checksum is a one byte sum of all the bytes in the command, not including the length, the status byte or itself.

7.4.3 List of Commands with their Subcommands, Data, and Response Data.

Command Subcommand/Prog Num	Sent Data	Response Data
E(cho)	Any string	String that was sent
H(ello)		"Composer Ver x.xxx" (x.xxx = controller firmware version)
Q(uery)		
00 pp Temperature Setpoint		Float
01 pp Carrier Molecular Weight		Float
02 pp Carrier Gamma		Float
03 pp Precursor Molecular Weight		Float
04 pp Precursor Gamma		Float
05 pp Process Gain		Float
06 pp Process Time Constant		Float
07 pp Process Dead Time		Float
08 pp Bubbler Max Flow		short integer
09 pp Bubbler Full Scale		short integer
10 pp Dilution Max Flow		short integer
11 pp Dilution Full Scale		short integer
12 pp Total Channel Flow		short integer
13 pp Target Concentration		float
14 pp Concentration Tolerance window		float
15 pp Control loop type	0 = PID 1 = Fuzzy	byte
16 Program number		byte
17 Main Bubbler Flow		short integer
18 Max Input Concentration		float
19 Min Input Concentration		float
20 Weight Fraction Multiplier		float

NOTE: Note: pp = One byte program number - value between 1 and 9.

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U(pdate)

Data - value of the parameter specified by the subcommand.

No response data unless there is a communications error.

Subcommands: Same as for the Q command. The format of the data sent is the same as the format of the response data of the Q command. For example, the Q command for total channel flow for program number 1 would look like:

03510C015E

with response:

03823200C4

The Update total channel flow command would be:

05550C01320094

with response:

018282

S(tatus)

00 Current Data — float float float float byte byte

(frequency amplitude concentration/phase temperature sample-number undefined)

01 Current Temperature — float

03 Digital Inputs — byte

Input Response	Input #	1	2	3	4	5	6	7
	Bit #	6	5	4	3	2	1	0

04 Relay Values — byte

Relay Response	Relay #	5	4	3	2	1
	Bit #	4	3	2	1	0

05 Configuration Switches — short integer

06 Analog input (voltage) — float

07 Error Log — 8 bytes
See definition of error log below.

08 State of Keyboard lock — byte (0=unlocked,1=locked)

09 Current data plus flow — float float float float byte byte float float

(frequency amplitude concentration/phase temperature sample-number undefined bubbler flow dilution flow) Note: if dilution flow not in use its value will be 0.

10 State Status bit pattern as follows: — byte

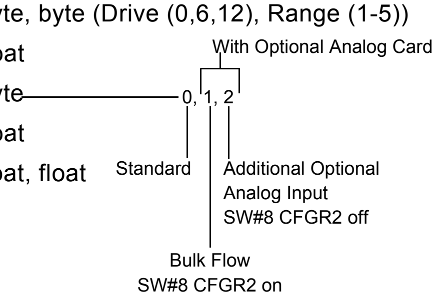
System Mode Bit:	3	2	1 Remote Stop Tracking Command issued
Idle	0	0	0
Amp Track	0	0	1
Sweep	0	1	1
Test	1	0	0
Error Idle	1	0	1 Fatal Error present

Control State Bit:	6	5	4
Manual	0	0	0
Bypass	0	0	1
Hold	0	1	0
Control	0	1	1
Stop	1	0	0

11 Drive Level and Amp Range — byte, byte (Drive (0,6,12), Range (1-5))

12 Control In — float

13 Composer Configuration — byte



14 Analog In Option — float

15 Bubbler Flow Dilution Flow — float, float

98 returns designer command measured values set up with R99.

99 Returns designer command codes set up with R99 (see see page 7-8)float

Codes for S and R 99

0	Frequency	Float	
1	Amplitude	Float	
2	Temperature	Float	
3	Concentration	Float	
4	BubblerFlow	Float	
5	DilutionFlow	Float	
6	R2	Float	
7	Q	Float	
8	Step	Float	
9	Error	Float	
10	TargetConcentration	Float	From input if configured that way, otherwise the parameter value
11	Analog Input	Float	Instantaneous reading at last measurement
12	Digital Input	1 Byte	bit pattern
13	Digital Output	1 Byte	bit pattern
14	Configuration Switches	2 Byte	bit pattern
15	Keyboard Lock	1 Byte	TRUE or FALSE
16	State Status	1 Byte	Same pattern as the current command
17	Drive Level	1 Byte	
18	Amp Range	1 Byte	
19	Configuration Option	1 Byte	No Option, Bulk Flow, extra output
20	Weight Fraction	Float	Only available if in Bulk Flow
21	MFC Readback	Float	Only available if in Bulk Flow
22	ActualBulkFlow	Float	Only available if in Bulk Flow
23	TargetBubblerFlow	Float	Only available if in Bulk Flow
24	TargetBulkFlow	Float	Only available if in Bulk Flow
25	OptionalAnalogInput	Float	Only available if in Bulk Flow
26	InAmpTrack	byte	1 = Amp Track mode 0 = not in AmpTrack mode
27	ControlLoopType	byte	0 = PID 1 = Fuzzy 2 = PI 3 = I 4 = Open Loop

NOTES:

S99 will not be updated when in sweep.

This has been tested for all codes except the ones that require the option board.

There is a maximum of 30 commands allowed in an R 99.

Formats of all values match the formats in the current "S" commands.

Addition codes can be added as needed.

R(emote)

No data sent

No Response data unless there is a communication error.

Performs an action depending on the subcommand.

Note: Remote commands will not be performed if there is a fatal system error. The communication error code 24 (can't complete command) will be returned.

00 Start Amp Tracking

02 Zero frequency

03 Start control loop

04 Hold control value (Must be in control for this command to be meaningful)

05 Stop control loop

06 Stop tracking

07 Put control loop in bypass mode i.e. bubbler = 0,dilution = total flow

08 Lock keyboard parameter/control entry

09 Unlock keyboard parameter/control entry

10 Enter manual control (requires Bubbler and Dilution Flow parameter values)

Syntax: 0A 52 10 float float chksum

Syntax Description: R10BubblerFlowDilutionFlow

11 Set zero frequency to factory default

12 Enter Manual Control using current Bubbler Flow and Dilution Flow vales.

99 Sets up the designer command. The codes (refer to see page 7-8) indicate which data will be returned and in the order requested.

7.4.4 Error Codes

7.4.4.1 Communication Errors

If there was an error with the command send to the Composer, the response message will have the MSB of the status byte cleared. There will be one byte of data with the following meaning:

03 . . . . Message length was zero.

17 . . . . Message length wrong for given command

18 . . . . Message checksum invalid

19 . . . . Sent Data value out of range

20 . . . . Unknown command

21 . . . . Data requested not currently available

22 . . . . 3 second time out. Entire message was not received in allotted time.

24 . . . . The action requested by a remote command could not be completed as requested. (E.g. A zero frequency command was sent when the Composer's frequency was not "STEADY")

7.4.4.2 Error Log

The error log (Status command S7) has the following structure:

2 byte system/hardware errors

2 byte system warnings

4 byte unused

In each of the error and warning data areas above, any errors or warnings that currently exist in the instrument are represented by one bit of the integer. The meanings of the bits for each word is listed below.

This list is represented in hexadecimal, so the bit patterns are easier to see.

For more information on the meaning, causes and correction of specific errors refer to Table 6-7 on page 6-7.

7.4.4.2.1 System and Hardware Errors

0x8000 . . . . Non Volatile Memory failed

0x4000 . . . . TI failed to initialize

0x2000 . . . . Temperature chip failed to initialize

0x1000 . . . . DSP Initialization failure

0x0800 . . . . Temperature chip lockup

0x0400 . . . . Heater failure/disconnect

0x0200 . . . . Temperature out of range

0x0100 . . . . Temperature A to D failure

0x0080 . . . . No signal

0x0040 . . . . Concentration result error

0x0020 . . . . A good fit could not be found

0x0010 . . . . Carrier and Precursor gases chosen are identical

7.4.4.2.2 System and Hardware Warnings

0x0100 . . . . Temperature A to D failure

0x0040 . . . . Concentration result error

0x0008 . . . . Bad peak shape - indicates possible problem with readings

0x0004 . . . . Gas combination could result in ambiguous results

0x0002 . . . . DSP took too long to respond

NOTE: Warnings 0x100 and 0x0040 are counterparts to the same numbered errors. These conditions are not serious unless the condition persists. If they persist, an error will be generated.
Likewise, with warnings 0x0008 and 0x0002, if the condition generating the condition is serious and persistent, other errors—most likely error 0x0080, 0x0040, or 0x0020—will be generated.
Warning 0x0004 will generate an Error 0x0040 if it enters a region of the curve when the combination is ambiguous.

7.4.5 Examples

NOTE: Commands and responses are all using hexadecimal representation.

Example 1

Send Hello command and receive the version number back

computer

014848(Hello command)

composer

1582434F4D504F534552205645522031 2E303030302056
(i.e. COMPOSER VER 1.0000)

Example 2

Send a command to set the total channel flow to 50 on parameter set 1, then verify it by doing a query.

computer

05550C01320094(Update Total Channel flow to 50)

composer

008282(Status byte only as a response)

computer

03510C015E(Query Total Channel Flow)

composer

03823200B4(Response = Status byte plus flow value of 50)

Example 3

Error condition. Send command to get current data, when there was no new data since the last request.

computer

02530053(Get current data)

composer

01021517(MSB of status byte clear indicates an error, “15” is the error code data not currently available.)

