OPERATING INSTRUCTIONS FOR

Model 3500 Series

Laser Gas Analysis System

P/N MXXXX

ECO:

DANGER

Toxic gases and or flammable liquids may be present in this monitoring system.

Personal protective equipment may be required when servicing this instrument.

Hazardous voltages exist on certain components internally which may persist for a time even after the power is turned off and disconnected.

Only authorized personnel should conduct maintenance and/or servicing. Before conducting any maintenance or servicing, consult with authorized supervisor/manager.

Warranty

This equipment is sold subject to the mutual agreement that it is warranted by us free from defects of material and of construction, and that our liability shall be limited to replacing or repairing at our factory (without charge, except for transportation), or at customer plant at our option, any material or construction in which defects become apparent within one year from the date of shipment, except in cases where quotations or acknowledgements provide for a shorter period. Components manufactured by others bear the warranty of their manufacturer. This warranty does not cover defects caused by wear, accident, misuse, neglect or repairs other than those performed by Teledyne or an authorized service center. We assume no liability for direct or indirect damages of any kind and the purchaser by the acceptance of the equipment will assume all liability for any damage which may result from its use or misuse.

We reserve the right to employ any suitable material in the manufacture of our apparatus, and to make any alterations in the dimensions, shape or weight of any parts, in so far as such alterations do not adversely affect our warranty.

Important Notice

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

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

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

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

Specific Model Information

Instrument Serial Number: ________________________

Instrument Range: ________________

Calibrated for: ________________

Background Gas: ________________

Zero Gas: ________________

Span Gas: ________________

Safety Messages

Your safety and the safety of others is very important. We have provided many important safety messages in this manual. Please read these messages carefully.

A safety message alerts you to potential hazards that could hurt you or others. Each safety message is associated with a safety alert symbol. These symbols are found in the manual and inside the instrument. The definition of these symbols is described below:

GENERAL WARNING/CAUTION: Refer to the instructions for details on the specific danger. These cautions warn of specific procedures which if not followed could cause bodily Injury and/or damage the instrument.

CAUTION: HOT SURFACE WARNING: This warning is specific to heated components within the instrument. Failure to heed the warning could result in serious burns to skin and underlying tissue.

WARNING: ELECTRICAL SHOCK HAZARD: Dangerous voltages appear within this instrument. This warning is specific to an electrical hazard existing at or nearby the component or procedure under discussion. Failure to heed this warning could result in injury and/or death from electrocution.

Technician Symbol: All operations marked with this symbol are to be performed by qualified maintenance personnel only.

No Symbol

NOTE: Additional information and comments regarding a specific component or procedure are highlighted in the form of a note.

CAUTION: THE ANALYZER SHOULD ONLY BE USED FOR THE PURPOSE AND IN THE MANNER DESCRIBED IN THIS MANUAL.

IF YOU USE THE ANALYZER IN A MANNER OTHER THAN THAT FOR WHICH IT WAS INTENDED, UNPREDICTABLE BEHAVIOR COULD RESULT POSSIBLY ACCOMPANIED WITH HAZARDOUS CONSEQUENCES.

This manual provides information designed to guide you through the installation, calibration operation and maintenance of your new analyzer. Please read this manual and keep it available.

Occasionally, some instruments are customized for a particular application or features and/or options added per customer requests. Please check the front of this manual for any additional information in the form of an Addendum which discusses specific information, procedures, cautions and warnings that may be peculiar to your instrument.

Manuals do get lost. Additional manuals can be obtained from Teledyne at the address given in the Appendix. Some of our manuals are available in electronic form via the internet. Please visit our website at: www.teledyne-ai.com.

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DANGER
COMBUSTIBLE GAS USAGE WARNING

Depending on the selected options, some instruments may be used in hazardous environments. This may involve the measurement or monitoring of flammable or explosive gases. It is the end user's responsibility to ensure that all safety related features of this instrument are properly functioning and that the operator is fully trained in the operation of the system as well as procedures for handling the gases employed.

Some instruments are approved as an intrinsically safe gas analyzers for usage in a category (ia) Group IIC hazardous area. This approval only to the equipment specified installed in accordance with the information contained within this manual. It is the customer's responsibility to ensure safety especially when combustible gases are being analyzed since the potential of gas leaks always exist.

The customer should ensure that the principles of operating of this equipment is well understood by the user and that the instrument as well as any approved support equipment is properly installed. Misuse of this product in any manner, tampering with its components, or unauthorized substitution of any component may adversely affect the certification and the safety of this instrument.

Since the use of this instrument is beyond the control of Teledyne, no responsibility by Teledyne, its affiliates, and agents for damage or injury from misuse or neglect of this equipment is implied or assumed.

DANGER

LASER RADIATION HAZARD

This instrument produces laser radiation which can cause damage to human tissue especially the eyes. Do not look at the laser beam nor open any chamber or device without first powering off the instrument.

WARNING: **THE WAVELENGTH OF THE LASER BEAM INSIDE THE MODEL 3500 SERIES OF ANALYZERS IS IN THE RANGE OF 0.7 ~ 2μM. IT IS INFRARED AND INVISIBLE. DO NOT LOOK DIRECTLY OR WITH OPTICAL INSTRUMENT AT THE DIRECTION OF THE LASER RADIATION**

Introduction

1.1 Overview

The Model 3500 series Laser Gas Analysis System comprises a range of instruments based on the features and configuration chosen at the time of purchase. The system uses laser spectroscopy to accurately measure and monitor the composition of a single or multiple gas species in a gas mixture. It is especially useful for in-situ measurements and is designed for online processes analysis. Options are available for applications involving hazardous environments.

This manual describes the installation, calibration, operation, and maintenance of the LGA system. The principles of instrument operation are detailed in Section 2.

1.2 Models Available in the 3500 Series

The Model 3500 series of instruments are classified depending on the options specified at the time of purchase. The specific model number assigned is described below following a brief description of the available options to choose from.

1.2.1 Available Options

The standard Model 3500 LGA System is configured for single gas species detection in a gas mixture using a flange mounted laser transmitter and receiver for online in-situ measurements in non-hazardous environments.

The following list indicates available options for the Model 3500 series of analyzers (see also Table 1-1):

- Two gas detection in a gas mixture
- Fiber optic connection to remove sensitive laser and electronics from monitoring environment
- Explosion-proof housing
- Intrinsically safe instrumentation

Table 1-1 Instrument Designation for Selected Options

Model	Number of Gas Species		Detection		Optical Signal Transmission		Analysis Environment		
	One	Two	*In Situ*	By-Pass	Optical Fiber	Non-optical Fiber	General Purpose	Explosion-proof Positive Pressure	Intrinsically Safe
3500C	√		√			√	√		
3500P	√		√			√		√	
3500CS	√			√		√	√		
3500PS	√			√		√		√	
3500-2C		√	√			√	√		
3500-2P		√	√			√		√	
3500-2CS		√		√		√	√		
3500-2PS		√		√		√		√	
3500F	√		√		√		√		
3500I	√		√		√				√
3500FS	√			√	√		√		
3500IS	√			√	√				√
3500-2F		√	√		√		√		
3500-2I		√	√		√				√
3500-2FS		√		√	√		√		
3500-2IS		√		√	√				√

1.2 Classification of LGA-2000 Laser Gas Analysis Systems

The instruments in the Model 3500 range are named according to the following rule:

Model 3500: Single gas analyzer

Model 3500-2: Two gas analyzer

Suffix C: Standard configuration without optical fiber

Suffix F Standard configuration with optical fiber

Suffix I: Intrinsically safe

Suffix P: Explosion-proof

Suffix S: Bypass sampling mode

For example, the Model 3500C would indicate a standard (non-explosion proof) single gas analyzer without an optical fiber capable of in-situ analysis in non-hazardous environments. Similarly, the Model 3500F would indicate the same instrument but with an optical fiber connection with the laser source located remotely from the monitoring site.

1.2 Typical Applications

The Model 3500 Laser Gas Analysis System is a versatile tool for online analysis and monitoring of a gas flow process. The Model 3500 is suitable for a wide range of industrial applications including petrochemical and steel industries where critical monitoring of process gases is vital. Depending on the gas specie or species of interest, the instrument is capable of measuring from the parts per million (ppm) to 100% range of concentration.

Table 1-1 shows typical gas species and their measurement range for the Model 3500.

Table 1-2: Typical Gas Analysis and Range

Gases	Threshold	Measurement Range
O_2	0.01%Vol.	0-2% Vol., 0-100% Vol.
HCL	0.1 ppm	0-15 ppm, 0-8000 ppm
HF	0.02 ppm	0-5 ppm, 0-1000 ppm
NH_3	0.2 ppm	0-20 ppm, 0-10000 ppm
CO	200 ppm	0-8000 ppm, 0-100% Vol.
H_2O	0.05 ppm	0-10 ppm, 0-70% Vol.
H_2S	5 ppm	0-1000 ppm, 0-30% Vol.

CH_4	20 ppm	0-200 ppm, 0-10% Vol.
HCN	0.5 ppm	0-40 ppm, 0-10000ppm
CO_2	1 ppm	0-100 ppm (min)
C_2H_2	0.2 ppm	0-20 ppm (min)
C_2H_4	2.0 ppm	0-200 ppm (min)

1.3 Features

Compared to conventional gas analysis systems, the DLGA-3500 series have the following advantages:

- On-the-spot online measurement ability
- Options available for use in adverse environment conditions
- Quick response
- High measurement accuracy
- Minimal maintenance
- No replacement parts
- No cross interference from background gas species
- Enhanced accuracy over conventional IR and photonic measurement systems

1.4 System Components

The Model 3500 consists of:

- Control unit
- Analysis section
- Purging system

The central processing or control unit is a separate wall-mounted enclosure located remotely from the process or point of analysis. It houses the system electronics and includes the operator interface panel on the front door. Figure 1 shows the Model 3500 control unit. A separate enclosure is provided for the power supply

The operator interface consists of a panel of membrane switches for controlling the operational mode of the instrument as well as entering data. A large LCD display provides feedback to the user and indicates the gas composition during analysis.

Figure 1-1 Control Section

The system is equipped with a separate power supply and output control section which is also mounted remotely from the measurement site. It houses power supplies and connectors for signal and relay output. See Figure 1-2.

The analysis section is typically mounted at the point of measurement and consists of the laser transmitter, receiver and flanges for interfacing the unit with the process.

The transmitter unit and the receiver unit are mounted on flanges which are welded onto the gas flow pipe. The transmitter is mounted onto one flange with special adjustable fittings while the receiver is mounted onto a similar flange diametrically opposed from the transmitter. The transmitter unit launches a collimated laser beam into the environment under test, and onto the sensor in the receiver unit. The signal is sent to the central processing unit housed in the control unit.

An integral purging unit is incorporated to keep dust and gas deposits from collecting on the analysis section windows thus eliminating any interference or degradation of the laser induced signal.

Figure 1-2 shows a typical Model 3500 Laser Gas Analysis System with the control section remotely located from the analysis portion.

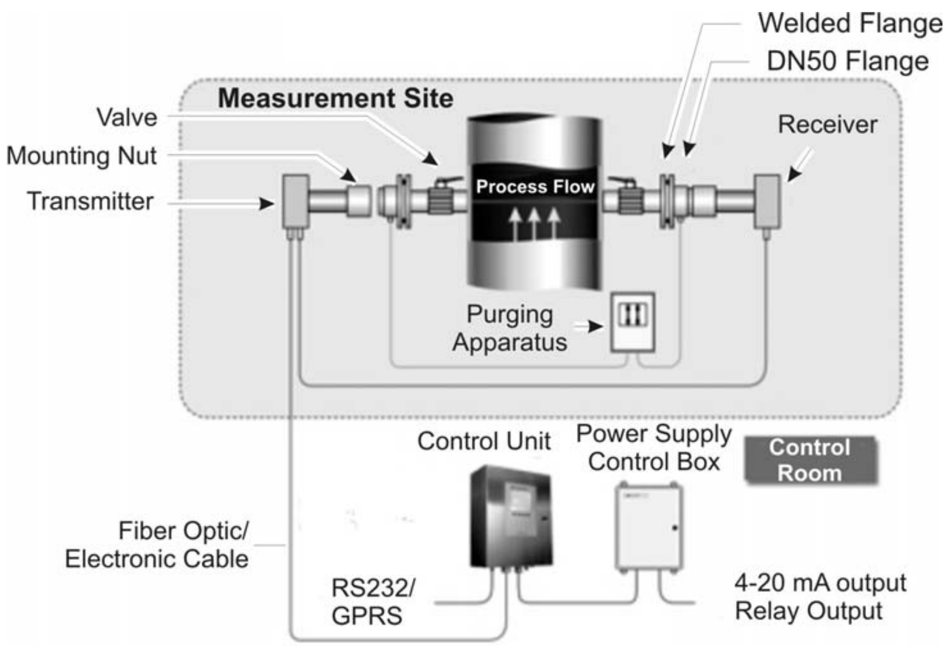


Figure 1-2: Model 2500 Laser Gas Analysis System

Operational Theory

2.1 Introduction

The Model 3500 Laser Gas Analysis System is a high precision gas concentration measurement and monitoring system capable of on-the-spot online operation. It is comprised of three subsystems:

1. Central Processing Unit (Control Unit)
2. Analysis Section
3. Purge System

In the analysis section, the transmitter launches a laser beam across the diameter of the industry pipe under test onto the receiver placed at the other end. The resulting electrical signal is then sent to the central processing unit and analyzed to yield the gas concentration and displayed on the LCD screen. Signal and relay output is taken from the power supply/control box. See Figure 2-1.

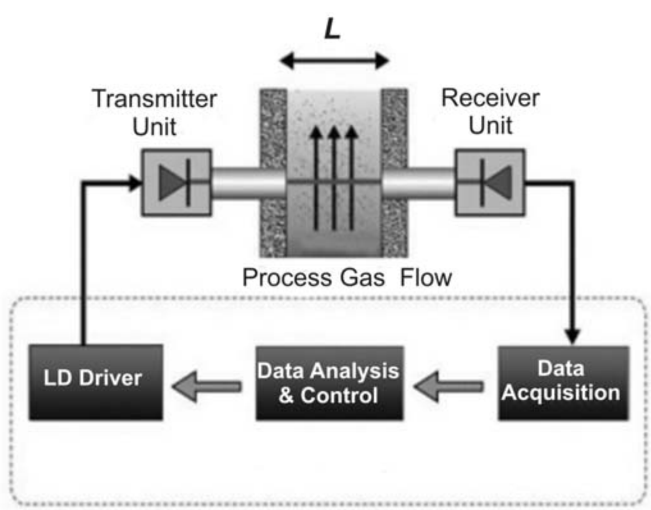


Figure 2-1: System Diagram for the Model 3500 Series Analyzers

2.2 Principles of Operation

The Model 3500 Laser Gas Analysis System uses laser spectroscopy to generate a signal based on the composition of a gas mixture. While similar in nature to other photonic analyzers, the Model 3500 Laser Gas Analysis System offers many advantages over these technologies.

Traditional online gas analyzers such as the Non-dispersive Infrared (NDIR) Spectroscopy Online Gas Analyzer are subject to interference from other constituents in the environment (including dust and other gas species such as water vapor). This could be especially severe when the measured gas is of low concentration. However, the Model 3500 Laser Gas Analysis System series employ advanced Laser Absorption Spectroscopy (DLAS) gas analysis and measurement technology, i.e. “single-line” spectroscopic methods.

Conventional infrared spectroscopy uses light sources such as lamps or LED’s that are normally non-laser and have very broad line-widths. The absorption spectrum obtained includes not only the spectral lines from the gas under test, but also those from background gas species which introduces cross interference. DLAS gas analyzers use diode lasers that have line-widths of less than 0.0001nm, or only $1/10^6$ of that of the non-laser sources. By selecting a laser that will emit a specific absorption line close to that of the gas under test and tuning its wavelength through changing its temperature and driving current, an absorption spectrum that only covers a single line of the gas under test can be obtained and eliminates cross interference. See Figure 2-2.

The line-width of a diode laser is much narrower than that of the gas molecule absorption spectrum. The Laser spectral line is depicted in the figure as a light solid line.

The diode laser output from the transmitter goes through the environment under test, gets absorbed by the target gas molecules, and the resulted attenuated light is collected by the optical sensor in the receiver unit. The attenuation is in proportion to the concentration of the target gas. Varying the wavelength of the diode laser within the carefully selected laser spectral scanning range (Figure 1.2), a gas absorption spectral line without interference from the absorption spectra of background dust and other gas species can be obtained for high precision data analysis. This feature, no interference from background dust and gases, enables the laser gas analysis systems to be applied on the spot for online gas analysis. Conventional infrared spectroscopy, due to their vulnerability to interference from background gases and dust, cannot or can hardly conduct on-the-spot measurement.