Chapter 8
Software Guide

8.1 Introduction

The two software applications available for interfacing the Composer with a computer are called the Composer Monitor software and the Setup Tool.

The Composer Monitor software provides an effective means of monitoring and storing data using a standard RS-232C COM port. There are two display modes: Amplitude Track, and Sweep. Amplitude Track is the default mode for the Composer. The Sweep mode is used to show the shape of the resonant peak and thereby derive diagnostic information about the sensor's performance. The Monitor software is compatible with Windows 95, Windows 98 and Windows NT operating systems.

A simple version of the Monitor software, called the Setup Tool, is shipped with every instrument with an LED display, free of charge. Its purpose is to customize instrument's parameter values for a specific application that will not be frequently changed.

When the instrument encounters difficulty due to a hardware failure, inadequate gas pressure in the cell or inappropriate parameter entry, the existence of the problem is reported on a pop up window. This is applicable for the Setup Tool as well as for the Monitor software. For information concerning details of errors and warnings reporting, see section 8.4 on page 8-29.

Provided that there is adequate hardware resources, up to twelve instances of the Monitor software/ Setup Tool can concurrently run on a single computer to track that many Composers. See section 8.5 on page 8-30 for a discussion on additional hardware requirements and tips on concurrent operations.

8.2 Getting Started

The Monitor software and Setup Tool provides an effective means of monitoring data using a standard RS-232C COM port. We recommend a good quality straight serial cable to be used with the Composer instrument. See section 7.2 on page 7-1 and Table 7-1 on page 7-1 for details. Both software are compatible with Windows 95, 98, 2000, and NT systems.

Before installing the software, ensure that your computer system meets the requirements as shown in section 8.2.1.

8.2.1 Computer System Requirements

Table 8-1 Computer System Requirements

	Minimum System	Recommended System
Processor	Pentium 166MHz	Pentium II 350MHz
RAM	32 Mb (Win95, Win98) 64 Mb (Win NT)	64 Mb
Hard Disk Space (Program)	4Mb	4Mb
Hard Disk Space Data (24 hours)	approx. 24 Mb	approx. 24 Mb per sensor
Monitor	14 inch, VGA	17 inch, SVGA
Resolution	800 x 600	800 x 600 or better

8.2.2 Software Installation

Either the Composer Monitor or the Setup Tool software can be installed in a computer with either Windows 95, Windows 98 or Windows NT operating system.

1. Insert the installation disk #1 into your floppy disk drive, typically "`a`".
2. In the **Start Menu**, select **Settings >> Control Panel**.
3. In the **Control Panel** double click on **Add/Remove Programs**.
4. Click on the **Install** button in the upper right of the dialog box.
5. Follow the directions to complete the installation.

NOTE: Depending upon your computer system, you may be prompted to reboot the system after it updates older system files in your computer. In this case, go back to step 1 after rebooting your computer.

6. It will prompt you for the final destination directory. The default destination is `c:\Program Files\Composer Monitor` or `c:\Program Files\Composer Setup Tool`, depending on the software being installed. If you select a directory other than the default, be sure to setup the log file before logging any data.
7. When the Installation is complete, put the original disks in a safe storage area.

8.2.3 First Time Use

After you have connected Composer to a free COM port on your computer and applied power to it, go to the **Composer Monitor** or **Setup Tool** entry in your start menu and run the application.

When the application starts, a dialog box will open up and ask for a .ini file name. It is advisable to choose a unique name for each Composer, because it stores all system parameters in that <Composer_ unique_name>.ini file. Similarly, when the application shuts down, another dialog box will open up for confirming the .ini file's name.

8.2.3.1 Set Up Communications

The application is initially configured to use COM 1 as the default serial communication port. If COM 1 is not available, you will get a warning message that COM 1 is in use. Proceed as follows to assign a new port to Composer.

1. Go to the **Setup** menu item.
2. Select **Communications**.
3. Select an appropriate baud rate and communications port and click OK.

NOTE: Insure the baud rate selected matches the DIP switch setting of the instrument. Refer to section 4.3.6.5, CFGR1, on page 4-25.

8.2.3.2 Verify Communications with Composer

Once you have appropriately set the communications parameters, verify its working in the following manner.

1. Click on **Help >> About** menu item.
2. If communications is working properly, Composer's Send and Receive lights will blink once. A pop up on the monitor screen will show Monitor software's version number and the Composer's firmware version number. If error is reported, check cable, DIP switch setting on Composer and make appropriate adjustments.

NOTE: When the Composer Monitor/ Setup Tool application is active, front panel programming is disabled in a Composer equipped with keypad and display.

8.2.3.3 Set Up Process Parameters

Once you have set up the communications parameters,

1. Go to the **Setup >> Process Parameters**.
2. Click on the **Get** button to read the parameters stored in the Composer.

NOTE: You may want to save these parameters as the factory defaults. This can be done through the **Settings-File >> Save As** menu item.

This dialog is structured to read a Composer's parameters by clicking on the **Get** button or to download the displayed set of parameters to the controller by clicking on the **Send** button. The parameters can be altered by placing the cursor within the appropriate parameter's data field and modifying them. If any particular field is not relevant, it is grayed out. When complete, click the **Send** button to download the parameters into the Composer.

Parameter sets may be saved and opened via the **Settings-File >>** menu item.

For a description of each parameter and its allowed range, see section 8.3.5 on page 8-14.

NOTE: This application cannot read or modify the switch setting of either CFGR1 or CFGR2. Particularly important is SW#7 on CFGR1. When it is ON, it locks the parameters and will not allow any of the downloaded parameters to be accepted. In addition, when SW#5 on CFGR2 is OFF, Composer will ignore the Dilution Flow parameters.

8.2.3.4 Using the Applications

Both applications are primarily used in the Amplitude Track mode for real time monitoring and control of precursor concentration. The Monitor software may also be used in Sweep mode as a diagnostic tool. These two principal functions will be briefly described.

8.2.3.4.1 Amplitude Track Mode

The Amplitude Track mode is the default operating mode of the instrument system. In this mode the resonance of the gas is tracked and converted into composition data. From the menu bar select **Actions >> Resume Collection** to begin monitoring process. See section 8.3.7 for details.

Before running your process, a baseline frequency must be established with pure carrier gas. If running in dilution control mode, select the **Actions >> Bypass** item from the menu bar. Once the sensor has been collecting data long enough to stabilize at the desired temperature, click the **Calibration >> Set User Zero** button**.** This frequency will be used in subsequent calculation of the precursor concentration. This button should not be pressed at any other time as it will cause offset errors in the composition calculation.

8.2.3.4.2 Sweep Mode

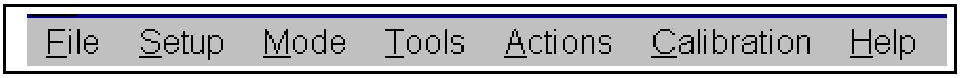
The Sweep mode is not available in Setup Tool. This mode is used to provide information about the shape and amplitude of the resonance peak. In this mode the sensor sweeps through a frequency range starting at the user provided initial frequency in steps defined by the step size. Selecting **Mode >> Sweep** will bring up the relevant window. For details, see section 8.3.6.

8.3 Software Reference

This section describes the function of every button in the Composer Monitor and Setup Tool graphical user interface and shows what the various dialog boxes and windows look like.

8.3.1 Menu Bar

Figure 8-1 Menu Bar



All essential functions of the software are accessible through the menu items as shown in Figure 8-1. In a specific situation, when a menu item is not relevant, it remains visible but not accessible. The following table summarizes the functions of each of the menu items. Some items are appropriately cross referenced and elaborated in later sections of this guide.

Table 8-2 Menu Bar Functions

Menu	Sub-menu	Function
File	Save Graph As	This feature is not available in Setup Tool. This function is equivalent to a screen capture. It creates a text file (default) or an image file containing all data points used in the currently displayed graph. User is prompted for a file name and destination path. The user may choose total number of data points from the menu item Setup >> Data Display. See section 8.3.10 on page 8-25.
	Print Graph	This feature is not available in Setup Tool. Sends the currently displayed graph to an attached printer.
	Exit	Terminates current session of the software.

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Table 8-2 Menu Bar Functions (continued)

Menu	Sub-menu	Function
Setup	Communications	Brings up a dialog box for setting up communications with Composer. See section 8.3.4 on page 8-13.
	Process Parameters	Brings up a dialog box for setting up MFCs, gas properties and control loop parameters. See section 8.3.5 on page 8-14.
	Data Display	Brings up the Data Display dialog box for setting up graph scaling and the number of data points to be displayed across a full screen. See section 8.3.10 on page 8-25.
	Warning Reporting	Enables or disables reporting of warnings. Default is Enabled. See section 8.4 on page 8-29.
Mode	Amplitude Track	Amplitude Track is the standard operating mode. In this mode the sensor will find and then lock on to the resonant frequency of the sample gas and track its movements. Refer to section 8.3.7 on page 8-21.
	Sweep	This feature is not available in Setup Tool. Sweep Mode is a diagnostic mode for the instrument. It is used to provide information about the shape and amplitude of the resonance peak. Refer to section 8.3.6 on page 8-20.
Tools	Tool Bar	Shows or hides Tool bar.
	Ribbon Bar	Shows or hides Ribbon bar.
	I/O Status	Shows the status of back panel I/O. See section 8.3.13 on page 8-28
	Gas Properties Database	This database conveniently holds the values for the physical parameters of commonly used gases. See section 8.3.11 on page 8-26.
	Gas Concentration Calculator	This feature is not available in Setup Tool. The gas concentration calculator is an off-line utility. It can calculate precursor concentration either from frequency input or from gas flow conditions. See section 8.3.12 on page 8-27.

Table 8-2 Menu Bar Functions (continued)

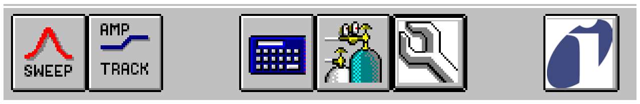
Menu	Sub-menu	Function
Actions	Resume Collection	Initiates or resumes data collection in current mode of operation.
	End Collection	Terminates data collection in current mode of operation.
	Log Data	This feature is not available in Setup Tool. Initiates data logging in current mode of operation. See section 8.3.9 on page 8-24.
	STOP	Stops all gas flows. For details, see section 8.3.8 on page 8-22
	CONTROL	Starts or resumes gas flow control. See section 8.3.8 on page 8-22
	HOLD	Maintains gas flow at the current level. See section 8.3.8 on page 8-22
	BYPASS	Maintains only dilution flow. See section 8.3.8 on page 8-22
	MANUAL	Brings up a pop up for manual gas control. See section 8.3.8 on page 8-22
	Alarm	Turns on and off the Alarm. When enabled and Alarm condition exists, an alarm icon is displayed in the graph area. It is not available in Sweep mode.
	Clear Graph	Clears currently displayed graph.

Table 8-2 Menu Bar Functions (continued)

Menu	Sub-menu	Function
Calibration	Set User Zero	Sets instrument zero. Should be done only when pure carrier gas is flowing at steady operating pressure. Available only in Amplitude Track Mode and only when the sensor temperature has reached set point, concentration readings are stable and bubbler MFC Min flow parameter is zero. section 8.3.8 on page 8-22. *Exercise extreme caution in using this feature*. **CAUTION** **Do not press Set User Zero during processing because the composition calculation will be offset by an amount equal to the measured composition at the time Set User Zero was pressed. The instrument sensitivity may also be affected.**
	Use Factory Zero	Sets instrument back to default factory zero. Available only in Amplitude Track Mode. *Exercise extreme caution in using this feature*.
Help	User's Guide	Opens hypertext enabled Users' Guide.
	About	Clicking this button shows the version number of software as well the version number of firmware in the Composer. See section 8.3.14 on page 8-28.

8.3.2 Toolbar

Figure 8-2 Toolbar



The Main Toolbar provides easy access to the two measurement modes and other utilities. If the Toolbar is not visible on the screen, it can be turned on by selecting **Tools >> Toolbar**. The function of each button on the Toolbar is explained below in Table 8-3.

Table 8-3 Toolbar buttons

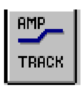
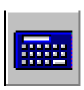
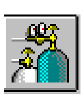
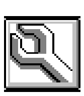
Menu Equivalent	Function
 Sweep	This feature is not available in Setup Tool. Sweep Mode is a diagnostic mode. It is used to provide information about the shape and amplitude of the resonance peak. See section 8.3.6 on page 8-20.
 Amplitude Track	Amplitude Track is the standard operating mode. In this mode the sensor will find and then lock on to the resonant frequency of the sample gas and track its movements. See section 8.3.7 on page 8-21.
 Gas Concentration Calculator	This feature is not available in Setup Tool. Gas concentration calculator is an off-line utility. It can calculate precursor concentration either from supplied frequency (speed of sound) information or from gas flow conditions and vapor pressure data. See section 8.3.12 on page 8-27.
 Gas Properties Database	This database conveniently holds physical parameters of commonly used gases. Allows user to add, remove or edit any gas entry. See section 8.3.11 on page 8-26.
 Setup Process Parameters	Brings up a dialog box for configuring MFC's range, gas properties and control loop parameters. See section 8.3.5 on page 8-14.

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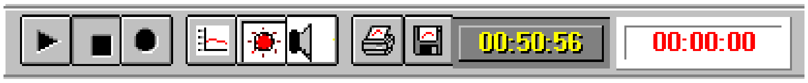
Table 8-3 Toolbar buttons (continued)

Menu Equivalent	Function
About	Clicking this button shows the version number of software as well the version of firmware in the Composer. See section 8.3.14 on page 8-28.

8.3.3 Ribbon Bar

Figure 8-3 Ribbon Bar



The Ribbon bar provides access to often used functions. If the Ribbon bar is not visible on the screen, it can be selected from menu item **Tools**. The function of each button on the Ribbon bar is explained below.

Table 8-4 Ribbon Bar Buttons

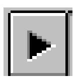
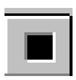
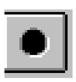
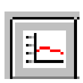
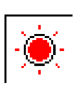
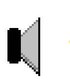
Button	Function
 Resume Collection	Initiates or resumes data collection in current mode of operation.
 End Collection	Terminates data collection in current mode of operation.
 Log Data	This feature is not available in Setup Tool. Initiates data logging in current mode of operation. Refer to section 8.3.9 on page 8-24.
 Data Display	Brings up the Data Display setup dialog box. Refer to section 8.3.10 on page 8-25.
 Clear Graph	Clears currently displayed graph screen.
 Alarm	Turns on and off the alarm. The alarm is set by the concentration set point and the concentration window. If the concentration drifts outside of this bandwidth, an alarm icon is displayed on the graph and alarm relay on the system I/O closes.
 Print Graph	This feature is not available in Setup Tool. Send the currently displayed graph to an attached printer.

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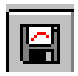
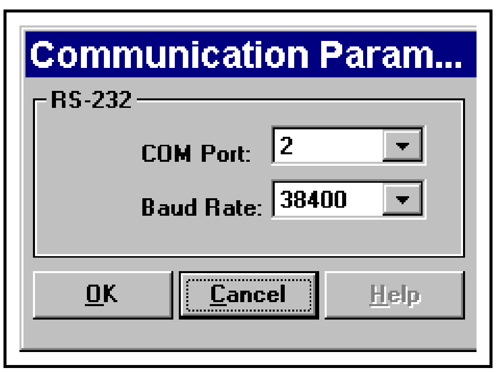
Table 8-4 Ribbon Bar Buttons

Button	Function
 Save Graph As	This feature is not available in Setup Tool. Creates a text file (default) or an image file containing all data points in the currently displayed graph. User is prompted for a file name and destination path. This function is equivalent to screen capture. The user may choose total number of data points from the menu item **Setup >> Data Display**. See section 8.3.10 on page 8-25.
 Monitor Timer	This timer shows the time elapsed since the monitor program was activated. Double clicking resets the timer. This feature cannot be accessed from Menu bar.
 Control Timer	This timer is visible when Composer is in active control. Double clicking resets the timer. It is not accessible from Menu bar.

8.3.4 Setup Communications Parameters

These parameters are necessary to set up communications between the computer and Composer. The **Setup >> Communications** menu choice brings up the dialog shown in Figure 8-4. Make sure that correct COM port is selected from the pull-down menu. The baud rate must conform to the DIP switch setting on Composer. Refer to section 4.3.6.5, CFGR1, on page 4-25. Supported baud rates are 4800, 9600, 19200, 38400 and 57600.

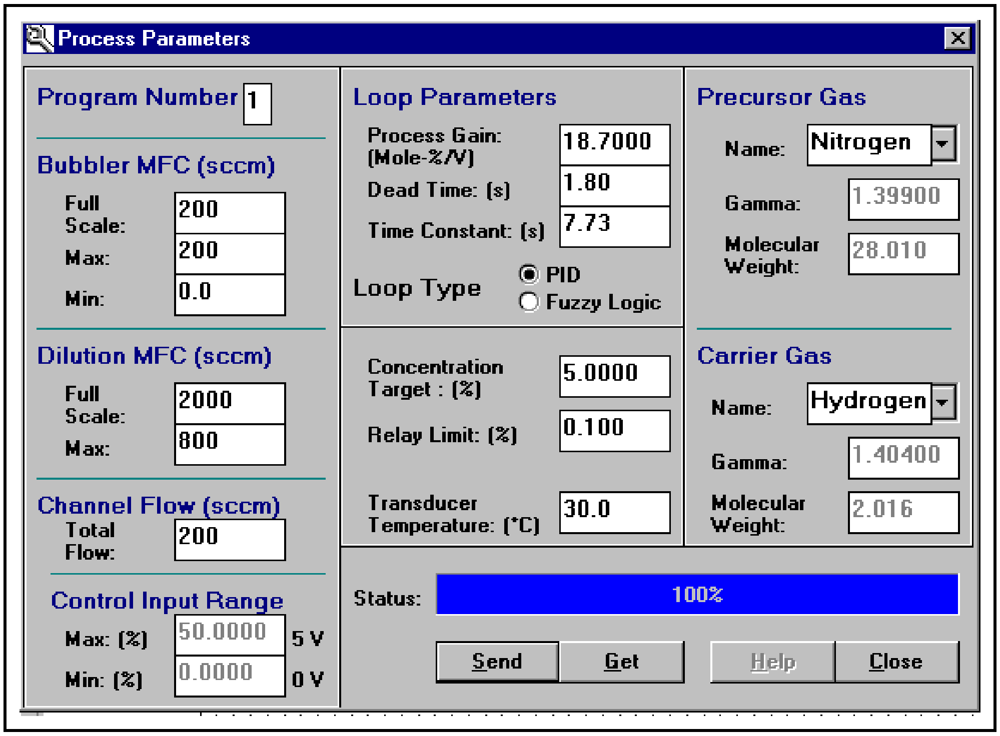
Figure 8-4 Communications setup dialog



8.3.5 Setup Process Parameters

These parameters are necessary to set the sensor's temperature, provide gas properties data, set up control loops and set the desired concentration. These are located in the **Setup >> Process Parameters** menu. The associated dialog shown in Figure 8-5. Any combination of parameters can be saved through **Settings-File >> Save As** menu in this dialog. Likewise, any previously saved setup file can be opened and downloaded.