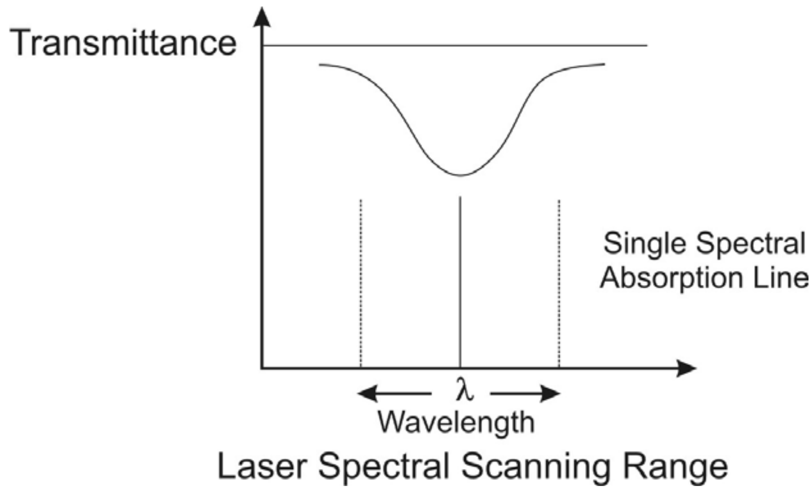


Figure 2.2 Schematic of "Single line" Spectroscopy.

The Model 3500 series of analyzers do not need complex gas sampling and pretreatment. They have extremely quick response because they skip the long gas sampling and transport process. As a result, system maintenance is minimal since gas sampling and pretreatment systems contribute to the majority of the maintenance workload for conventional sampling gas analysis systems.

In conventional sampling gas analysis systems, it is the gas concentration in the vicinity of the sampling tip that is sampled and measured. Since gas concentration can have significant variance across the section of gas flow pipe, inaccurate measurements result. No matter how precise the subsequent data analysis is, the measurement results do not accurately indicate the overall gas concentration in the gas flow pipe.

In contrast, the Model 3500 measures the average gas concentration from the transmitter to the receiver. This represents the gas concentration of the gas flow process much more accurately.

In addition, laser gas analysis systems have built-in temperature and pressure auto-correction capability to enhance measurement accuracy. These systems compensate for the temperature and pressure variance in the environment under test using a proprietary algorithm by having input for temperature and pressure.

2.3 Software

An executable program is embedded program in the microprocessor of the central process unit and is programmed to perform a multitude of tasks including:

Signal processing

Data analysis

Managing system I/O including keyboard operations and display

Performs the system self-test

Calibration,

Alarm activation

In addition, the software establishes data communication with PC through the RS232 serial communication port and GPRS modules. TAI provides WINDOWS-based PC service program for all models in the 3500 series. Please refer to Appendix A for details.

Installation

Installation of the Model 3500 includes:

- Unpacking
- Mounting
- Flange connections
- Installing transmitter and receiver
- Electrical connections
- Optical transmission adjustments and fine tuning

3.1 Unpacking the Instrument

The unit is shipped with all the materials you need to install and prepare the system for operation. Carefully unpack the analyzer and inspect it for damage. Immediately report any damage to the shipping agent.

3.2 Installation Preparation

It is very important to prepare thoroughly before installing the system. This includes having all the tools needed handy, choosing a proper installation location, and correct welding of the flanges to the gas flow pipe well. See section 3.3.1. Figure 3-1 shows the general layout of the Model 3500 Laser Gas Analyzer.

3.2.1 Installation and Adjustment Tools

The following tools will be required for proper installation:

Wrenches M5 wrench—used to tighten the M5 bolts connecting the instrument flange and transmitter/receiver.

Two 12" adjustable wrenches—used to tighten EMC and nut connector.

Two 8” adjustable wrenches—used to tighten socket screws in purging system.

Socket screwdrivers M6 hexagonal socket screwdriver—used to tighten M6 hexagonal socket bolt on the receiver and transmitter box cover.

M5 hexagonal socket screwdriver—used to tighten M5 hexagonal socket bolt on the receiver.

Screwdrivers 6mm slotted screwdriver—used to rotate the M8 fastening screws between the instrument and the weld flanges, and the purging apparatus snap ring screws.

3mm slotted screwdriver—used to connect electric parts and components.

Digital multimeter.

Tubing cutter.

Tube bender for 6 and 12 mm tubing

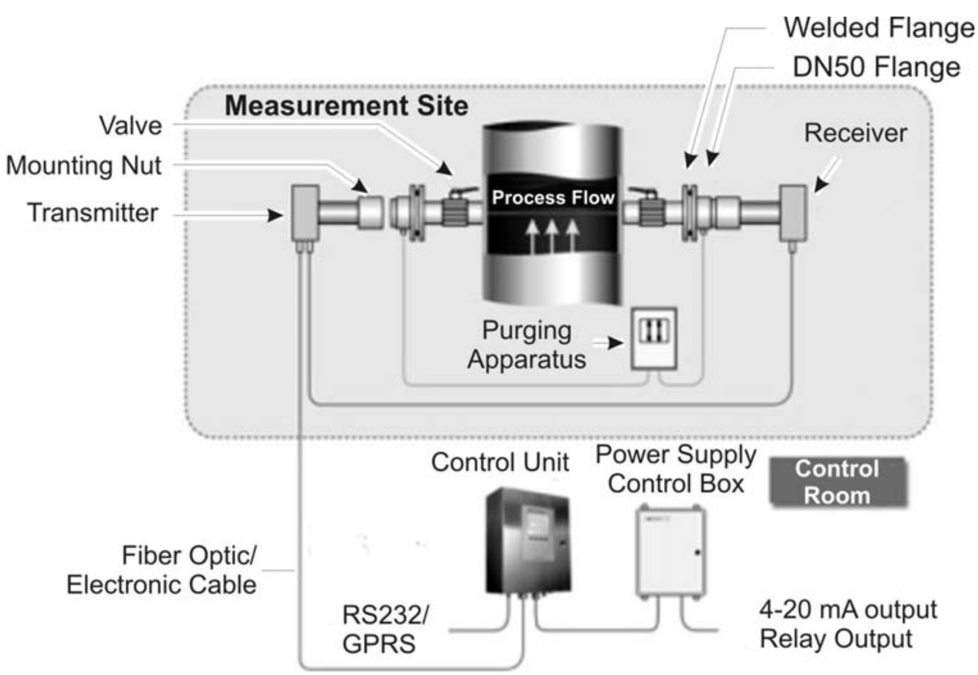


Figure 3-1: General Layout of the Model 3500 Series Analyzer

3.2.2 Choosing Installation Spot

It is strongly recommended to install the system probes on a straight section of the gas flow pipeline to ensure uniformity of the gas flow. The length of straight pipe before the installation spot should be at least twice (5 times, recommended) as much as the diameter of the pipe, and half (twice, recommended) after the installation spot.

Note: The laser gas analysis system measures the average concentration along the laser beam path (see Figure 1.2). If there is no straight pipe section for mounting the flanges, it may still be possible to get accurate measurements. (Please contact our technical support center).

In addition, the installation spot should be chosen carefully considering both safety and ergonomic factors. A platform should be constructed when the chosen spot is not fully accommodating.

3.3 Analysis Section Installation

Installation of the analysis section involves:

- Welding flanges onto the process pipe
- Installing instrument flanges
- Checking the offset angle using the laser pen
- Adjusting the coaxial angle of the two instrument flanges,
- Installing the transmitter unit and the receiver unit.

3.3.1 Welding Flanges

The transmitter and receiver units of the analysis section are mounted on DN50 flanges and mate to corresponding flanges which must be welded onto the process pipe.

Note: The customer is responsible for correct welding of the flanges onto the process pipe. The use of a competent professional welder is required to ensure proper placement of the flanges and provide a leak-free weldment.

The precision adjustment between the welding flange and the instrument flange with the supplied O-ring can fine tune the optical transmission to a limited extent. This allows for the two welding flanges to have a limited coaxial offset between them. When welding the two welding flanges the offset angle between their axes must be held to less than 4°. Typically, the two welded flanges are positioned horizontally on the gas flow pipe well across the pipe diameter As Shown in Figure 3-2.

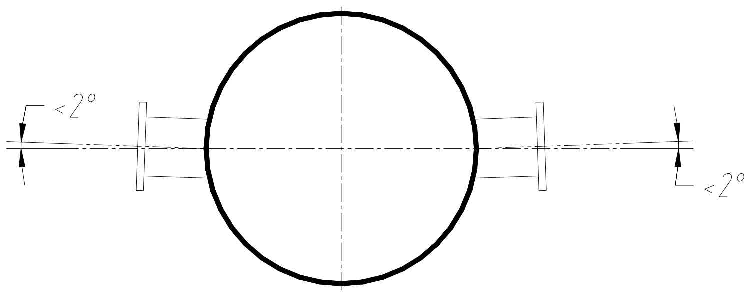


Figure 3.2: Allowed offset for welded flanges

3.3.2 Installing Instrument Flanges

After welding the flanges, the Model 3500 probes can be installed. Before installing, apply a lubricant to all the screw connections. To make adjustments easier it is suggested that you use the adjusting aid tools available from TAI (P/N XXXXX). These include a visible light laser pen and a scaled target for alignment.

WARNING: POWER TO THE SYSTEM MUST BE OFF DURING THE INSTALLATION OF THE TRANSMITTER AND RECEIVER UNITS. DO NOT CONNECT OR SWITCH ON THE POWER SUPPLY AT THIS STAGE. THE LASER BEAM IS INVISIBLE AND CAN CAUSE EYE DAMAGE.

Mount the two instrument flanges onto the welded welding flanges with 8 M16 bolts (with spring washer and plain washer) and 2 O-rings. Raise the instrument flanges to the same height as the welded flanges, then tighten the 8 M16 bolts to about half tight to make sure that the O-rings are sealing. Typically the distance between the instrument flange and the welding flange is around 3mm. See Figure 3.3.

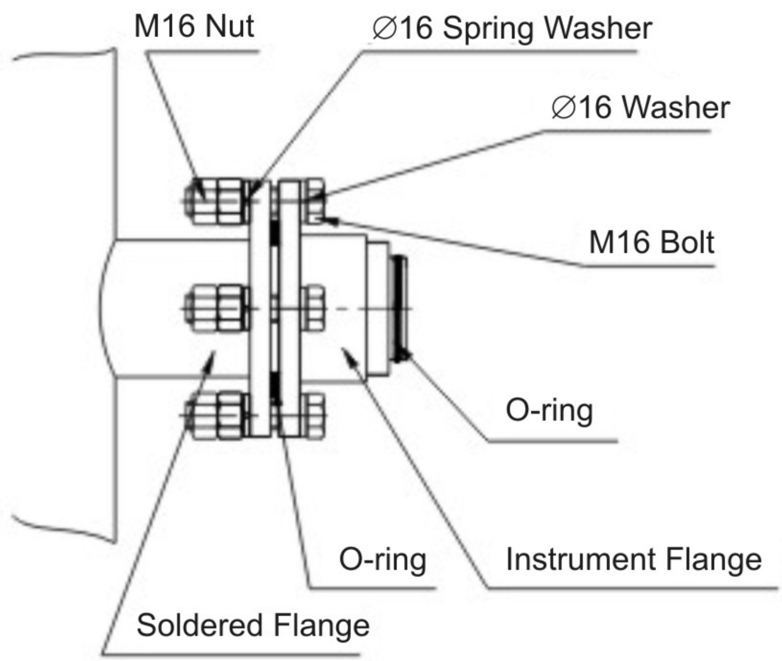


Figure 3-3: Instrument Flange

3.3.3 Checking Offset Using the Laser Pen and Target

The laser pen is an optical transmission adjustment aid tool available through TAI. The part number is listed in the Spare Parts List in the Appendix. The laser pen emits visible red light beam and is used to adjust the coaxial offset of the two instrument flanges. This assumes that the welded flanges were installed correctly and held to within 4 degrees total offset with respect to each other.

Prior to adjusting the instrument flanges the laser pen must first be checked for alignment.

3.3.3.1 Checking the Laser Pen for Alignment

To see if the laser pen is suitable for your installation, apply the following test:

1. Mount the laser pen on one instrument flange and the scaled target onto the other instrument flange. Tighten with mounting nuts.
2. Turn on the laser pen and observe the light spot on the target.

3. Loosen the mounting nut, rotate the laser pen around and tighten the mounting nut again. Record the new light spot.

The trace of light spot on the target forms a circle. If the diameter is less than 1/600 of the distance between the laser pen and the scaled target, then the coaxial degree of the pen is adequate. Otherwise, please contact our technical support center. See Figure 3.4.

3.3.3.2 Adjusting the Coaxial Offset of the Instrument Flanges

To adjust the coaxial offset of the two installed instrument flanges use the following procedure:

a. Tighten the laser pen on one of the instrument flanges with a mounting nut. Install the scaled target on the other instrument flange. Turn on the laser pen and check whether the light spot is on the center of the scaled target. If not, adjust (tighten or loosen) the 4 M16 bolts on the instrument flange where the laser pen is mounted until the light spot is at the center of the target. See Figure 3.4.

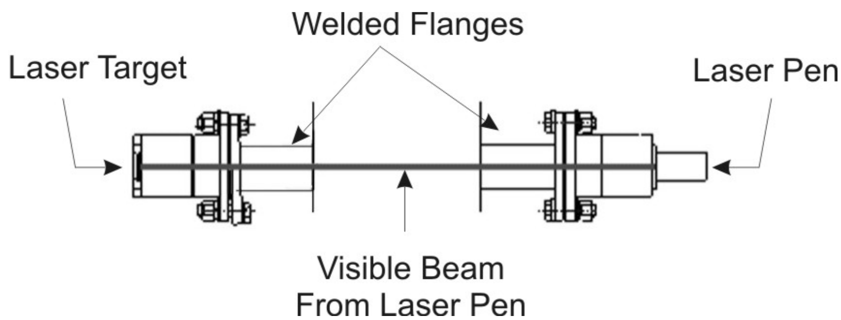


Figure 3.4 Adjusting the Instrument Flanges with Laser Pen and Target.

4. Switch the laser pen with the scaled target, and redo step 1.
5. Redo step 2 repeatedly until the light spot is always at the center of the scaled target without any adjustment.
6. Keep the laser pen on, tighten the 4 fastening screws on the instrument flange where the laser pen is mounted, and keep an eye on the light spot on the scaled target. If it moves, repeat steps 1, 2, and 3 until the light spot does not move.

7. Repeat step 4 to tighten 4 fastening screws on the other instrument flange.

3.3.4 Installing the Transmitter Unit and the Receiver Unit

Mount the transmitter unit on one of the instrument flanges as shown in Figure 3.1. Tighten it with the mounting nut, then tighten the fastening screw. Mount the receiver unit the same way.

3.4 Central Processing Unit Installation

The central processing unit is a wall-mountable enclosure that is hung on the wall of the instrument control center or in an analysis room in the field. There are four pothooks on the housing for this purpose. Secure the unit case to the wall using 4 M6 screws. Refer to Figure 3.5 for the case dimensions. The central processing unit should be hung at a proper height for comfortable operation.

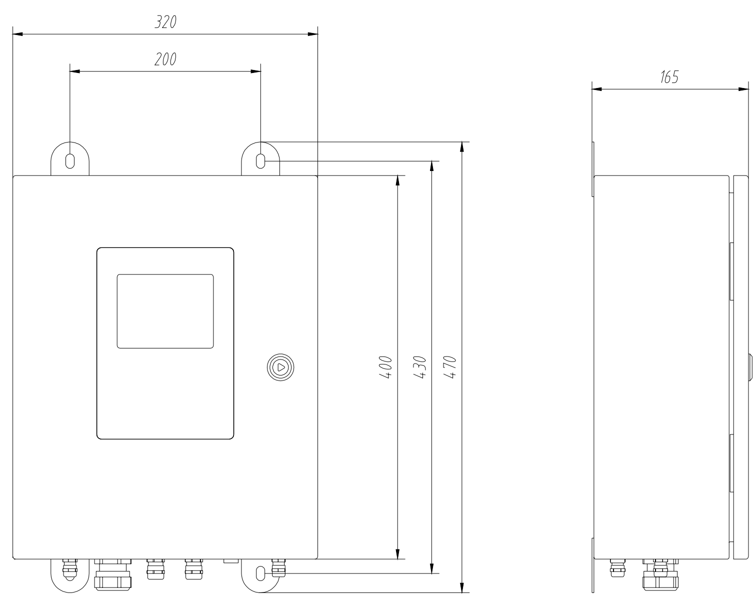


Figure 3.5 Dimension of the Central Processing Unit (in mm).