Figure 8-5 Setup Process Parameters Dialog



NOTE: Before attempting to set loop parameter values review section 3.2.3, How to Determine Process Parameters, on page 3-28, and section 3.2.1, Control Loop Fundamentals — Concentration Control, on page 3-21.

The parameters are downloaded to composer by pressing the **Send** button on the dialog. Similarly, the **Get** button is used for recalling parameters from Composer. The **Close** button closes the Composer Setup window. The **Status** field shows progress of downloading or uploading of parameters when **Send** or **Get** button is pressed. Other data fields are elaborated as follows. During the time the instrument is in the state of control, only process gain, dead time, time constant, loop type, concentration target, and relay limit can be downloaded into Composer. See Table 4-1 on page 4-15 for a list of parameters, their format and allowed ranges.

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8.3.5.1 Index

Program Number. . . . . The Composer instrument can store up to nine sets of parameters under this index field. Thus, it is important that this field be appropriately selected before downloading any parameter. This field can be altered only when the control state is in **Stop** position. When this field is modified (1 through 9), the **Get** button is automatically pressed to retrieve the chosen parameter set, which becomes the current parameter set.

8.3.5.2 Bubbler MFC (sccm)

Full Scale: . . . . A numeric data field representing the maximum flow range (sccm) of the Mass Flow Controller used to control bubbler’s gas flow. This parameter accepts values from 0 to 5000.

Max: . . . . A numeric data field representing the maximum flow to be allowed. This parameter accepts numbers from 0 to 2000 (sccm) and must not exceed **Full Scale** value.

Min: . . . . A numeric data field representing the minimum flow to be maintained. This parameter accepts numbers from 0 to 2000.0 (sccm) and must not exceed **Max** value.

8.3.5.3 Dilution MFC (sccm)

Full Scale: . . . . A numeric data field representing the maximum flow range (sccm) of the Mass Flow Controller used to control dilution gas flow. This parameter accepts values from 0 to 5000.

Max: . . . . A numeric data field representing the maximum flow to be allowed. This parameter accepts numbers from 0 to 2000 (sccm) and must not exceed **Full Scale** value.

NOTE: The dilution flow parameters are only active if SW#5 on CFGR2 is set.

8.3.5.4 Channel Flow (sccm)

Total Flow: . . . . A numeric data field representing the targeted total flow from the controlled gas channels into the reactor. It is the sum of the manipulated bubbler Flow and the slaved dilution Flow. This parameter accepts numbers from 0 to 2000 (sccm). It must not exceed the sum of bubbler max flow and dilution max flow.

8.3.5.5 Control Input Range (%)

Max (%): . . . . A numeric data field representing the concentration target corresponding to maximum allowed analog input signal (Sw#7 of CFGR2). This parameter accepts numbers from 0 to 100 (%).

Min (%): . . . . A numeric data field representing the concentration target corresponding to 0.0 volt at the Control Input. This parameter accepts numbers from 0 to 100 (%) and must not exceed the value in the **Max** field.

8.3.5.6 Loop Parameters

Process Gain: (Mole-%/V) . . . . . . A numeric data field representing the Processes' gain (Δ concentration (%) / Δ output (volts)). This parameter accepts numbers from 0.0001 to 999.9999.

Dead Time: (s) . . . . A numeric data field representing the process dead time. This parameter accepts numbers from 0.01 to 1000.0 (seconds).

Time Constant: (s) . . . . A numeric data field representing the process time constant. This parameter accepts numbers from 0.01 to 1000.0 (seconds).

Loop Type . . . . Select a full function PID (Proportional Integral Differential) or Fuzzy logic control loop.

8.3.5.7 Miscellaneous

Concentration Target: . . . . A numeric data field representing the concentration of the gas flowing through the Transducer. This parameter is relevant when the instrument is in the Bulk Flow Control mode. It is used to multiply the flow read from the CONTROL IN connector to produce the Bulk Flow target. This parameter accepts numbers from 0.0000 to 100.0.

Relay Limit: (%) . . . . A numeric data field representing the range (single sided) of measured concentrations that will satisfy the lighting of the CONCENTRATION lamp on the Controller's front panel and closing the @ concentration relay on the SYSTEM I/O connector. This parameter accepts numbers from 0 to 100.0 (%).

Transducer Temperature: . . . . . . A numeric data field representing the desired operating temperature for the Transducer's resonant Chamber. The Transducer can be heated for use in systems with heated lines. The temperature of the cell is controlled to a maximum of 65 °C. Normal temperature excursions are ± 0.01 °C or less. This parameter accepts values from 0.1 to 65.0 (°C).

8.3.5.8 Precursor Gas

Name: . . . . This alphanumeric data field is only for the convenience of recalling gas parameters from the Gas Properties Library. It is not downloaded to Composer.

Gamma: . . . . A numeric data field representing the Precursor's specific heat ratio and accepting numbers from 1.0000 up to 2.0000.

Molecular Weight: . . . . A numeric Data field representing the molecular weight of the precursor and accepting numbers from 1.00000 to 1000.00.

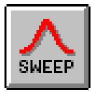
8.3.5.9 Carrier Gas

Name: . . . . An alphanumeric data field is only for the convenience of recalling gas parameters from the Gas Properties Library. It is not downloaded to Composer.

Gamma: . . . . A numeric data field representing the specific heat ratio of the Carrier Gas accepts numbers from 1.00000 up to 2.00000.

Molecular Weight: . . . . A numeric Data field representing the molecular weight of the Carrier Gas and accepting numbers from 1.00000 to 1000.00.

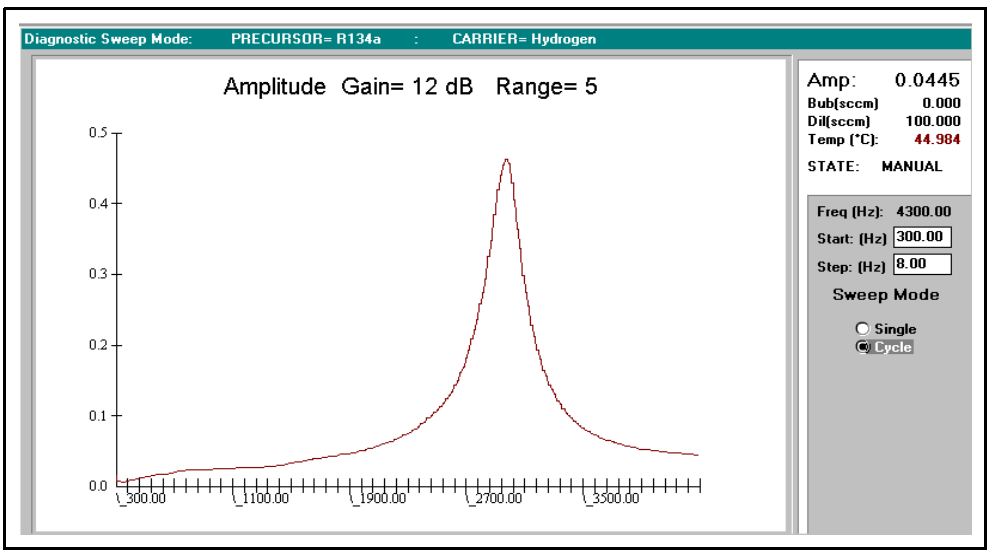
8.3.6 Sweep Mode



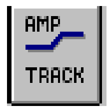
Sweep mode is not available in Setup Tool. This mode is used primarily as a setup and diagnostic aid. In this mode the instrument will sweep through a range starting at a user provided **Start** frequency and incrementing at desired **step** size. During the sweep the amplitude is plotted. The sensor's temperature, amplitude (arbitrary scale) and phase (degree) at the current excitation frequency is shown in the data window. The extent of the sweep depends on the **Start** frequency, **Step** size and data points to be plotted as chosen in section 8.3.10 on page 8-25.

Once the sweep begins, the **Start** and **Step** input fields cannot be modified until the sweep is completed normally or interrupted by the user. The user can choose a **single** sweep or **cycle** continuously. A normal sweep plot is shown in Figure 8-6.

Figure 8-6 Normal sweep plot



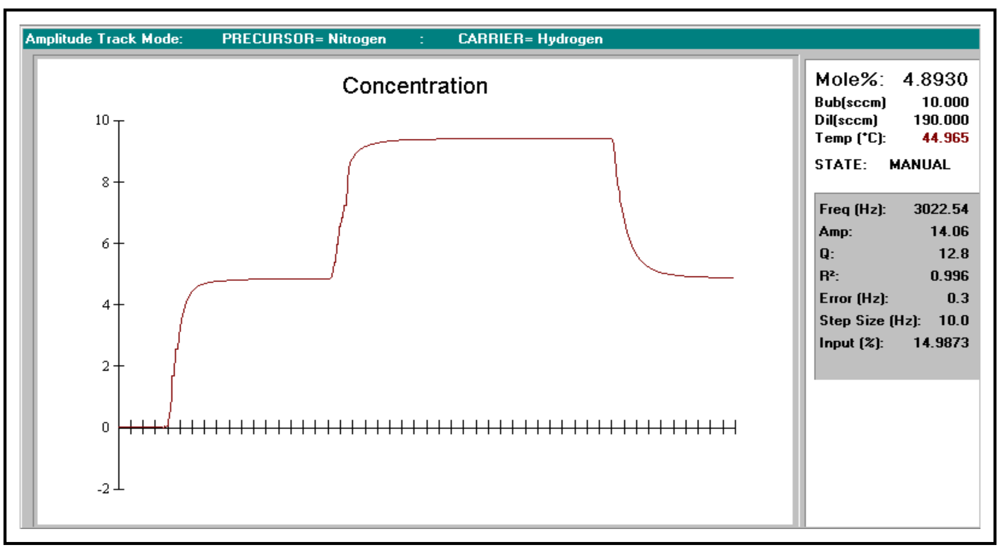
8.3.7 Amplitude Track Mode



Amplitude Track is the instrument's default operating mode, as shown in Figure 8-7. In this mode the instrument will find and then lock on to the resonant frequency of the sample gas and track its movements. While tracking, the concentration of the precursor gas is plotted as mole-percent. For the sake of absolute accuracy, it is recommended that the zero frequency be first established. When the sensor has attained stable operating temperature and the pure carrier gas flow and line pressure have stabilized (Steady LED on the instrument will be on), then the instrument is ready for setting zero frequency. It is to be found under menu item **Calibration >> Set User Zero**.

The user can set the number of data points to be displayed (section 8.3.10 on page 8-25). Optionally, data can be logged into a data file (section 8.3.9 on page 8-24). The user can choose to display/log only concentration data or a host of other ancillary data as well.

Figure 8-7 Amplitude Track Plot



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8.3.8 Control State

The **Control State** menu choices under Action item in the menu bar allow access to control state functions otherwise available through I/O connector at the rear of the instrument or through keyboard entry on units with display. The check mark next to the menu item displays the current Control state. The function of each selection is explained below.

Control . . . . It starts the control loop action. If data collection was not already in progress, it is initiated as well. Appropriate signals are sent to connected mass flow controllers to achieve and maintain desired concentration level.

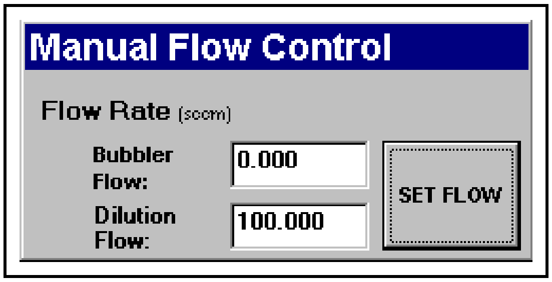
Stop . . . . It terminates control loop action and sets all control voltages to zero.

Hold . . . . It holds the control outputs at their current level. Thus, it is equivalent to open loop control. This option is unavailable from **Stop**, **Bypass** or **Manual** state.

Bypass . . . . It (in dilution flow mode) sets the bubbler control voltage to zero and sets the dilution flow equal to the total flow. Thus, it can be conveniently used to setup pure carrier gas flow for precisely establishing zero frequency.

Manual . . . . It brings up a Manual pop up box as shown in Figure 8-8. In this mode, the user can directly manipulate two mass flow controllers by appropriate entry in the input boxes and pressing the **Set Flow** button. This is a very convenient way to look at the system dynamics and to estimate process gain, as defined in section 8.3.5.6 on page 8-16. Clicking mouse button anywhere else on the screen removes this pop up, but maintains flow settings. Pressing **Stop**, **Control** or **Bypass** (**Hold** is unavailable) terminates **Manual** state.

Figure 8-8 Manual Flow Control Dialog



NOTE: **Control**, **Stop**, **Hold**, **Bypass** and **Manual** are mutually exclusive functions. The instrument will execute the last pressed function, as seen from the respective button status.

8.3.9 Setup Data Log File

This feature is not available in Setup Tool. In the Amplitude Track and the Sweep modes, the instrument can automatically log data while it is being displayed. When the **Log Data** icon is pressed in the Ribbon bar or Menu item **Actions >> Log Data** is selected, the Data Log File Setup dialog is opened as shown in Figure 8-9. User can select the drive and directory, and enter a file name. The complete path is displayed at the bottom of the dialog. The optional comment header containing information about the process, the date and the time is attached to the data file. When data logging is turned off, a line containing the time and a message indicating that logging was terminated is appended to the file.

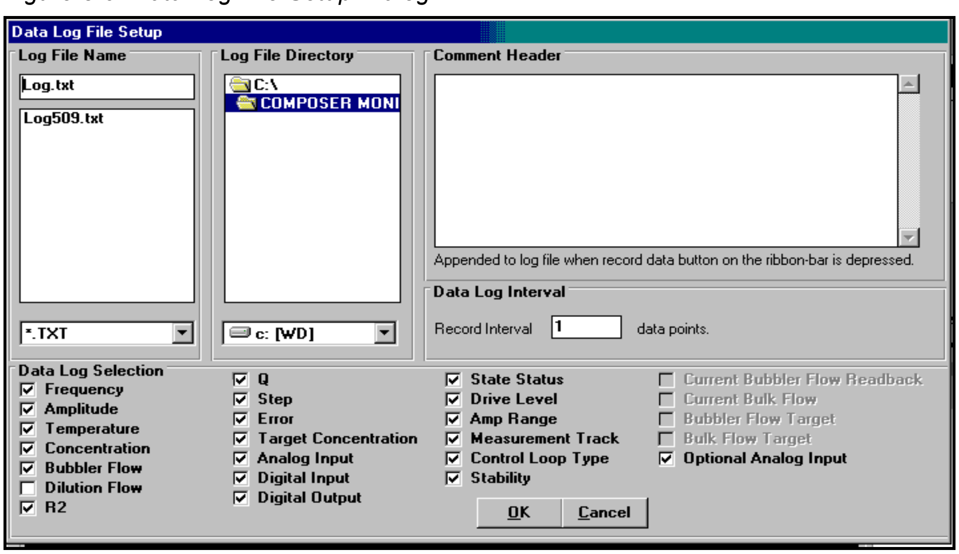
The interface provides complete flexibility for choosing which measurement variables are to be included in the data log. Every entry in the data log contains time stamp automatically.

The input field **Record Interval** will accept a value between 1 and 100. When it is 1 (default value), every measured data point will be recorded in the log file. For any other value, either data will be averaged over the **Record Interval** (if the appropriate field is checked) or those data points will be skipped. This is particularly useful when logging data over a long period of time. The maximum rate of logging is about once a second in **Amplitude Track** mode.

All data is appended to the file. Data is not overwritten if a single data file is used more than once.

NOTE: The sensors can produce a considerable amount of data (up to approximately one megabyte per hour per sensor). If the disk drive runs out of space, the log file will be closed and no more data will be stored. In order to reduce file size, the user should choose only those variables which are important at the moment.

Figure 8-9 Data Log File Setup Dialog



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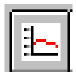
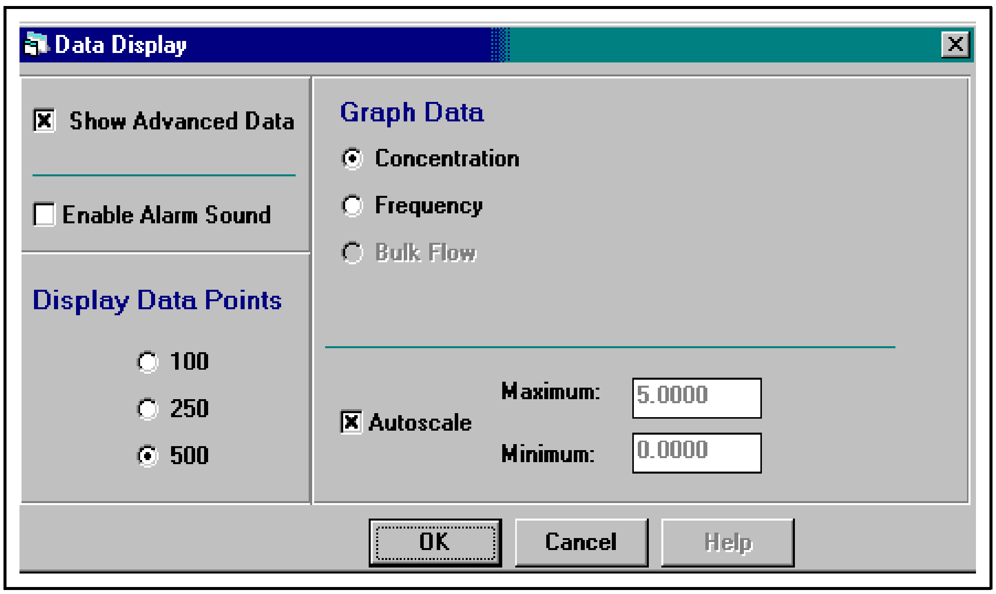
8.3.10 Setup Data Display

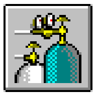


This option is located in the menu item **Setup >> Data Display** or can be accessed from the ribbon bar button. The dialog is shown in Figure 8-10. The user can select the number of data points to be plotted on the graph. The user can also keep auto-scaling on or off. When auto-scaling is turned off, the vertical axis is scaled in accordance with **Maximum** and **Minimum** values entered in the input fields. In **Amplitude Track** mode, user can choose to display **Advanced Data** pertaining to the resonance peak. When this option is turned off, only concentration or bulk flow data (depending on configuration), in addition to Control state, dilution flow, bubbler flow and temperature are displayed. User can select to graph either concentration or frequency in concentration configuration. Alternatively, in Bulk Flow configuration, either bulk flow or concentration may be graphed.