To avoid turning on the power supply inadvertently and possibly causing harm to operators in the field, the central processing unit is designed without a power switch. A separate wall mountable enclosure is supplied for housing the power supply and switches.

CAUTION: **DO NOT DISCONNECT THE CABLE BETWEEN THE CENTRAL PROCESSING UNIT, THE TRANSMITTER UNIT AND THE RECEIVER UNIT WHEN THE POWER SUPPLY IS ON. THIS COULD CAUSE DAMAGE TO THE LASER.**

3.5 Purge System Installation

If dust or other pollutant concentration is relatively high in the environment under test, a purging system must be installed to protect the optical devices in the transmitter and receiver units.

In a typical purging system, the purge gas is directed through the inside of the instrument flange, the welding flange or a special purging pipe, and into the gas flow pipe. The purging gas forms an air wall to protect the optical devices. The purge flow required depends on the process environment. Usually, a purge gas flow rate in the range of 5-50 L/min×2 is required.

Compressed air or nitrogen is the most frequently used purging gas sources. A filter should be installed to remove dust, water and oil droplets larger than 1 micron in size before entering the system to prevent the purge gas from contaminating the optical devices,. TAI provides a range of purge systems for various applications and most are equipped with appropriate filters. Please contact technical support if your application requires a purge system.

A typical purge system is shown in Figure 3.6. This unit uses compressed air (or nitrogen) as the purge gas and includes a 1 micron filter. Two needle valves and flowmeters are installed to monitor and control the purge rate to the transmitter and receiver. The housing is equipped with a window for visual access while the housing door is sealed.

To install the purge unit, connect each gas outlet of the purge system to a purge inlet on the instrument flanges. Connect the inlet to a suitable purge gas supply. A regulator should be used to control the pressure to the purge system. The gas pressure depends on the particular purge system installed and will be noted on the unit.

Open the gas supply and set the regulator to the proper pressure. Turn the needle valve on the flow meter to the maximum, and then adjust the needle valve adjacent to the flow meter to get the required flow rate.

CAUTION: **THE PURGE FLOW SHOULD REMAIN ON AFTER THE POWER TO THE UNIT HAS BEEN TURNED OFF. THIS PREVENTS DUST AND OTHER POLLUTANTS IN THE ENVIRONMENT UNDER TEST FROM CONTAMINATING THE OPTICAL DEVICES IN THE TRANSMITTER AND RECEIVER UNITS.**

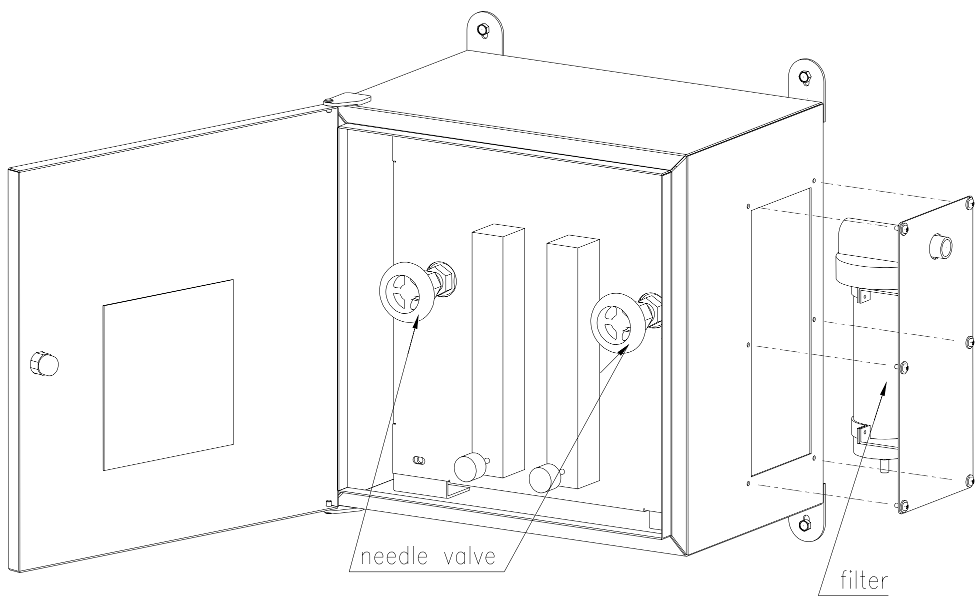


Figure 3.6 Typical Purging System for the Model 3500

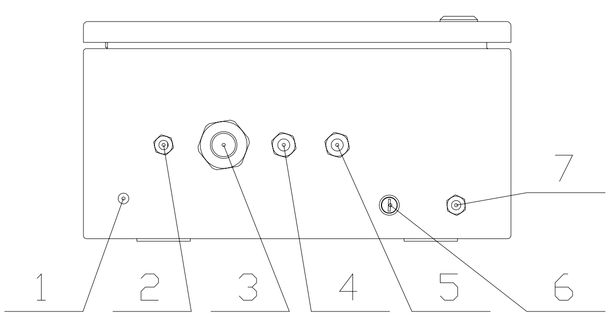
3.6 Electric Wiring and Connection

Depending on the instrument configuration, the Model 3500 Laser Gas Analysis System can be categorized as Non-fiber optic and Fiber optic. Non-fiber optic models (C option) use diode lasers without a fiber pigtail. In these models, the laser diode is located in the transmitter unit. The fiber optic models (F option) use a fiber pigtail to transmit the laser radiation to the process. In these models, the laser diode is located in the central processing unit, and the laser output beam is sent to the transmitter unit through optical fiber. The electrical connections are slightly different between the two models as shown in Figures 3.7 and 3.8. These figures show the connection ports on the central processing unit for non fiber optic unit (Figure 3-7) and the fiber optic unit (Figure 3-8). Both instruments use 250V/2A fuses.

The Model 3500 provides input, output, and communication ports on the bottom of the central processing unit enclosure. The following input/output/communication signals are supported:

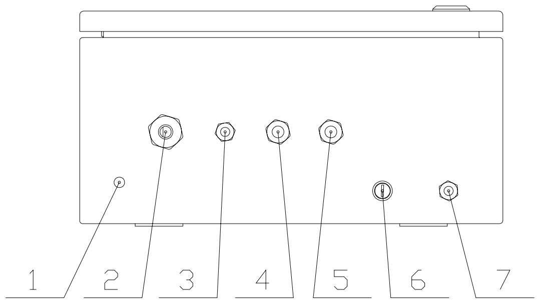
Output:	3-channel relay alarm output 1 4-20mA gas concentration output
Input:	2 4-20mA pressure and temperature input
Comm:	1 channel RS232/GPRS port for communications with PC.

The input and output signal lines are connected to the motherboard inside the central processing unit via a connection socket. Table 3.1 shows the specific electric connection for different input and output signals. Customers may choose to connect these signal lines according to their needs.



1. Grounding pole
2. RS232 connection port
3. Cable port between the central processing unit and the probe
4. 4-20mA connection port
5. Relay connection port
6. Fuse socket
7. Power supply port

Figure 3.7 Electric Connection Ports on the Central Processing Unit for Non-fiber Optic Analysis Systems.



1. Grounding pole
2. RS232 connection port
3. Cable port between central processing unit and the probe
4. 4-20mA connection port
5. Relay connection port
6. Fuse socket
7. Power supply port

Figure 3.8: Electric Connection Ports on the Central Processing Unit for Analysis Systems Using Fiber Optic Pigtail

Table 3.1 Electric connections & definitions of Input, Output Signals of Central Processing Unit

Socket No. On Motherboard	Name
31	5V Power Supply
32	DGND Power Supply Ground
33	RS232-RXD
34	RS232-GND
35	RS232-TXD
36	4-20mA Concentration Output (-)
37	4-20mA Concentration Output (+)
38	4-20mA Pressure Input (-)
39	4-20mA Pressure Input (+)
40	4-20mA Pressure Input24V Power Supply
41	4-20mA Temperature Input (-)
42	4-20mA Temperature Input (+)
43	4-20mA Temperature Input 24V Power Supply
44	Warning Alarm Relay 1

45	Warning Alarm Relay 2
46	Error Alarm Relay 1
47	Error Alarm Relay 2
48	Concentration Alarm Relay 1
49	Concentration Alarm Relay 2

WARNING: TURN OFF THE POWER BEFORE ELECTRIC WIRING. OTHERWISE THE SYSTEM WOULD BE DAMAGED.

3.7 Optimize of the Optical Transmission Alignment

At this point, the installation and initial adjustment of all components have been completed and the instrument can be powered up.

Turn on the power supply. The LCD screen displays the startup, initializing, and self test screens successively. Images of these screens can be found in the next section as Figures 4.2, 4.3, and 4.4 respectively. If the self test is successful, the LCD screen will then display measurement and status information. Note the *transmittance* value on the status bar. If this value is greater than 80%, then the installation and adjustment step is successful and the system can be placed in service. Otherwise, follow the steps below to fine tune and optimize the optical transmission between the transmitter unit and the receiver unit.

a. Open the receiver unit box cover.

b. Use a voltage meter to measure the voltage between 3(+) and 4(-) of the wiring extremity. When the optical transmission is optimized, the voltage is about 4.2V.

c. Loosen the 4 fastening screws on the instrument flange where the transmitter unit is mounted (see Figure 3.3). Adjust the flange by either tightening or loosening the 4 M16 bolts until the measured voltage stabilizes to its maximum value. Tighten the four fastening screws.

d. Replace the box cover.

Operation

The executable embedded program in the MCU of the central process unit performs signal processing and data analysis, manages system I/Os including keyboard operations and LCD, and runs system self-test, calibration, and alarm. Furthermore, it establishes data communication with PC through RS232 serial communication port and GPRS modules. FPI provides WINDOWS-based PC service program for all models of LGA-2000 analysis systems. Please refer to Appendix A for details.

4.1 Front Panel

The Model 3500 front panel consists of a LCD screen and a 16 key membrane keyboard. The LCD screen displays system information as described in the following sections. The membrane keyboard is used to carry out all user operations such as setting alarm parameters, setting environment temperature and pressure, setting the optical path length, doing system calibration, etc. The front panel is showed in Figure 4.1.

Figure 4-1: Model 3500 Series Front Panel

There are 16 available keys on the membrane keyboard. They include 2 function keys (SET and ESC), 2 direction keys for navigation (<,>), 0-9 digit keys plus a decimal point for input, and a backspace key (BKSP). They function as follows:

- “SET” is a function keystroke. Press it to enter sub menu or confirm data input.
- “<” And “>” are direction keystrokes. They are used to move the cursor.
- “ESC” is a function keystroke. Press it to exit the sub menu and go back up the menu, or to cancel the input data.
- “0-9” are digit keystrokes. They are for number input.
- “.” is the decimal point.
- “BKSP” is the backspace keystroke. It is used to delete the last input digit.

4.2 System Mode

During operation the Model 3500 Laser Analysis System can be in three different modes.

- Start-up Mode
- Normal Mode
- Error Mode

4.2.1 Start-up Mode

When the power is turned on, the system will automatically invoke the start-up mode. In this mode, the system initializes and performs the self-test routine.

The first menu on LCD screen is the start-up menu and shows the company logo and name, instrument model and name. See Figure 4.2.

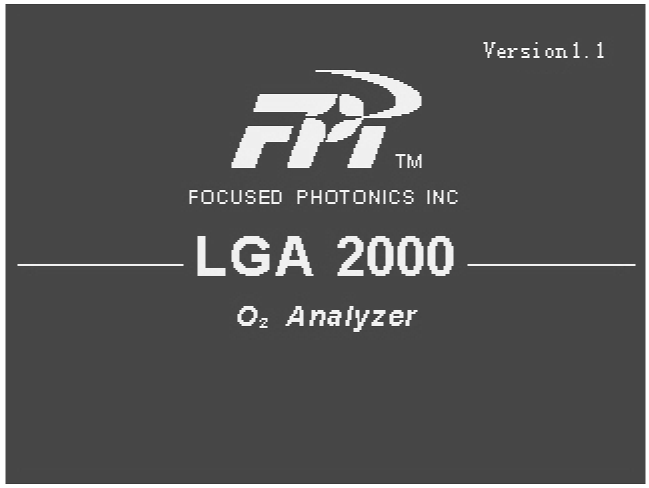


Figure 4.2 System Start-up Screen

After two seconds, the system enters the initialization stage. The process lasts 5 seconds. Figure 4.3 shows the system init menu on LCD screen displaying " System initializing…" status.

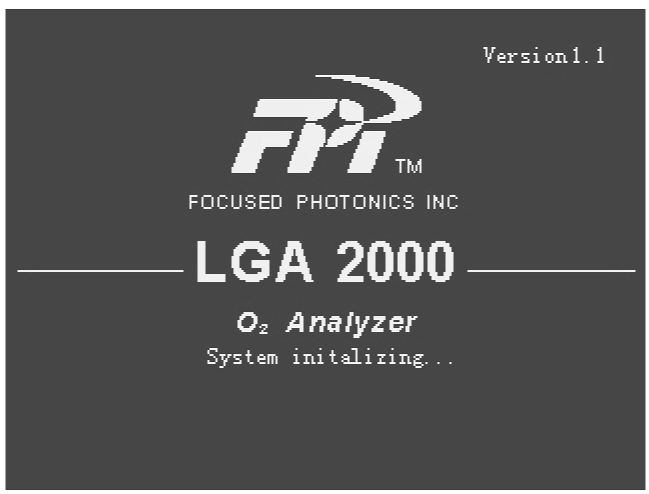


Figure 4.3 System Init Screen

After initialization, the system starts the self test routine to examine whether the system function modules are working properly. Normally, the process takes about 6 minutes. Figure 4.4 is the system self test screen showing "System Selftesting…" status. If everything is OK, system the self test ends and the system automatically enters normal mode. In the normal mode, the LCD displays system information.

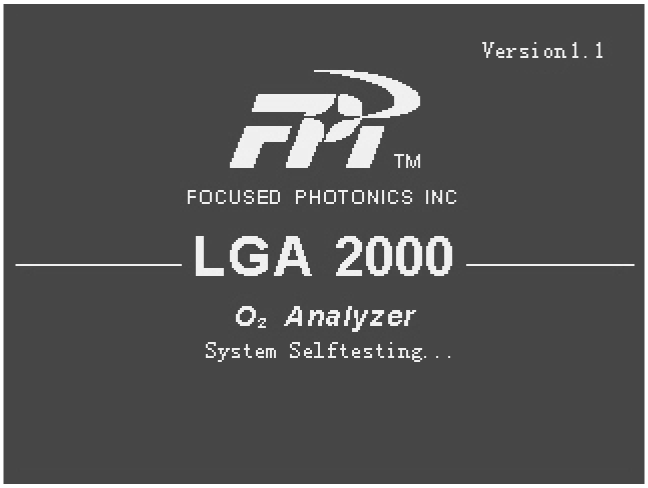


Figure 4.4: Self Testing Screen

4.2.2 Normal Mode

In the normal mode, the system performs gas concentration measurement and monitoring. There are two different working states within the normal mode:

Normal working status: In this state, the system is measuring normally. The LCD shows the measured gas concentration value and other system information; “Normal” is shown on the status bar. The analog output port (4-20mA) sends out the corresponding measured value.

Warning working status: When the system finds that the system external input parameters (mainly the pressure and temperature of the gas under test) are abnormal or the optical transmittance is too low, it automatically switches to warning working status. In this status, the front panel of the LCD shows the corresponding warning signal (Alarm code on the status bar, and warning symbol ⚠ in MainMenu in graphics mode). The system computes the gas concentration value using default values for input parameters and sends out 4-20mA output

CAUTION: **SCREEN DISPLAY OF THE MEASURED CONCENTRATION MAY BE HIGHLY INACCURATE IN THIS MODE.**

4.2.3 Error Mode

When the analysis system detects any fatal error that may damage the system permanently (for instance, when the temperature in the central processing unit is too high or the temperature of the laser device is abnormal), the system automatically switches from start-up mode or normal mode to error mode. In this mode, the system will stop gas concentration measurement and most system operations, and enter protection status. The front panel on LCD shows the corresponding error information (Alarm code in the status bar, and error symbol ⊗ in MainMenu in graphics mode). The output ports (4-20mA and relay) still send out alarm information.

4.3 System Menu

The Model 3500 operation interface employs a user-friendly menu structure. There are six main menus:

- **MainMenu**
- **Display**
- **System**
- **Cali.**
- **Com.**
- **Alarm**

The entire menu has a simple and clear structure as shown in Figure 4.5 and is easy to operate.