Figure 8-10 Data Display Setup Dialog



8.3.11 Gas Properties Database

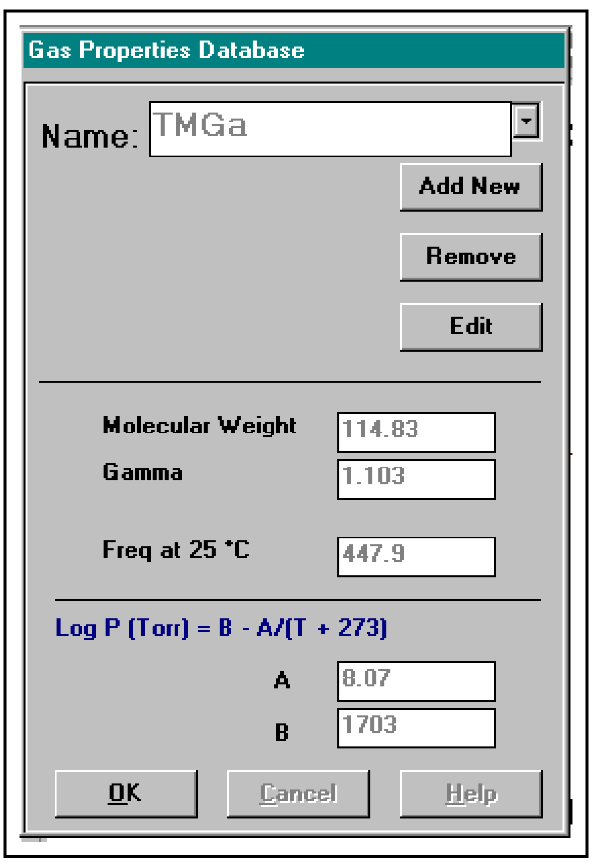


Pressing the button on the Toolbar or selecting from menu item **Tools >> Gas Properties Database** opens the **Database** dialog. (see Figure 8-11.) This is where the properties of all the commonly used gases are stored. To step through the gases, use the scroll bar at the bottom of the window. To add a material to the database, press the **Add New** button. Fill in the blanks for the material's name, molecular weight and gamma. Do not leave any required entries blank. Your entry will be saved to the database when you hit the **OK** button or if you move to another material. To remove a material, use the scroll bar to select it and then hit the **Remove** button. The entry will be deleted from the database. To edit a particular entry, press **Edit** button after selecting that entry.

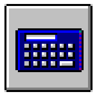
The **Freq at 25 °C** field cannot be edited and is for reference only. If the vapor pressure constants, **A** and **B** are not known, leave them as zero.

NOTE: The data base parameter, Gamma, is the specific heat ratio referred to as γ in Chapter 2; refer to equations [1] and [6] on page 2-2.

Figure 8-11 Gas Properties Database Dialog



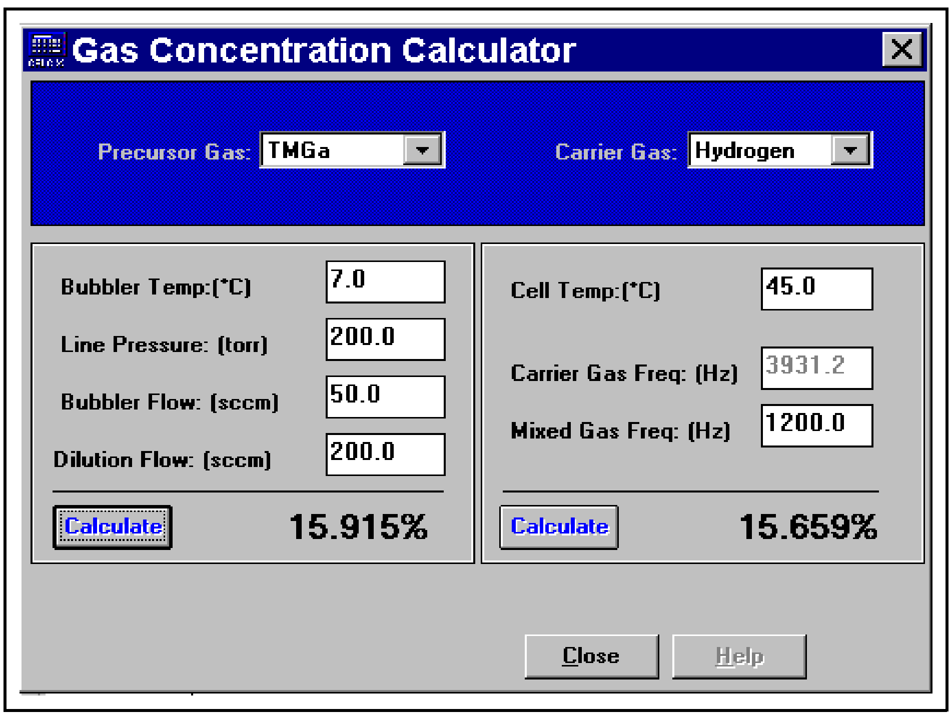
8.3.12 Gas Concentration Calculator



This feature is not available in Setup Tool. The **Gas Concentration Calculator** contains two separate utilities. One calculator allows off line calculations of concentration given two reference frequencies and the other calculator estimates concentration from vapor pressure and flow parameters. See Figure 8-12. Select the carrier and reactant gases from the drop down lists. Enter the resonant frequency of the pure carrier and the resonant frequency of the carrier (depends on cell temperature) and precursor mixed gas. Press the associated **Calculate** button and the concentration will be calculated and displayed.

On the other hand, enter the appropriate flow and pressure parameters. Press the associated **Calculate** button and the concentration will be calculated and displayed, assuming constant pickup efficiency of the carrier gas.

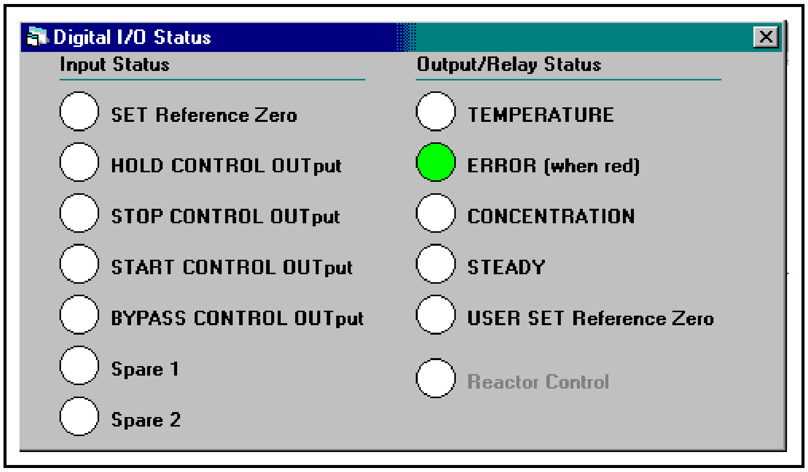
Figure 8-12 Gas Concentration Calculator Dialog



8.3.13 I/O Status

The I/O Status menu item allows easy readout of the status of back panel system I/O input ports and output relays as displayed in Figure 8-13. Refer to section 4.3.6.1 on page 4-22 for description of digital inputs and relay outputs.

Figure 8-13 Digital I/O status display



8.3.14 About

The **About** button or menu item **Help >> About** allows easy readout of the date and version number of the Monitor software and the Composer firmware, as seen in Figure 8-14. Thus, it confirms that communications between the computer and Composer is working properly.

Figure 8-14 About Message Window

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8.4 Errors and Warnings Reporting

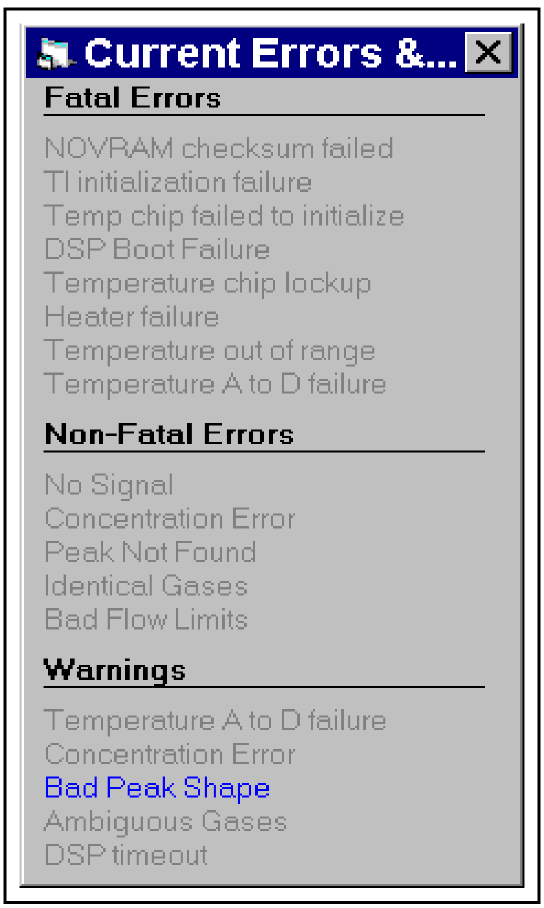
Errors and warnings reporting is identical in the Composer Setup Tool and the Monitor software. The errors and warnings log show up on a separate window, which gets focus when a fault occurs or the fault is removed. The fault can be related to hardware failure, broken cable, insufficient gas in the cell or simply erroneous parameter entry. Depending on the severity of the fault, the errors are organized in Fatal Errors and Non Fatal errors. Lesser faults are reported as warnings. The warnings reporting can be disabled through menu item **Setup >> Warning Reporting**. However, error reporting is always on.