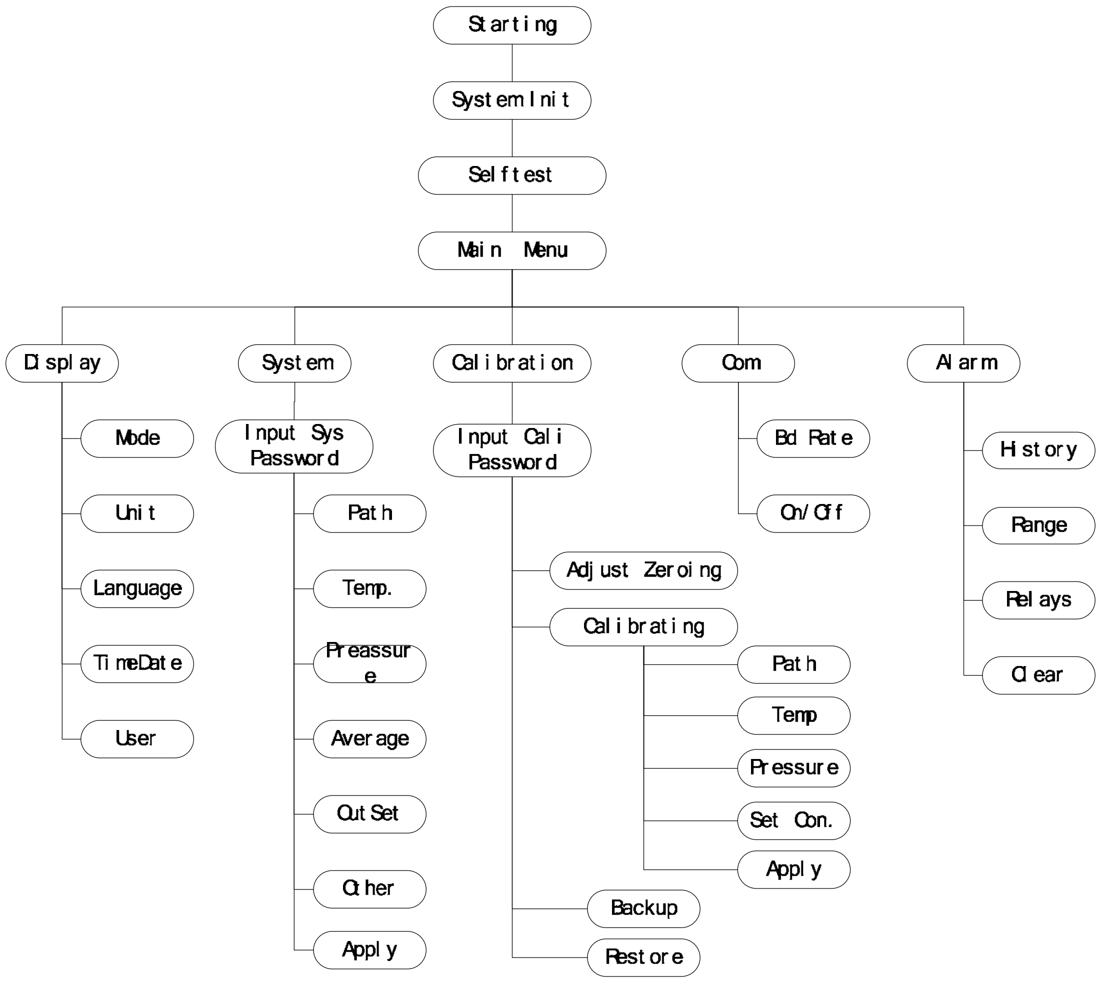


Figure 4.5: System Menu Structure

4.3.1 MainMenu

MainMenu is the menu displayed after the system finishes start-up, initializing and selftesting, and enters normal working status. The **MainMenu** has two display modes—graphics, and numeric. The two modes are switched through the **Display** menu. The graphics mode is shown in Figure 4.6.

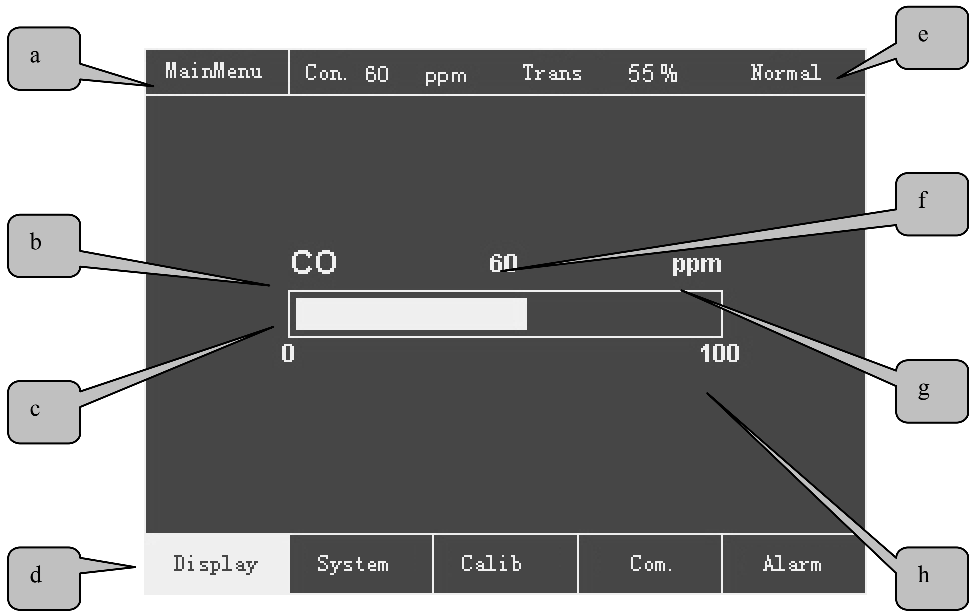


Figure 4-6: MainMenu—Graphic

The meaning of each location on the menu is described below:

a. Menu name (the same for all the other menus)

b. The name of the gas under test

c. Bar that shows measured gas concentration value

d. The button pointing to sub menus. When the cursor is on the button, it is highlighted. Press SET to enter the submenus. (Functions the same for all the other menus).

e. Status bar that shows the current measured gas concentration value and the working status of the system (If everything is OK, it displays Normal; Otherwise, it gives the Alarm Code). (Functions the same for all the other menus).

f. Average gas concentration value

g. Units for gas concentration

h. Upper limit of gas concentration alarm range. The lower limit is shown on the left side. These two values can be reset from the **Alarm** menu.

The numerical value mode is shown in Figure 4.7.

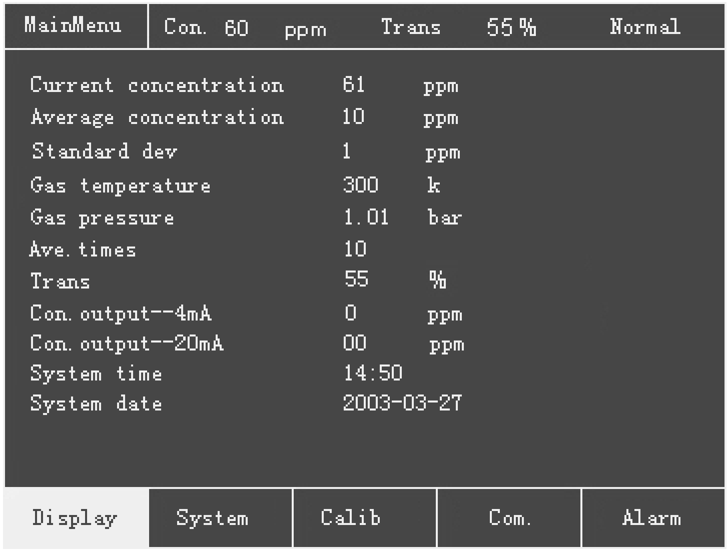


Figure 4.7 Numerical Value Mode of the MainMenu

The meaning of each item on the menu is listed below:

- Current concentration: the gas concentration value just measured
- Average concentration: gas concentration value after digital filtering. It can alleviate the influence caused by the uncertainty of gas flow.
- Standard dev: standard deviation of the measured gas concentration.
- Gas temperature: the temperature of the gas under test.
- Gas pressure: the pressure of the gas under test.
- Ave. times: Number of times used in digital filtering.
- Trans: Transmittance of laser beam in the environment under test. If the optical windows in the transmitter and the receiver are contaminated by dust in the environment under test, or if the optical path between the transmitter and the receiver deviates from the optimal position, the transmittance decreases.
- Con. output--4mA: gas concentration value corresponding to 4mA of the 4-20mA gas concentration output.

- Con. output--20mA: gas concentration value corresponding to 20mA of the 4-20mA gas concentration output.
- System time: the time of system clock.
- System date: the date of system clock.

Note: The Model 3500 outputs average gas concentration at the 4-20mA gas concentration output port.

The computation method for average concentration and standard deviation is described below:

Average Concentration

$$\overline{g}_{new} = \frac{1}{N} g_{cur} + \left(1 - \frac{1}{N}\right)\overline{g}_{old}$$

Where:

$\overline{g}_{new}$ ——Average concentration value

g_{cur} ——Current concentration value

$\overline{g}_{old}$ —— the average concentration value before adding the latest measurement g_{cur} stored in the system memory

N ——Ave. times

The method is in equivalent to having the current concentration value pass through a low-pass filter with a cut-off frequency at $f = \frac{1}{2\pi N\tau}$, where τ is the time the system needs to finish one measurement. Typically, the Model 3500 series instruments have τ set at ~1 second at the factory. However, it can also be set at any value in the range of 0.1~1 second upon customer request to suit particular applications that require faster response time. Contact technical support for more information.

Normally, every time the system finishes one measurement cycle, the LCD display and output at the 4-20mA output port refreshes.

Standard Deviation

In a sequence of the last k current concentration values: $C_{n-k+1}, \ldots\ldots C_{n-2}, C_{n-1}, C_n$. The average value of the sequence is:

$$\overline{C} = \frac{C_{n-k+1} + \ldots + C_{n-1} + C_n}{k}.$$

The standard deviation of current gas concentration is given by:

$$e_n = \sqrt{\frac{(C_{n-k+1} - \overline{C})^2 + \ldots + (C_{n-1} - \overline{C})^2 + (C_n - \overline{C})^2}{k-1}}.$$

The Model 3500 sets k to 20 by default. For a strictly random concentration sequence, statistically, different k produces the same standard deviation.

*Note: The 4-20mA output port on the Model 3500 outputs the **average** gas concentration value computed with the above method, the **standard deviation** at the port is therefore about $1/\sqrt{N}$ of the value displayed on the LCD, where, N is the average times set by the user.*

In the **MainMenu**, there are 5 submenus: **Display**, **System**, **Cali.**, **Com.** and **Alarm**. In the MainMenu, the system only reacts to "SET", "<" and ">". All the other keystrokes are disabled.

Press "SET"—the system enters the submenu selected by the cursor.

Press "<"—the cursor moves one position left. If the cursor is already on the leftmost button, the cursor moves to the rightmost button.

Press ">"—the cursor moves one position right. If the cursor is already on the rightmost button, the cursor moves to the leftmost button.

By operating the above keystrokes, you can enter the submenu of the **MainMenu**:

- **Display**: Press "SET"—the system enters the **Display** menu.
- **System**: Press "SET"—the system asks for *Sys Pwd*. If the password is correct, the system enters the **System** menu.

- **Cali.**: Press “SET”—the system asks for *Cali Pwd*. If the password is correct, the system enters the **Cali.** menu.
- **Com.**: Press “SET”—the system enters the **Com.** menu.
- **Alarm**: Press “SET”—the system enters the **Alarm** menu.

4.3.2 Display

In **Display** menu, there are five submenus, **Mode**, **Unit**, **Language**, **TimeDate** and **Admin.** See Figure 4-8. Pressing “<”,”>” and “SET”, users can select display mode, unit of parameters, language (English/Chinese), set system clock time and date, and change passwords. Press “ESC”, the system goes back to the **MainMenu**.

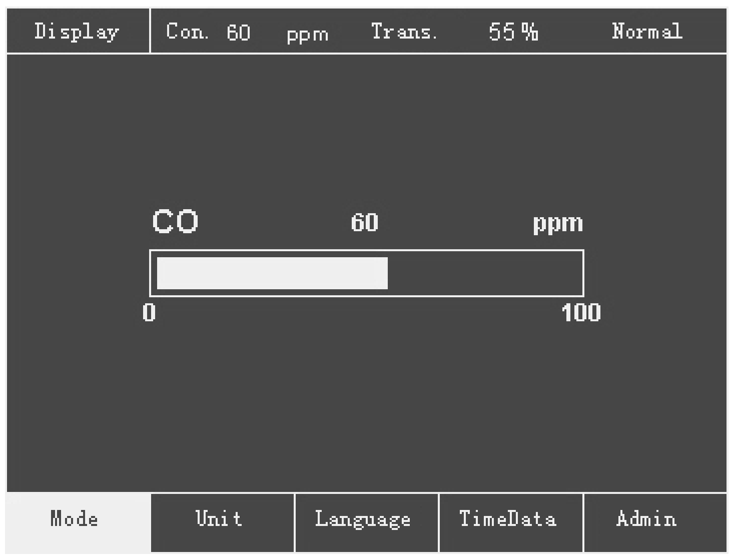


Figure 4.8 Display menu

- **Mode**: Press “SET”, a small window popes up, asking the user to choose between Numerical Value Mode and Graphics Mode. The difference between the two display modes is described in Section 4.3.1 **MainMenu**.

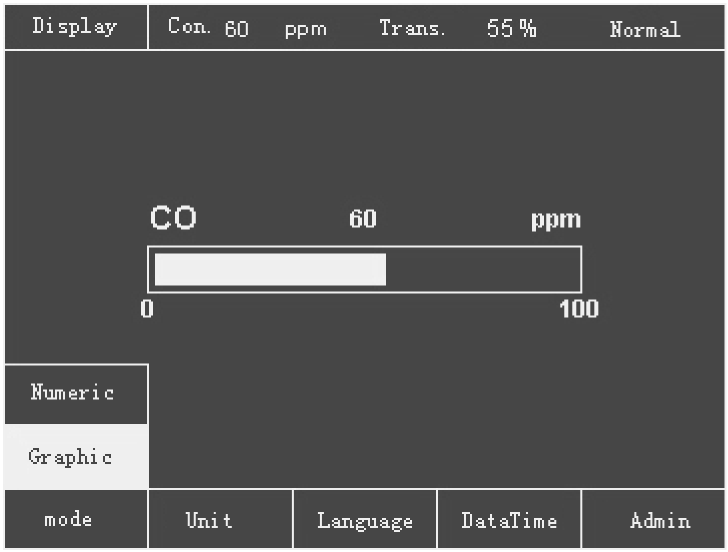


Figure 4.9 Display Mode Options

- **Unit**: Choose unit for different parameters. Press "SET" to enter **Unit** submenu.

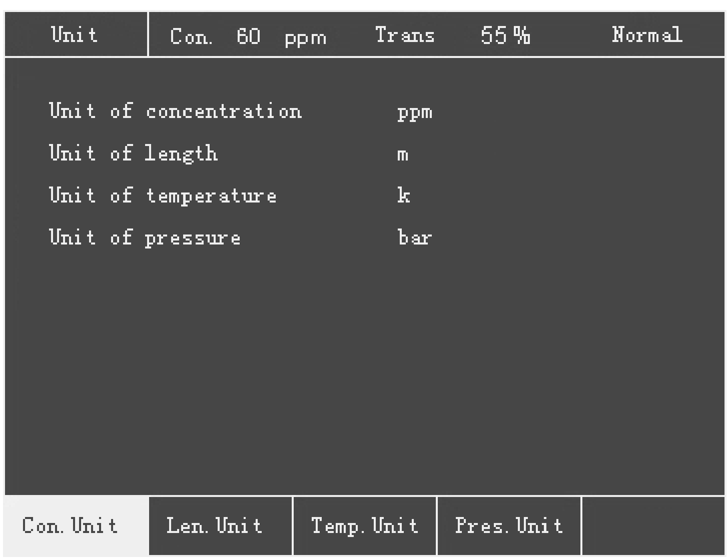


Figure 4.10 Unit Menu

Users can set the unit for concentration, length, temperature and pressure by pressing “SET” in different cursor locations. For example, press “SET” when the cursor is on **Con. Unit**, the system enters the following menu:

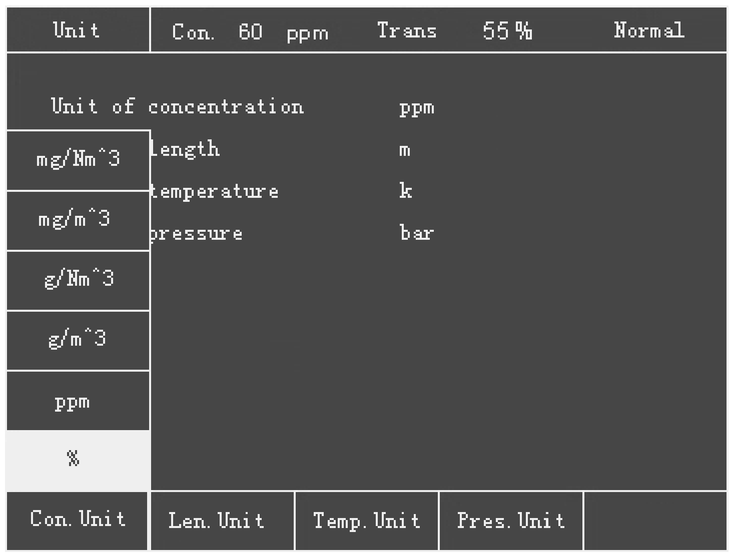


Figure 4.11 Set Con. Unit menu

The following units for concentration, length, temperature and pressure are available:

- Con. Unit: ppm, %, g/m^3, g/Nm^3, mg/m^3, mg/Nm^3
- Len. Unit: m, cm, ft, inch
- Temp. Unit: °F, K, °C
- Pres. Unit: bar, Pa, mbar, psi, Mpa

Six units are provided in the **Con. Unit** menu to choose from: ppm, %, g/m^3, g/Nm^3, mg/m^3, and mg/Nm^3. Units in ppm and % are commonly used for volume percentage concentration while g/m^3 and mg/m^3 are mass volume ratio concentration units related to volume percentage concentration through the ideal gas equation. The units g/Nm^3 and mg/Nm^3 are mass volume ratio concentration units (standard state , pressure: 1.01325Bar, temperature: 273.1K).

- **Language**: Press "SET" to select between Chinese and English.

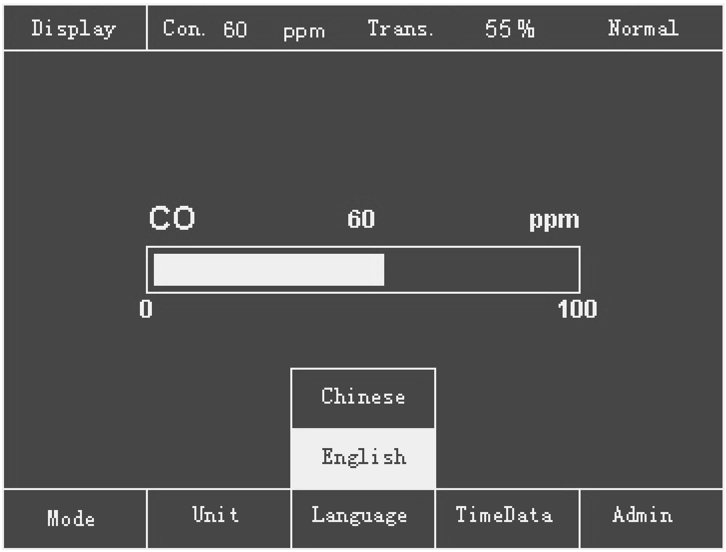


Figure 4.12 Pop-up Window for Language Selection

After the selection, all menus are in the language selected.

- **TimeDate**: Press "SET" to set system clock time and date.

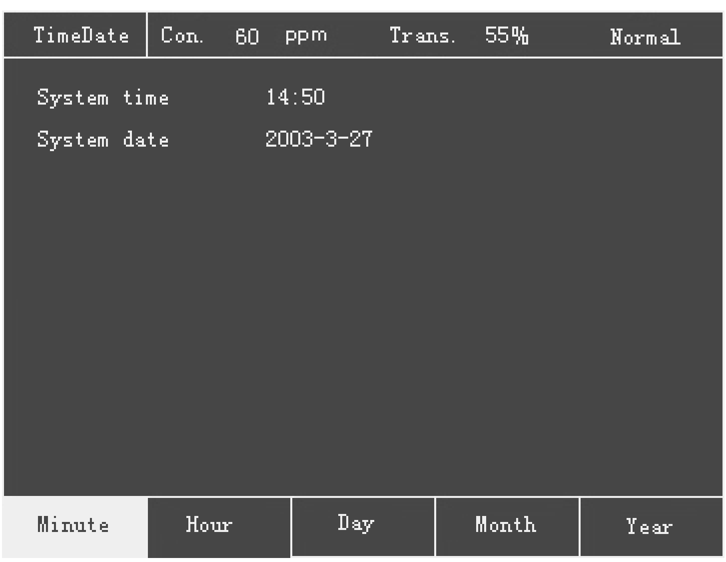


Figure 4.13 TimeDate Menu

- **Admin.**: Press “SET”, the system asks for Pwd. If the Pwd is entered correctly, the system enters the **Admin.** menu. (Figure 4.14).

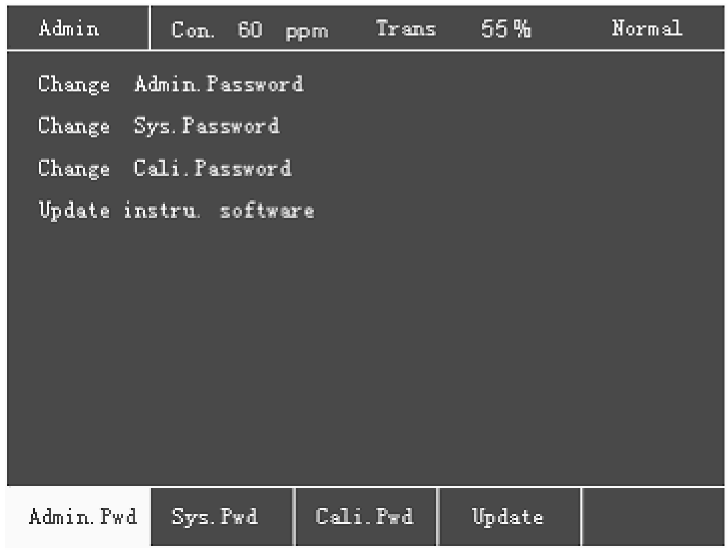


Figure 4.14 Admin. Menu

From the Admin screen you can change passwords and update the system software. The selectable items are:

- Change Admin. Pwd: change the password to **Admin.** menu. (Figure 4.14).
- Change Sys. Pwd: change the password to **System** menu (Figure 4.15).
- Change Cali. Pwd: change the password to **Cali.** menu (Figure 4.23).
- Update instrument software: press to enter software update interface to upgrade system software.

To change the passwords of **System** and **Cali.**, you must enter the **Admin.** Menu. The user who has the **Admin.** password has the highest authority. With this privilege you can reset **System** pwd and **Cali.** pwd to ensure authorized system management.

The default **Admin.** Pwd is 2222. The default **System.** Pwd is 1111. The default **Cali.** Pwd is 3333.

Additional information about software updates is available through the technical support center.

4.3.3 System

System menu includes System main menu and System sub menu. In the **MainMenu**, move the cursor to **System** and press "SET", the system asks for password, if the password keyed in by the operator is correct, the system enters the System main menu.

Note: In error mode, the system is in Error Protection Menu (see Figure 4.39), and the System main menu is not accessible.

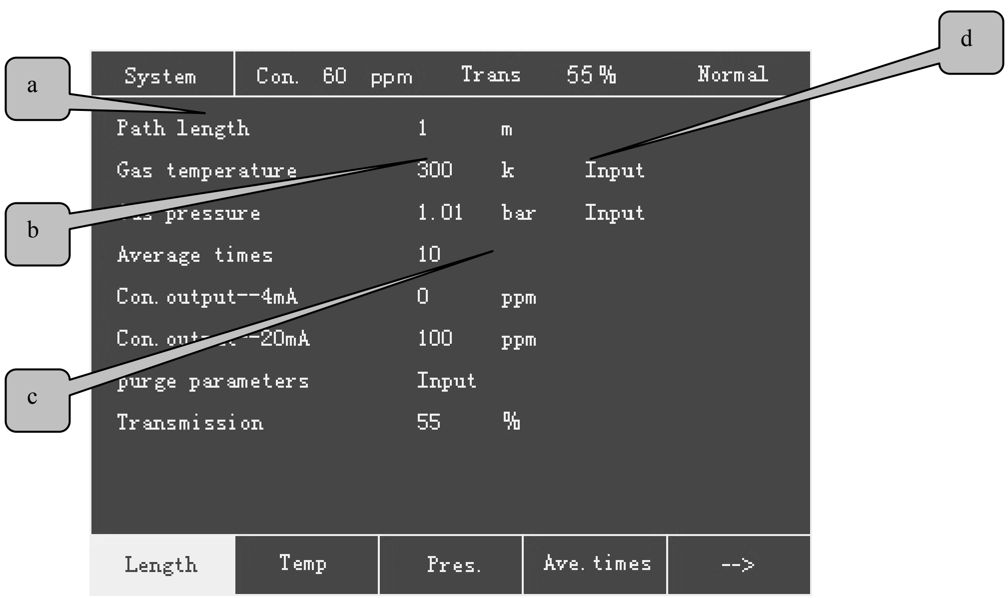


Figure 4.15 System main menu

The system main menu is shown in Figure 4.15. The data fields for this menu are as follows:

- Path length: optical path length of the gas under test.
- Gas temperature: temperature of the gas under test.
- Gas pressure: pressure of the gas under test.

- Average times: number of times used to calculate average concentration.
- Con. output--4mA: gas concentration value corresponding to 4mA of the 4-20mA gas concentration output.
- Con. output--20mA: gas concentration value corresponding to 20mA of the 4-20mA gas concentration output.
- Purge parameter: purging system parameters including the length, temperature and density of the purging gas. Interaction with the purge system is done through this menu.
- Transmission: Transmittance of laser beam in the environment under test.

On this menu, the operator can move the cursor to a parameter button, press “SET”, and a pop-up window occurs for the operator to reset it (Figure 4.15). The items in the column refer to:

a. Item name
b. Value
c. Unit
d. Way to set the item (key in manually or from a measurement). None will be shown here if it can only be keyed in.

4.3.3.1 System Parameter Input Method

As an example, the following demonstrates the way to reset optical path length.

1. Move the cursor to “Length” button and press “SET”. The Path length input window pops up.

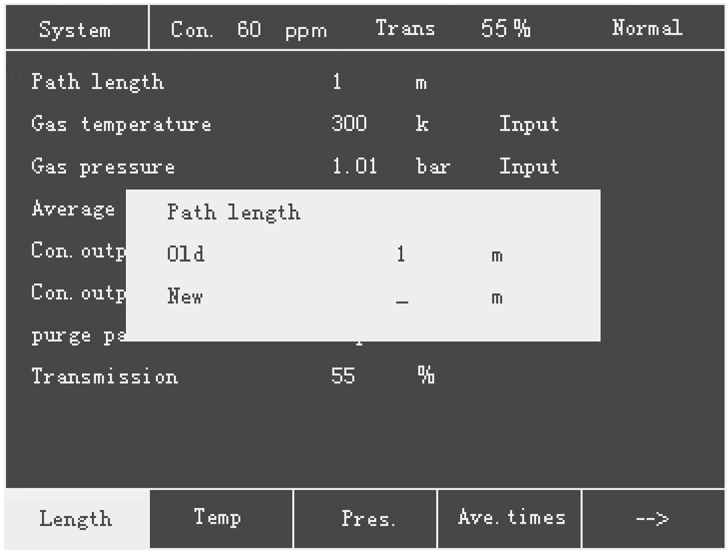


Figure 4.16 Set Optical Path Length

2. Key in the new optical path length value (Figure 4.17).

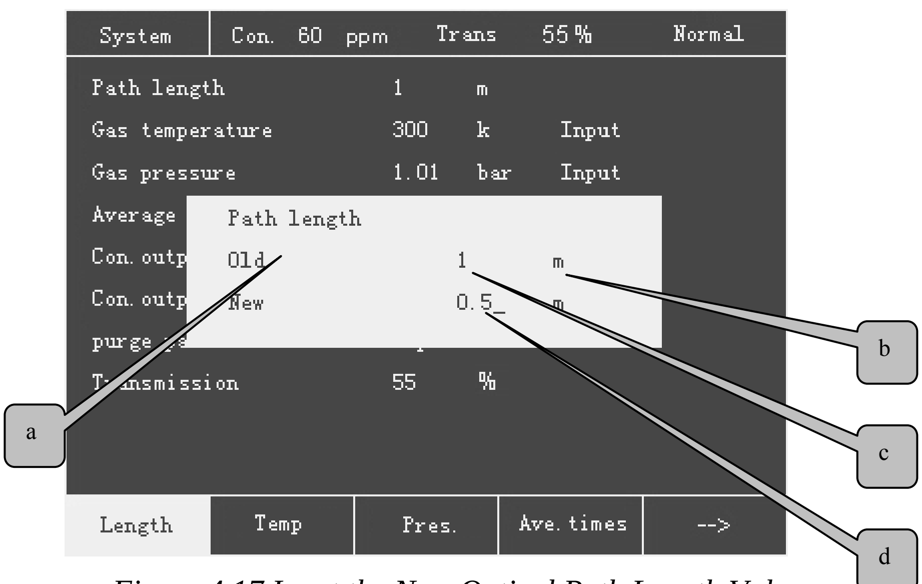


Figure 4.17 Input the New Optical Path Length Value

3. Press “SET” to accept the new setting.

The call-outs on Figure 4.17 refer to:

a. Item name

b. Unit of the item

c. Current value

d. New data input. The underscore after the number shows where the next digit goes.

Note: After the system parameter input window pops up, keystrokes “<” and “>” are disabled.

The “SET” key is used to accept the new setting and close the input window. If no data is keyed in, and “SET” is pressed, the system defaults to 0. If the data keyed in is out of range, an error alert is issued.

Use the “ESC” key to reject the new setting and close the input window. The “ESC” key is used when you have input wrong data and do not want the system to accept it.

The numerical keys “0-9” are used to enter data digits. The underscore moves a position to the right with each input. Similarly, the decimal point key “.” Is used to input the decimal point.

The Backspace key, “BKSP”, is used to delete the last data digit, The underscore moves a position to the left with each deletion.

4.3.3.2 SYSTEM SUB MENUS

The sub menus of the System menu are:

- Path: —set optical path length value (0-12m), manual.
- Temp: — set temperature of the gas under test (200-3000) K, manual or from a measurement. When choose Measure, the system enters Measured Temperature Set menu.
- Pressure: —set pressure of the gas under test (0-20) bar, manual or from a measurement. When choose Measure, the system enters Measured Pressure Set menu.
- Av Times: —set number of times used to calculate average concentration (0-90), manual.
- Out Set: —set the range of 4-20mA concentration output.
- Purge: —set parameters of the purging gas including purging gas concentration, purging path and purging gas temperature.

- Apply: —after entering all the data, press this button to finish the process.

Additional sub menus are located on the next screen. Move the highlighted button to the ---- > symbol and press "Set".

The additional system sub menus areas follows:

1. Measured Temperature Menu

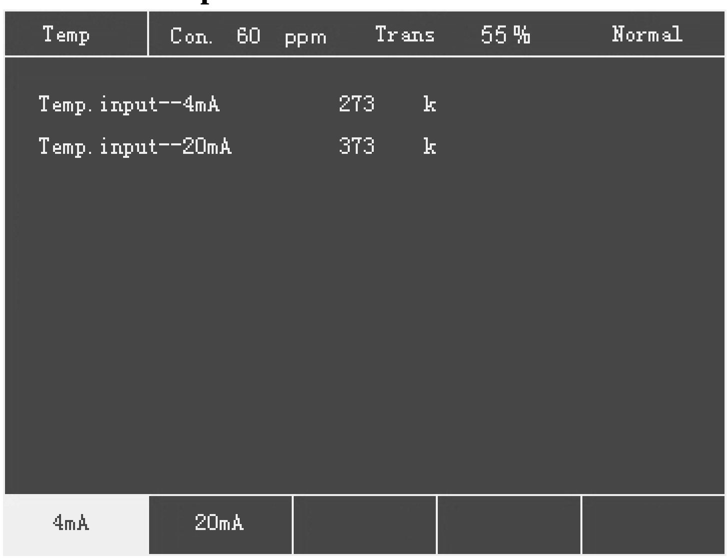


Figure 4.18 Measured Temperature Menu

Items displayed on the Measured Temperature screen (Figure 4.18) are:

- Temp.input--4mA: The gas temperature input is taken from a measurement. It is input to correspond with a 4-20mA output signal. Temp.input--4mA is the gas temperature corresponding to 4mA.
- Temp.input--20mA: This is also taken from a measurement. It is the gas temperature corresponding to 20mA.

The buttons on this menu refer to:

4mA: Set the corresponding gas temperature when the temperature input signal is 4mA.