In the case of Fatal Error, which indicates hardware problem, the instrument must be reset via the power switch.

Non Fatal errors are recoverable when the fault disappears and requires no user intervention.

Warnings are rather temporary conditions, which are expected to be self-correcting. See details in the Figure 8-15.

Figure 8-15 Current Errors And Warnings Window



8.5 Multiple Composers

Monitor software and Setup Tool both will support multiple Composers on one computer. With either application, up to twelve units can be simultaneously monitored provided that there is adequate number of communication ports available on the computer. When the application is started, it will ask for a unique .ini file name. It is advisable to make this name distinct and meaningful for quick identification during future use. When one instance of the software is running, another instance of it can be started with a new ini. file name.

Ordinarily, a PC has two serial communication ports. Add-on communication cards may provide another extra pair. The drawback of this method is that each communication port requires a unique IRQ. Finding more than four spare IRQs in a PC is rare. If an IRQ is assigned to more than one COM port, Monitor software or Setup Tool will not function properly. There are two distinct ways to solve this problem.

One of these solutions is to use a 7 port USB Hub with USB to Serial 9 pin converters. The USB to Serial 9 pin converters are connected to the RS-232C port for each Composer. These converters are then fed to the 7 port USB Hub which connects to the USB port on the PC. We have had success with this solution. We purchased components from Entrega Technologies Inc. (www.entrega.com). The USB to Serial 9 pin Converter is model number Con-USB-S9. The 7 Port USB Hub for PCs is Hub-7U. There are no problems with interrupt conflicts when using this solution. The Composer Monitor Software is designed to work with up to 12 Composers.

One drawback to this method is that Windows NT does not support a USB and therefore this solution is not viable if you are using Windows NT. Entrega states in their web site that this will work for Windows 98 and Windows 95b. Windows 2000 versions supported USB and worked flawlessly. Entrega provides the needed software with the components mentioned above.

The second solution we found is to use a multi-port serial card with Windows drivers that uses only one IRQ (interrupt) and multiplexes it among all its ports. We used an 8 port serial card from Circuit Specialists (www.web-tronics.com) Model C-588 (pci card + octopus cable). This solution was tested on Windows NT, Windows 98B, and Windows 95B systems and worked flawlessly. We also find the connectors to be more rugged than the USB connectors. We believe this is a very effective, inexpensive, and universal solution for connecting many Composers to a single computer.

Chapter 9
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Chapter 10
Glossary

Absolute (Pressure)
The pressure of a gas measured relative to a perfect vacuum.

Algorithm
A mathematical procedure.

Ambient
The conditions of the environment, such as temperature and pressure that surround a body or object, especially a condition that affects the body or object but is not affected by it.

Amplitude Track Mode
This instrument system's method of measurement that Curve Fits the resonance's shape to determine the exact frequency of the maximum amplitude.

AMU
Atomic Mass Unit

Back Pressure Controller
An apparatus used to maintain the pressure in the delivery lines to the reactor.

Bubbler
The common name for the bottle used to contain the source of solid or liquid precursor.

Bulk Flow
The product of the measured weight fraction and bubbler flow rate.

Bulk Flow Control
The mode of Composer operation that varies the flow through the bubbler to maintain the target bulk flow.

Concentration
A measure of the comparative population of components in a mixture, see Mole Fraction.

Concentration Control
The mode of Composer operation that varies bubbler and dilution flow to maintain the target concentration.

Controller
The electronic portion of the instrument system. Includes the transducer's conditioning and controlling circuits, microprocessors for determining the speed of sound (frequency), analog input and output signals and system status indicators.

Control Gain
The steady state process gain. This is normally quantified as the ratio of change of the controlled variable resulting from a small change of the manipulated variable.

Control Loop
The complete electromechanical system that is involved with the intelligent manipulation of a variable to maintain the controlled variable at the desired value, effectively minimizing process error. A brief description of control loop theory is given elsewhere in this manual. The control algorithm used in this instrument system is commonly known as a PID type.

Control Time Constant
The time required for a step change of the manipulated variable to produce a change in the control variable equal to 63.2% of the final change in the control variable.

Control Dead Time
The period of time between a change in the manipulated variable and a noticeable response in the controlled variable.

Control Variable
The variable that is to be controlled, i.e., held constant. In a typical CVD reactor this would be the concentration of precursor entering the reactor as measured by the instrument system.

Curve Fit
A mathematical procedure (algorithm) for finding the best match between a set of data and a curve of a particular shape.

CVD
Chemical Vapor Deposition

Delivery Line
The reactor's tubing that extends from the source of gas or precursor to the reactor.

Delivery System
The reactor's complete apparatus for delivering a precise quantity of precursor to the chamber.

Diaphragm
The tensioned membrane that separates the resonant chamber from the drive and receive microphones.

Dilution Flow
The additional carrier gas added to the flow from the bubbler prior to entry into the reactor's chamber.

Diluent

The gas used for dilution of the bubbler flow to produce the desired concentration and flow.

DVM

Digital Volt Meter; an instrument for precision measurement of voltage.

Drive Microphone

The electroacoustic element that is used to amplitude modulate the diaphragm and indirectly the gas in the resonant chamber

EDMIn

ethyldimethylindium

Enunciator

A basic display device providing a message or warning to the user.

External Control (state)

The machine state that exists when the reactor is directly generating the voltage to be applied to the bubbler's MFC in Bulk Flow Control mode.

Fluence

The number of particles (or molecules) passing across a unit area. Commonly expressed as the number per second.

Fundamental Mode

The lowest frequency standing wave possible in a resonant structure.

Gauge (pressure)

The pressure of a gas measured relative to standard atmospheric pressure.

Head Space

The empty space above the solid or liquid precursor in a bubbler.

Helmholtz Resonator

A type of acoustic resonator structure that has two chambers connected by a restricted neck. It is analogous in shape to a dumbbell.

Instrument System

The complete measurement system consisting of the Controller, the Transducer, Interconnection Cable and Power Supply

Interconnection Cable

That portion of this measurement system that electrically connects the Controller and the Transducer.

Internal Control (state)

The machine state that exists when the Composer is actively manipulating the bubbler's MFC in the Bulk Flow Control mode.

Lorentzian

A term that mathematically describes the shape of a resonance peak. This instrument uses a Lorentzian curve fit to very accurately determine the precise frequency of the resonance's amplitude peak when operating in the Amplitude Track Mode.

LSB

Least Significant Bit, a term associated with the precision of analog to digital and digital to analog converters.

Manipulated Variable

The variable that is used to induce changes in the controlled variable. For typical CVD reactors the control variable normally would be the carrier gas flow rate through the precursor's source (bubbler).

MOCVD

Metal-Organic Chemical Vapor Deposition. Frequently used synonymously with OMVPE.

Molecular Weight

The mass in grams of a mole of a given substance. It is also the weight in AMU of a single molecule of gas. This is used in the determination of binary gas concentration by measuring the speed of sound.

Mole Fraction

A way of expressing the Concentration of a mixture that expresses the relative abundance of each species to the total abundance of all of the mixture's constituents as a fraction (usually the decimal equivalent).

Monitor Software

The optional Windows software package providing a common graphical interface for up to nine instrument systems.

Multiplexer

A hardware interface that allows one of a computer's RS-232 ports to be switched among many RS-232 communication links. This allows many instrument systems to be connected to only one RS-232 port

NO

Normally Open, referring to relay contacts that stay open until the relay's coil is energized

OMVPE

Organometallic Vapor Phase Epitaxy. Frequently used synonymously with MOCVD

Permeability

The rate at which a gas flows through a material, usually an elastomer.

PID

Proportional
Integral
Differential; A type of control loop algorithm.

Power Supply Module

The portion of the instrument system that converts local line power to the 24 volt DC required to operate the controller.

PPM

Parts Per Million, a way of expressing Concentration.

Precursor

A complex chemical molecule used to carry a metal (or other) atom in the vapor state that is easily broken apart to leave the desired atom on the substrate to be coated.

PRT

Platinum Resistance Thermometer, the sensing element used to determine temperature of the Resonant Chamber.

RAV

See Root Allan Variance.

RAM

Random Access Memory; An electronic component used for computer data storage. When used in conjunction with a battery it provides nonvolatile storage of data, sometimes called NOVRAM for nonvolatile RAM.

Reactor

Usually refers to the growth chamber, but some times to the complete apparatus used to deposit materials in CVD, MOCVD and MOVPE processes.

Receiver Microphone

The acoustic energy measuring element of the transducer used for measuring the amplitude of the resonating gas.

Reference Zero

The instrument’s reference frequency that is used as the basis for concentration calculations. All calculations are based on this stored value of the speed of sound through the pure reference gas. A user may utilize the default value for the reference zero or carefully reset the zero to obtain better results for the immediate operating conditions.

Resonant Chamber

The portion of the transducer that contains the gas for measurement and is used indirectly for determining the length of the Standing Acoustic Wave.

Resonant Mode

A standing acoustic wave. The lowest frequency mode is called the fundamental.

Root Allan Variance

A measure of short term stability that is the square root of the sum of the difference between successive measurements squared.

sccm

Standard Cubic Centimeters per Minute, a measure of gas flow rate.

Self Resonance

A term that refers to the possible vibration modes of the individual components in an acoustical system. It is desirable that the Self Resonance of all of the individual components in the transducer be at a higher frequency than the normal operating frequency range of the instrument.