20mA: Set the corresponding gas temperature when the temperature input signal is 20mA.

2. Measured Pressure Menu

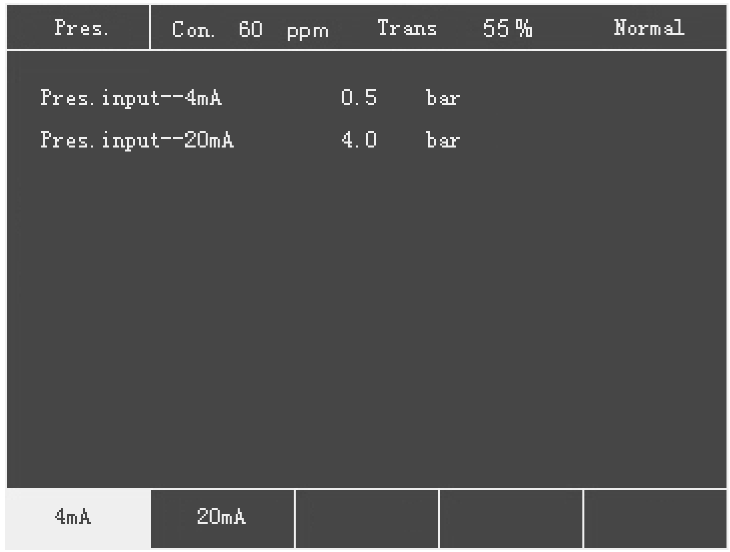


Figure 4.19: Measured Pressure Menu

Items displayed on the Measured Pressure screen (Figure 4.19) are:

- Pres. input--4mA: The gas pressure input is taken from a pressure measurement. It is input to correspond with a 4-20mA output signal. Pres. input--4mA is the gas pressure corresponding to 4mA.
- Pres. input--20mA: This is also taken from a measurement. It is the gas pressure corresponding to 20mA.

The buttons on this menu refer to:

4mA: Set the corresponding gas pressure when the pressure input signal is 4mA.

20mA: Set the corresponding gas pressure when the pressure input signal is 20mA.

3. Concentration Output Menu

Items displayed on the Concentration Output screen (Figure 4.20) are:

- Con. output--4mA: The measured gas concentration output is in the form of 4-20mA. Con. output--4mA is the gas concentration value corresponding to 4mA.

- Con. output--20mA: The measured gas concentration output is in the form of 4-20mA. Con. output--20mA is the gas concentration value corresponding to 20mA.

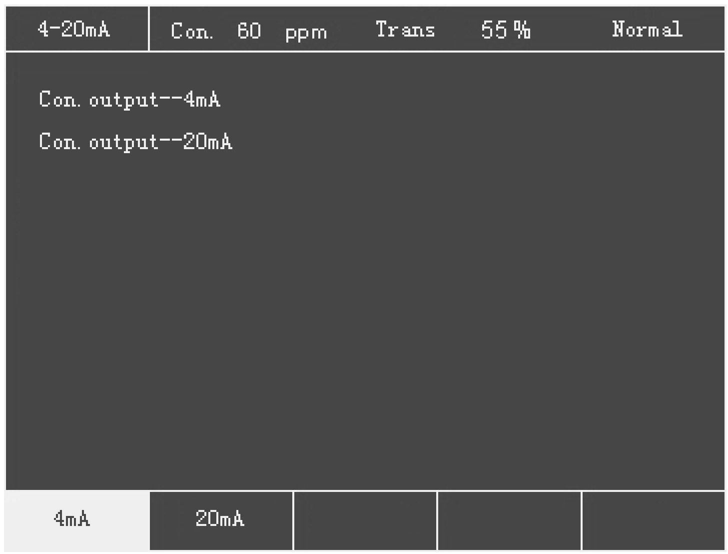


Figure 4.20 Concentration Output Menu

The buttons on this menu refer to:

4mA: Set the corresponding gas concentration (0-99.9999)% when the gas concentration output signal is 4mA.

20mA: Set he corresponding gas concentration (0-99.9999)% when the gas concentration output signal is 20mA.

4. Purge Parameter Menu

On the Purge Parameter Menu (Figure 4.21), the selections are:

- Pur Len: Set the purging path length (Lf2+Lf1+Lb1+Lb2, Figure 4.22).
- Pur. Temp: Set the purging gas temperature.
- Pur. Con.: Set the concentration of gas under test in the purging gas.

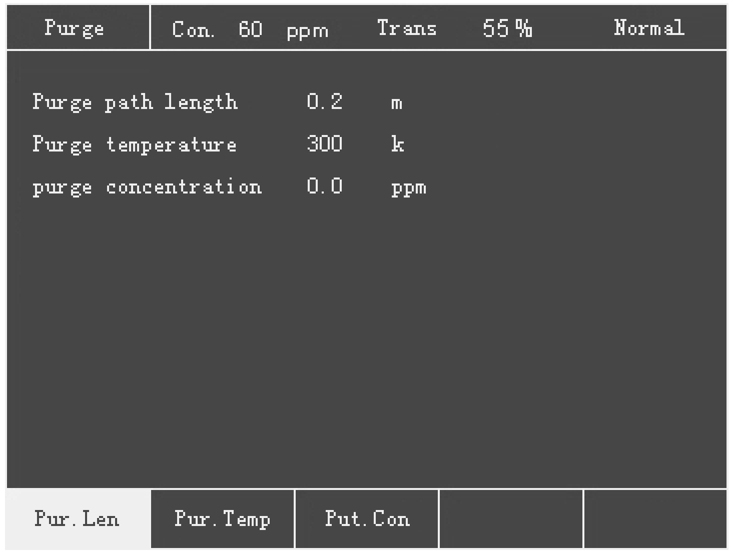


Figure 4.21 Purge Parameter Menu

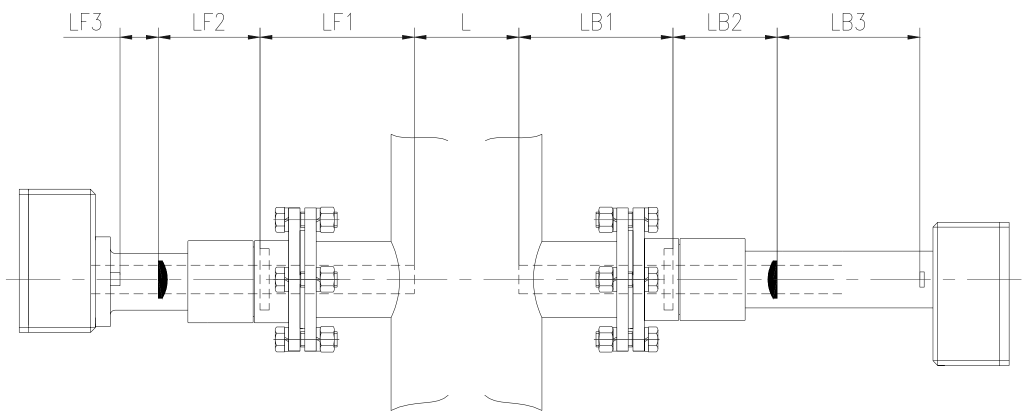


Figure 4.22 Schematic showing purging gas channel

Note: The residual gas in LF3 and LB3 has been interpreted during zeroing, and thus has no influence on the *measurement result.*

4.3.4 Cali.

Cali. main menu is third from left on **MainMenu**. Pressing “SET”, the system prompts for the password, if the password is entered correctly, the system enters **Cali.** main menu. (Figure 4.23)

Note: *In error mode, the system is in Error Protection Menu (see Figure 4.39), and the Cali. menu is not accessible.*

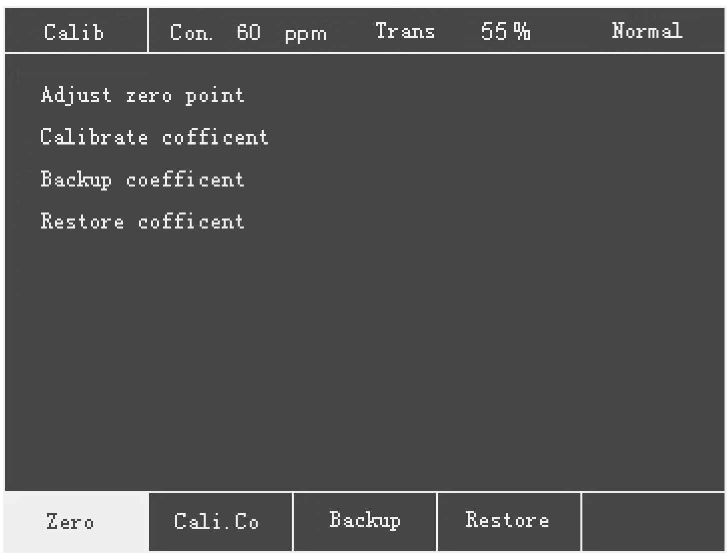


Figure 4.23 Cali. Main Menu

From this menu, the operator can perform the following operations:

- Adjust zero point: Fill the calibration tube with standard gas (such as high purity nitrogen) with 0% of the gas under test, and zero calibrate.
- Calibrate coefficient: Fill the calibration tube with standard gas (such as high purity Nitrogen) with known concentration of the gas under test, and perform a span calibration operation.

Note: *Perform the zero calibration before doing the span calibration.*

- Backup coefficient: Save current calibration coefficients as backup. The operator can choose to backup any set of calibration coefficients they are satisfied with. The Model 3500 has calibration coefficients backed up before shipping.
- Restore coefficient: When the users are not happy with the current calibration result, and are unable to get good calibration results, they can restore the old more satisfying backup calibration coefficients.

4.3.4.1 ADJUST ZERO:

Zero: Press “SET” when the cursor is on “Zero” button, the system enters the Pre zeroing menu (Figure 4.24).

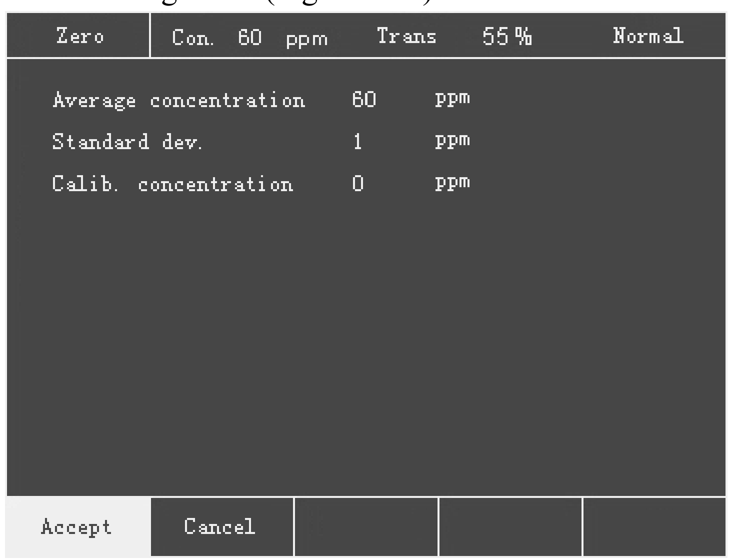


Figure 4.24 Pre zeroing sub menu

Choose “Accept” to accept the parameters, and the system starts zeroing (Figure 4.25). The zeroing gauge bar shows the progress of the process.

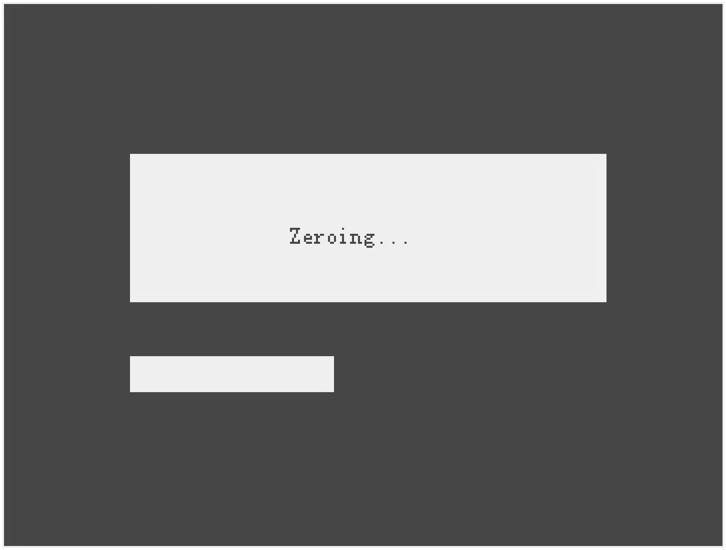


Figure 4.25 Zeroing menu

4.3.4.2 CALI. CO:

Figure 4.26 is the **Cali.Co** sub menu. On this menu, operators can set calibration optical path length, temperature, pressure, concentration parameters needed by the calibration system.

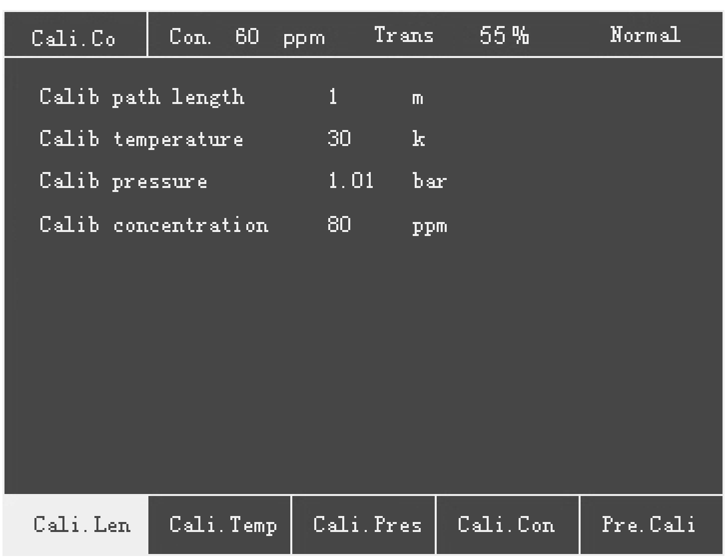


Figure 4.26 Calibration coefficient sub menu

The functions of the buttons on **Cali.Co** sub menu are:

- Cali.Len: Sets the optical path length of the calibration tube, manual.
- Cali.Temp: Sets the temperature of the standard gas used for calibration, manual or from a measurement. When “Measure” is chosen, the system enters Measured Temperature Set menu.
- Cali.Pres: Sets the pressure of the standard gas used for calibration, manual or from a measurement. When “Measure” is chosen, the system enters Measured Pressure Set menu.
- Cali.Con: Enters the concentration value of the standard gas used for calibration. This value is used to calculate calibration coefficients.
- Pre.Cali: After inputting all the parameters above, press Pre.Cali button to accept them, and the system enters the Calibration Confirmation menu (Figure 4.27).

Note: The system accepts the above input parameters only after Pre.Cali is pressed.

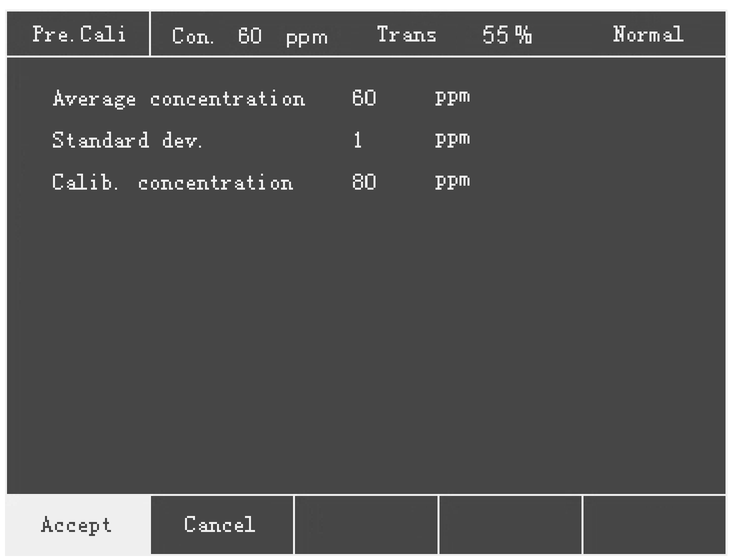


Figure 4.27 Calibration confirmation menu

The Calibration Confirmation menu (Figure 4.27) displays the measured average gas concentration, standard deviation and the concentration value of the standard gas (Calib. Concentration) which were entered in the **Cali.Co** sub menu (Figure 4.26).

Drift within a calibration interval is typically small in the Model 3500 series. If the measured average gas concentration differs significantly from the entered Calib. Concentration, it is recommended to choose “Cancel” to reject the calibration and check whether all parameters on **Cali.Co** sub menu (Figure 4.26) are correctly set. Check also for leaks in the calibration system and whether the standard gas has been in storage for too long a time..

Note also the standard deviation of the measured gas concentration. If it is too large with respect to the measured gas concentration, i.e. greater than 1%, the calibration inaccuracy would be high. Again, it is recommended to choose “Cancel” to reject the calibration, and check whether the gas concentration of the standard gas is too low. Make sure you are using a standard with the recommended concentration value as listed in the calibration parameter table that comes with the system.

If everything is OK, choose “Accept” to accept the calibration. The system starts the calibration process and automatically displays the calibration progression menu (Figure 4.28).

Figure 4.28 Calibration Progression

Note: The accuracy of the system depends on calibration. It is of the utmost importance to perform a good, accurate calibration. DO NOT accept any calibration that shows abnormal behavior.

4.3.4.3 Backup

Backup saves the current calibration coefficients to memory. The operator can choose to backup any set of calibration coefficients they are satisfied with. The Model 3500 has calibration coefficients backed up before shipping.

To backup the calibration parameters, move the cursor to the “Backup” position and press “SET”.

4.3.4.4 Restore

If the current calibration parameters are found to be unsatisfactory, you can restore previously stored backup calibration coefficients.

To restore the last saved parameters, move the cursor to the “Restore” position and press “SET”. This loads in the last save calibration parameters from memory replacing the currently displayed values.

4.3.5 Com

On this menu, users can query the communication status of RS232.

Move the cursor to “Com.” on the Main Menu, and press “SET” to enter the Com. Menu (Figure 4.29).

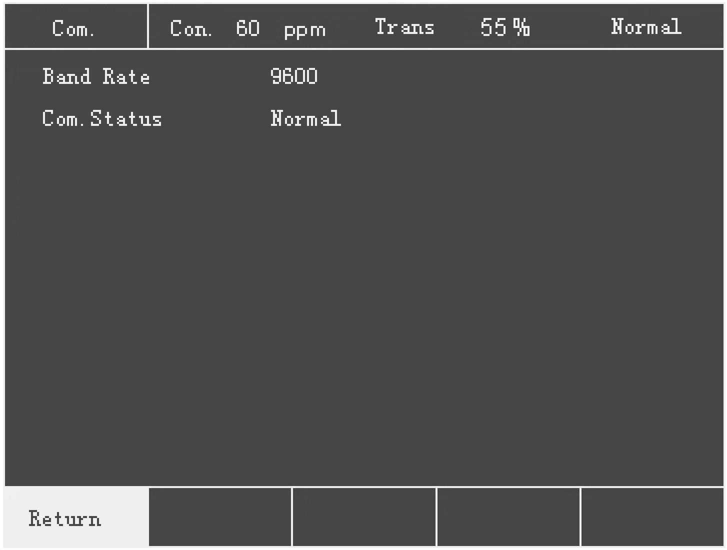


Figure 4.29 Com. Main menu

4.3.6 Alarm

Alarm is the fifth button from left on the Main Menu. Here the operator can read system alarm information, modify alarm settings and read previous alarm records.

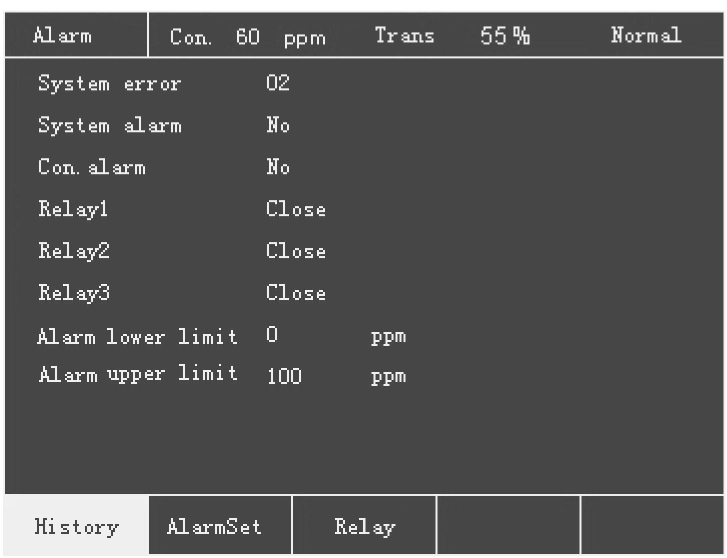


Figure 4.30 Alarm main menu

Items displayed on the Alarms screen (Figure 4.30) are:

- System error: The latest system error
- System warning: The latest system warning
- Con. alarm: The latest concentration alarm
- Relay1: The status of warning alarm relay
- Relay2: The status of error alarm relay
- Relay3: The status of concentration alarm relay
- Alarm lower limit: The lower limit of the concentration alarm range
- Alarm upper limit: The upper limit of the concentration alarm range

The functions of the buttons on the AlarmSet screen are:

History: The last 20 alarm records after entering this sub menu can be examined (Figure 31).

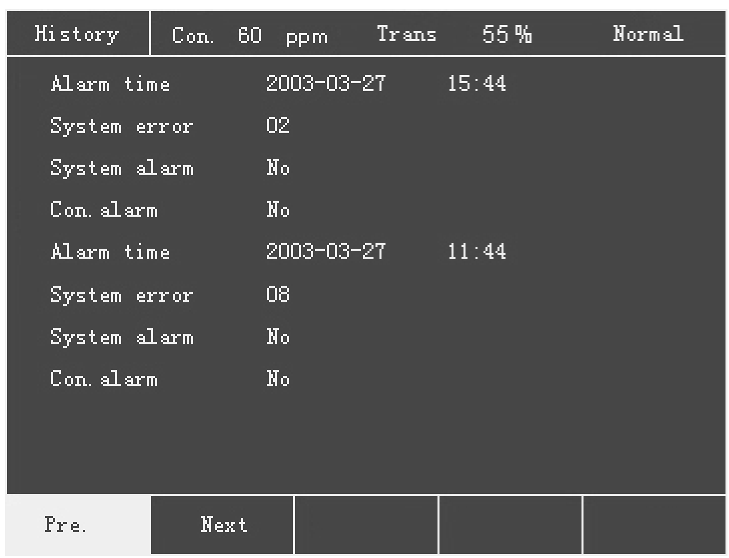


Figure 4.31 Alarm History Menu

AlarmSet: The users can set the range of concentration alarm, enable the automatic recovery function of the alarm relays and set their recovery time. (Figure 4.32)

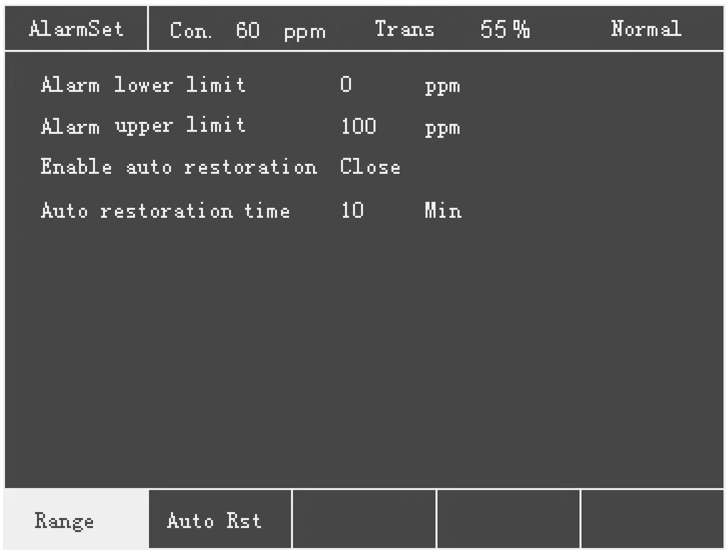


Figure 4.32 AlarmSet menu

There are two buttons on AlarmSet menu: alarm concentration and automatic recovery.

- Alarm concentration: Here you can set the concentration for triggering a low and high alarm. (Figure 4.33)
- Automatic restoration: Here you can set whether the alarm relay restores automatically after the alarm is cleared as well as the corresponding restoration time. The alarm relay restoration time is the time it takes for the alarm relay to return to the non-alarm or closed state. (Figure 4.34 and Figure 4.35)

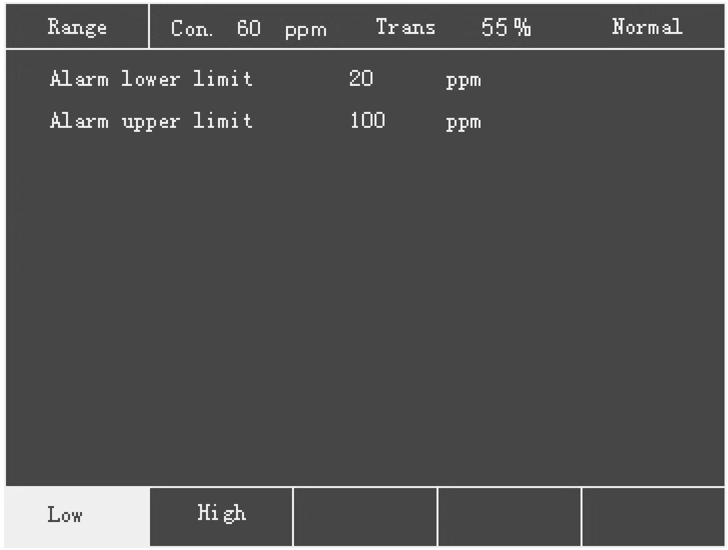


Figure 4.33 Alarm concentration range menu

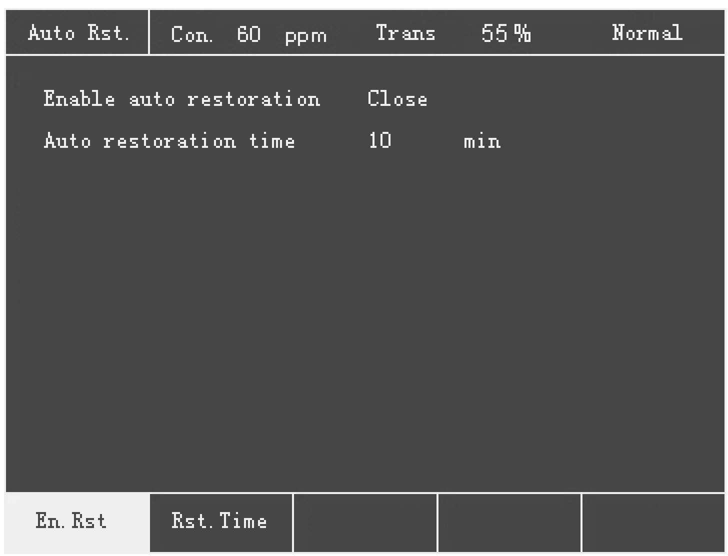


Figure 4.34 Menu to set automatic restoration

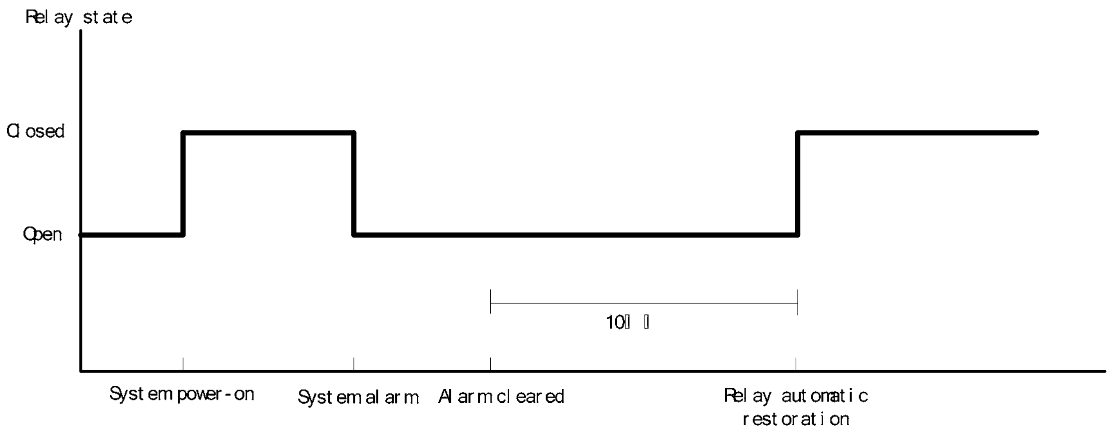


Figure 4.35 Time sequence of the alarm relay automatic restoration

Relay: Here you can query and set the relay status after entering relay menu. (Figure 4-36).

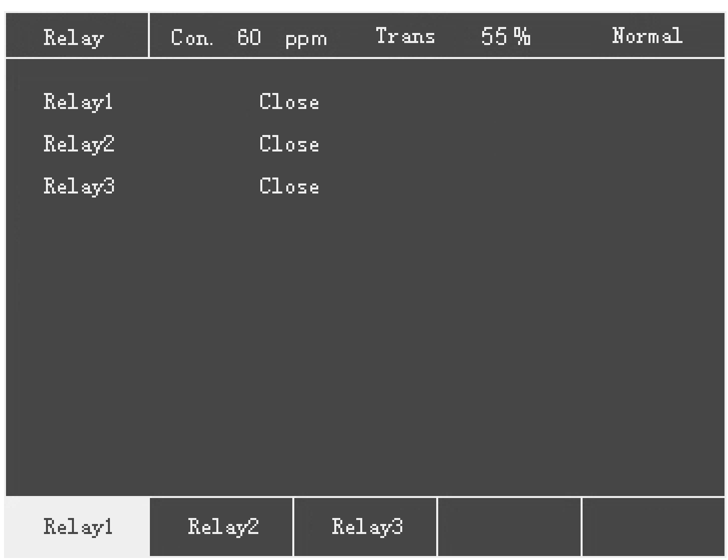


Figure 4.36 Relay Menu

4.3.7 Additional Menus

Three additional screens exist which are automatically invoked depending on the status of the instrument. These are: Message Code, Password Input, and Protection Mode Menu.

4.3.7.1 MESSAGE CODE:

Whenever there is an error, warning, or alarm, the system automatically switches to MainMenu in graphics mode, and the corresponding alarm icon and alarm code appear on the menu See Figure 4.37. The specific message codes are listed in section 5.3.

The icon is displayed when a warning or concentration alarm. Is triggered

The icon is used for an error.

For alarms represented by (warning or concentration alarm), the symbol disappears automatically when the alarm is cleared, and the alarm code changes to “Normal”. The alarm relay, however, does not go back to the “Close” state right away (see Automatic Restoration, Clear Alarm Button).

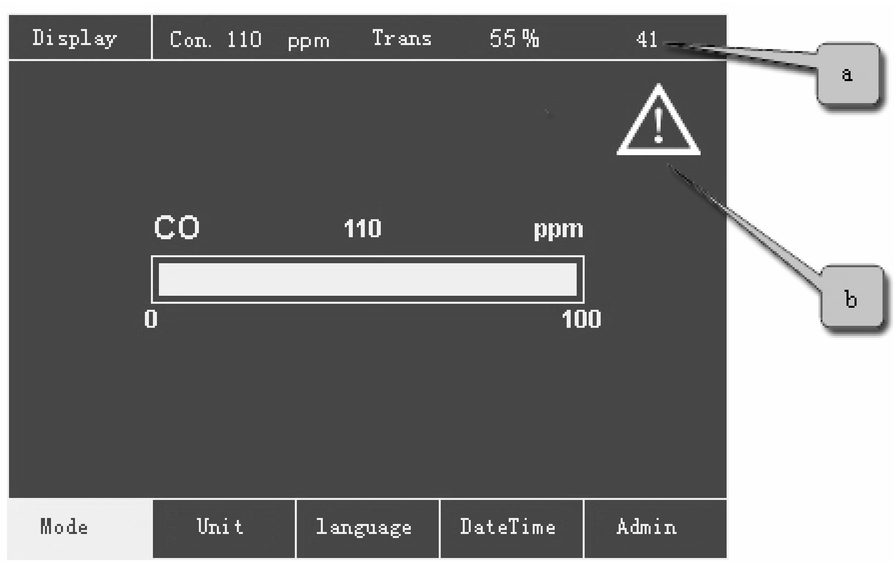


Figure 4.37 Message code interface

The call outs on Figure 4-37 refer to:

a. Message Code

b. Alarm Icon

4.3.7.2 PASSWORD INPUT:

A password is required to enter system menu, cali. menu or admin. menu. This is incorporated to protect the system from being modified by unauthorized personnel.