Specific Heat Ratio

The ratio of the specific heats of a gas, namely the ratio of the specific heat at constant pressure to the specific heat at constant volume, C_p / C_v (noted as γ on the LCD Display). This is used as a physical parameter for the calculation of binary gas concentration by the measurement of the speed of sound through the binary gas.

SPST

Single Pole Single Throw - A description of a relay's contact configuration.

Standing Acoustic Wave

A stationary acoustic wave that exists in the resonant chamber when the exciting frequency develops a wavelength exactly twice as long as the chamber. When this wave is at the fundamental frequency it will have the maximum amplitude possible for the existing conditions of gas, composition temperature and pressure.

TOF

Time of Flight, a method of determining the speed of sound by measuring the time interval for an acoustic pulse to travel a known distance.

TMGa

trimethylgallium

TMIn

trimethylindium

Transducer

That portion of the instrument system containing the physical measuring apparatus; including; the resonant chamber, gas line connectors, heaters, PRT, sending microphones, receiving microphone, and mounting enclosure.

Weight Fraction

A term used in the Bulk Flow Control mode that is used to describe the portion of the total weight of gas flowing that belongs to a specific component, usually the precursor. The range is 0 to 1.00.

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Chapter 11
Recommended Parts List

11.1 Replacement Parts

Table 11-1 provides details about the recommended spare parts.

Table 11-1 Inventory of Supplied Items

Part Number	Description
062-077	Fuse, 3.15 Amp Type T
059-196	Gasket (Ni-4-VCR-2)

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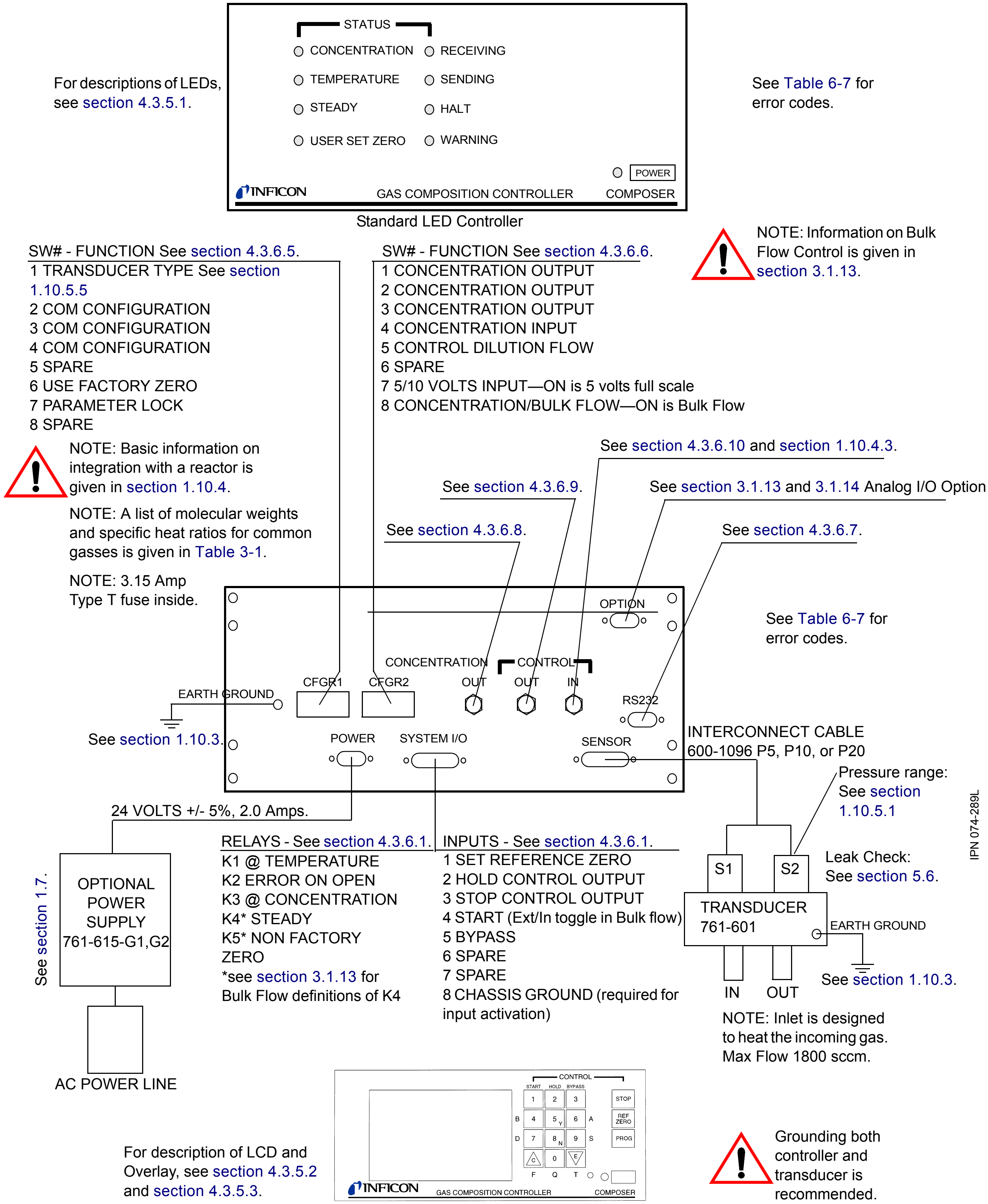
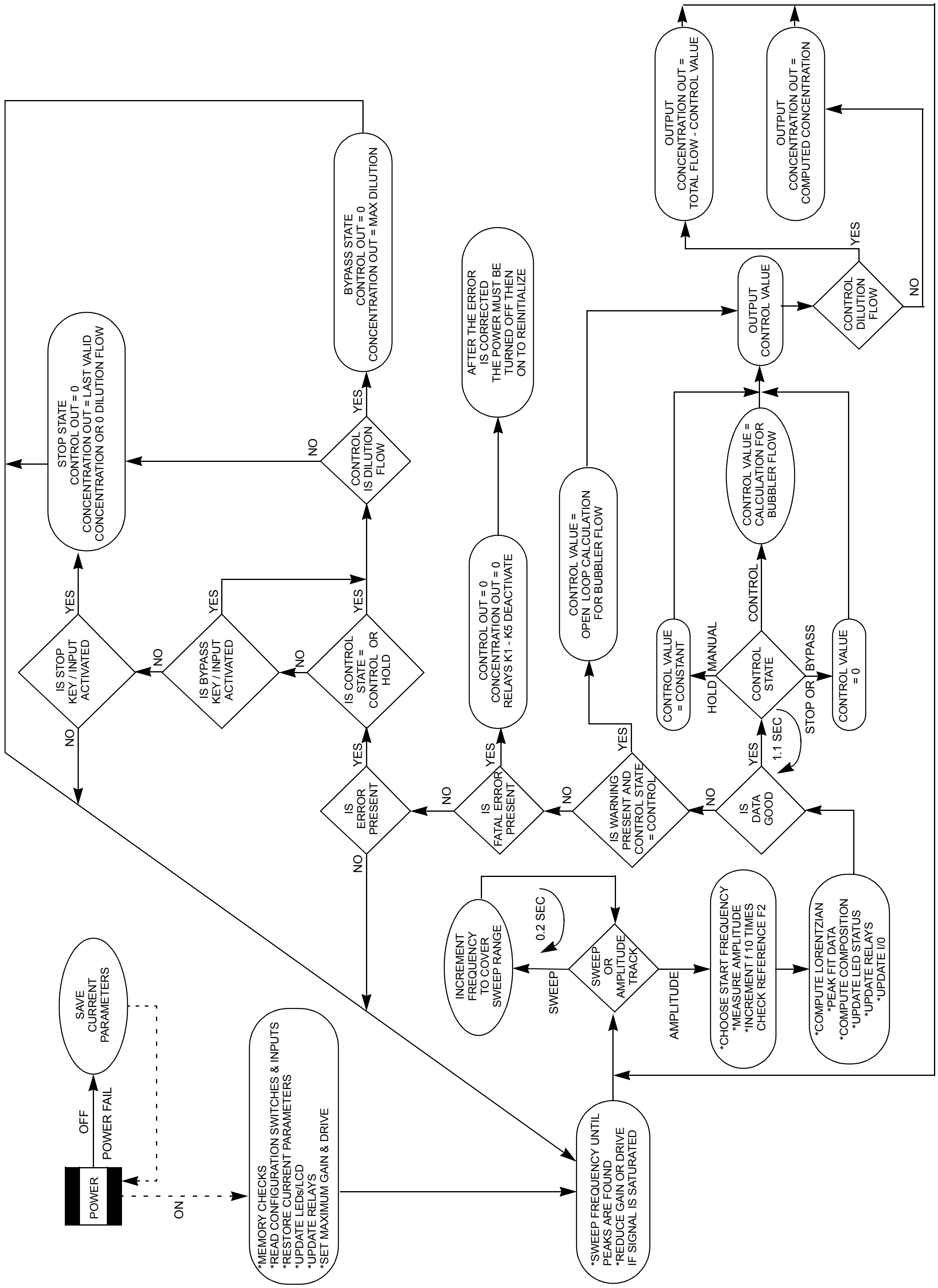
Chapter 12
Quick Use Guide

12.1 Introduction

The Quick Use Guide provides a reference for data concerning configuration, interfacing, and logic flow. You will also find convenient references to sections of the manual that provide more detailed explanations.



Optional LCD Controller



Concentration Control Configuration

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