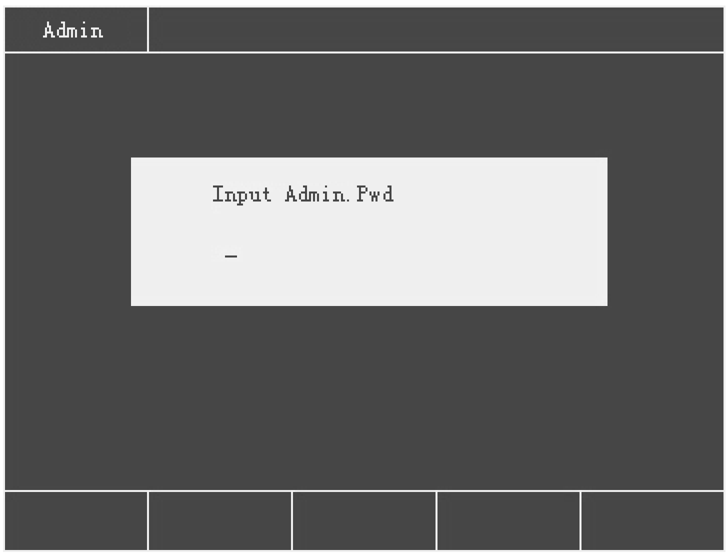


Figure 4.38 Password input interface

4.3.7.3 ERROR PROTECTION MENU:

When the system is in error mode it is not possible enter the system or calib. menu. Pressing “SET” when the cursor is on System or Calib. brings up a special screen indicating that the system is protected. (Figure 4.39).

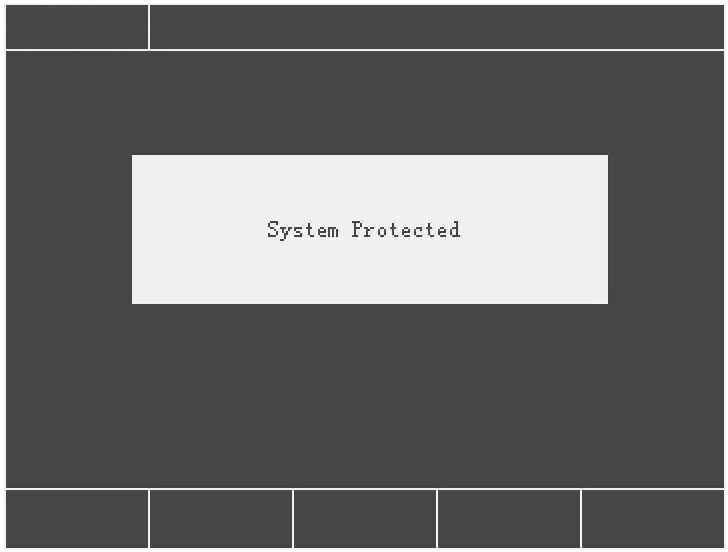


Figure 4.39 Error Protection Menu

Alarm Messages

Alarms installed in the Model 3500 include a 3-Channel Relay Alarm, a 4-20mA output alarm, and LCD display of alarm information.

5.1 Relay Alarm

The 3-Channel Relay in the Model 3500 is set up as follows:

Relay 1—warning alarm relay

Relay 2—error alarm relay

Relay 3—concentration alarm relay

The concentration alarm relay is triggered when the measured gas concentration has exceeded the high or low limits set by the user. When this occurs, the relay opens indicating that the current concentration is out of the set range.

The warning alarm and error alarm when triggered indicate that the system working status is abnormal (warning status in normal mode and system error).

Table 5.1 shows the relay and output state for various operational modes of the model 3500.

5.2 4-20mA Analog Output

When the system status is normal, the 4-20mA analog output represents the measured gas concentration. In general, 4-20mA corresponds to the user-defined measurement range. 4mA corresponds to the minimum value of the user-defined measurement range and 20mA corresponds to the maximum. When the system encounters an error and enters error mode, the output of the 4-20mA port is 2mA.

CAUTION: **2MA DOES NOT REPRESENT MEASURED GAS CONCENTRATION. IT ONLY SHOWS THAT THE ANALYZER HAS ISSUED AN ERROR ALARM.**

Table 5.1 Relays and output status for Various Operation Modes

System Working Status		LCD Status Bar	LCD Alarm Icon (Graphics Mode)	Relay			4-20mA Output
				Warning Alarm (Relay_1)	**Error Alarm (Relay_2)**	**Concentration Alarm (Relay_3)**	
Power-off		No	No	Open = Alarm	Open = Alarm	Open (Alarm)	0mA
Start-up Mode		No	No	Closed = No Alarm	Closed = No Alarm	Closed = No Alarm	0mA
Normal Mode	**Normal Status**	Normal	No	Closed = No Alarm	Closed = No Alarm	Depending on gas concentration	4-20mA
	Warning Status	Alarm Message Code	⚠	Open = Alarm	Closed = No Alarm	Depending on gas concentration	4-20mA
Error Mode		Alarm Message Code	⊗	Open = Alarm	Open = Alarm	Closed = No Alarm	2mA

5.3 LCD Alarm Message Display

When the Model 3500 enters an alarm condition an alarm message is displayed on the LCD screen. Detailed descriptions and solutions of these messages are listed in Table5.2.

.

Table 5.2: LCD Display Alarm Messages

Alarm Code on LCD	Possible Cause of the alarm	Relay Status a. Warning Alarm b. Error Alarm c. Conc. Alarm (O=Open C=Closed)	4-20mA Output	Trouble shooting
02 **03** **11** **13** **15** **17** **18** **57** **58**	Model 3500S has internal system error	a=O b=O c=C	2mA	Write down the alarm code; power off the system; reboot the system in an hour; If the same alarm persists, contact technical support center.
05/06	The temperature inside the Model 3500S central processing unit is too high/low.	a=O b=O c=C	2mA	Power off the system; check whether the environment temperature inside/outside of the central processing unit is abnormal; reboot the system after making sure that the temperature is normal. If the same alarm persists, contact the technical support center.
08/09	The laser temperature is too high/low.	a=O b=O c=C	2mA	Power off the system; reboot the system in an hour; If the same alarm persists, contact the technical support center.
20	Background radiation is too strong during system self test.	a=O b=O c=C	2mA	Power off the system; reboot the system in an hour; If the same alarm persists, contact the technical support center.

31/32	The pressure of the gas environment under test exceeds the Model 3500S application limit.	A=O b=C c=X X means that it depends on the gas concentration value.	4-20mA, the exact number is from calculation.	The gas concentration is calculated with the pressure limit; check the gas pressure in the environment under test. *Note: In this situation, the calculated concentration may be inaccurate*.
33	The sensor used to measure gas pressure is not wired correctly.	a=O b=C c=X	4-20mA, the exact number is from calculation.	The gas concentration is calculated with the default pressure value; check the wiring and working condition of the pressure sensor. *Note: In this situation, the calculated concentration may be inaccurate.*
35/36	The temperature of the gas environment under test exceeds the Model 3500S application limit.	a=O b=C c=X	4-20mA, the exact number is from calculation.	The gas concentration is calculated with the temperature limit; check the gas temperature in the environment under test. *Note: In this situation, the calculated concentration may be inaccurate.*
37	The sensor used to measure gas temperature is not wired correctly	a=O b=C c=X	4-20mA, the exact number is from calculation.	The gas concentration is calculated with the default temperature value; check the wiring and working condition of the temperature sensor. *Note: In this situation, the calculated concentration may be inaccurate.*
41/42	Current measured gas concentration exceeds the user-defined range	a=C b=C c=O	4-20mA, the exact number is from calculation.	
43	Model 3500S EEPROM fault	a=O b=O c=C	2mA	Power off the system; contact the technical support center.

45	During the measurement process, the laser power is too high or the background light is too strong	a=O b=C c=X	4-20mA, the exact number is from calculation.	Reboot the system; If the same alarm persists, and there is no strong background light in the gas flow pipe under test, contact the technical support center.
48	The measured gas concentration exceeds Model 3500S upper limit for 1 minute.	a=O b=C c=X	4-20mA, keep the last measured value	f the same alarm persists, and the gas flow is not abnormal, contact the technical support center.
59	Low transmittance due to contamination to the optical window or the dust density in the environment under test exceeds normal range.	a=O b=C c=X	4-20mA	Power off the system; clean the optical windows (follow the instructions in Users' Manual); If the same alarm still persists, contact the technical support center.
99	Model 3500 internal communication error alarm (the status shown on LCD may not reflect the actual system working status).	a=C b=C c=C	4-20mA, the exact number is from calculation.	Power off the system; reboot the system in an hour; If the same alarm persists, contact the technical support center.

Maintenance and Calibration

The Model 3500 Laser Gas Analysis System needs to be maintained and calibrated periodically to ensure it is working properly.

6.1 Maintenance

There are no user serviceable parts within the Model 3500. Daily preventive maintenance is limited to:

- Checking and adjusting the purge gas flow
- Visually inspecting and cleaning the optical devices
- Optimizing the optical transmission.

The Model 3500 Laser Gas Analysis System incorporates a purging system to protect the optical parts in the transmitter unit and the receiver unit from contamination by dust, water vapor, and process gas deposition. Maintaining an appropriate purge gas flow rate is a key factor in its ability to keep the components functioning. However, dust and other pollutants in the environment still could contaminate the optical parts during extended operation of the system which would result in lower the transmittance between the transmitter and receiver as well as influence the overall performance of the system. For this reason it is important to clean the optical parts periodically. Drift in the optical transmission alignment may also occur after a period of time, and needs to be re-adjusted and optimized periodically.

The Model 3500 uses specially designed signal processing circuits. As long as signal voltage from the sensor is no less than 30% of its normal value, the system measurement and analysis performance is not affected. It greatly reduces the demand of cleaning the optical parts and re-adjusting the optical transmission alignment.

6.1.1 Adjusting the Purge Gas Flow

The purge system is equipped with a gas regulator which provides steady purge gas flow even when the gas source pressure fluctuates over a large range. However, if excessive dust or other particles are present in the purge gas source, the filter may clog after a period of time. This will result in a fluctuation flow rate.

When a drop in the flow meter reading occurs, adjust the needle valve (Figure 3.6) on the apparatus to increase the flow rate. If the required flow rate cannot be achieved by opening the needle valve, the filter is probably clogged and needs to be replaced.

To replace the filter cartridge:

1. Turn off the purge gas source.
2. Remove the screw on the side of the purge housing and remove the filter (Figure 3.6).
3. Open the filter, and replace the old filter cartridge with a new one. See the Parts Listing in the Appendix for the proper part number for your instrument.
4. Reinstall the filter into the housing and fasten the screw.
5. Turn on the purge gas source.
6. Adjust the needle valve and set the flow rate to its the required value.

CAUTION: **DO NOT SHUT OFF THE PURGE SYSTEM TO CHANGE THE FILTER CARTRIDGE WHEN THERE IS GAS FLOW IN THE ENVIRONMENT UNDER TEST. POLLUTANTS IN THE ENVIRONMENT COULD DAMAGE THE OPTICAL PARTS.**

6.1.2 Clean the Optical Parts

For most applications, the time interval to do optical parts cleaning usually exceeds 3 months. Even for highly dusty applications, with proper purging, the optical parts are kept clean for a relatively long time. TAI recommends cleaning the system optical parts once every two or three months to ensure that the system will run continuously and dependably with minimum downtime. If the purge system malfunctions, check the optical parts for contamination.

The optical transmission information is shown on LCD screen. The transmittance decreases when the optical parts become dirty or the optical transmission alignment between the transmitter and receiver is off from the optimal position. The transmittance information thus can be used as an indicator to determine whether the optical parts need cleaning or adjustments to the optical transmission alignment are needed (see section 6.1.3). If there is no significant decline in transmittance, you can prolong the maintenance interval. When the transmittance does drop, shorten the maintenance interval.

In addition, the warning alarm relay triggers when the transmittance is lower than 30%. The corresponding alarm message appears on the LCD front panel (please refer to Table 5.2 for detailed alarm information) to remind the user to maintain the system.

Use the following procedure to clean the optical parts:

CAUTION: **LASER RADIATION CAN CAUSE DAMAGE TO THE EYES. POWER MUST BE DISCONNECTED DURING SYSTEM MAINTENANCE.**

CAUTION: **DO NOT REMOVE THE TRANSMITTER OR RECEIVER UNITS WHEN THERE IS GAS FLOW IN THE ENVIRONMENT UNDER TEST WITHOUT FIRST CLOSING THE VALVE BETWEEN THE UNITS AND THE PROCESS FLOW.**

1. Turn off the power supply to make sure that the transmitter unit does not emit during the maintenance process.
2. Loosen the mounting nut and remove both the transmitter unit and the receiver unit from the instrument flanges. Make sure the cable connection between the transmitter unit, the receiver unit and the central processing unit are not affected.
3. Check the contamination of the optical parts and look for possible damage (such as cracks). If there is any damage to the optical part, they must be replaced (Please contact TAI technical support center).
4. Clean the optical parts with a mixture of alcohol and ether, then dry with clean compressed air.
5. If the optical parts cannot be cleaned completely, they should be replaced . (Please contact TAI technical support center).
6. Reinstall the transmitter and receiver units, and turn on the power supply.

After initialization and self test, if the transmittance shown on LCD is still low (lower than 80%), optimize the optical transmission alignment according to instructions in section 6.1.3.

6.1.3 Optimize the Optical Transmission Alignment

For optimum analysis TAI recommends that you readjust and optimize the optical transmission alignment twice a year. Refer to section 3.6 for the specific optimization procedure and steps.

The Model 3500 automatically monitors the working conditions of all key units. The system will prompt when specific unplanned maintenance is needed. The above maintenance procedures are for preventive purposes. If other system malfunctions occur, please contact our technical support center immediately.

6.2. Calibration

All Model 3500 analysis systems are calibrated at the factory and do not need calibration the first time they are used. However, with time, system parameters may drift due to gradual aging of the laser device and electronic parts in the system. This will affect measurement accuracy. Therefore, periodic recalibration is necessary. Compared to the conventional analysis systems such as the NDIR systems, the Model 3500 has a long calibration interval (over 3 months) due to its advanced measurement principles and special low drift design.

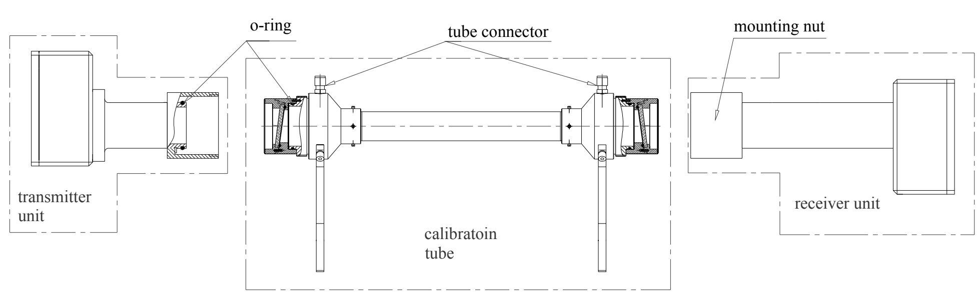


Figure 6.1 Schematic of the calibration setup

Always bear in mind that the measurement accuracy of the system is determined by the accuracy of its calibration. With this in mind, determine first if the system needs calibration. When it is indeed necessary, make sure it is performed correctly. We suggest that you use the calibration tube that comes with the system from TAI. Figure 6.1 is the schematic of the calibration setup. The calibration is performed either by operating the keyboard of the LCD front panel on the central processing unit or through a PC connected to the central processing unit through the RS232 port.

The concentration of the calibration gas depends on both the system's measurement range and the environment temperature. If the concentration is too high, it can saturate the measurement signal. If the concentration is too low, the calibration accuracy would be affected because the calibration tube and the connection tubes absorb some of the gas, and the background noise would be large with respect to the signal. **Calibration gas should be a mixture of nitrogen and the gas under test, and the concentration of the gas under test is set according to the calibration requirement.**

When calibrating some highly absorptive gases (such as H_2O, HCl, HF and NH_3), especially if the measurement range of the system is small, special care should be taken as the calibration tube and the connection tubes could absorb a significant amount of the gas and severely affect the calibration accuracy. When calibrating these gas species, it is strongly recommended to:

- Use short tubes for connection, especially those used to connect the standard gas container to the calibration tube.
- Make sure calibration devices and connection tubes are dry. Purge them with dry clean nitrogen a few times before injecting the standard calibration gas.
- Before starting the calibration process, purge the calibration tube a few times with the standard calibration gas.
- Use relatively large flow rate, such as 5 L/min.
- Connect the calibration system with Teflon tubes.
- Wait till the measured gas concentration value is stable.

Observe whether the measured gas concentration value changes much when the flow rate is increased. If it doesn't, then the gas absorption by the calibration tube and the connection tubes are negligible.

6.2.1 Calibration Procedure

To calibrate the system, follow the procedure listed below:

1. Turn off the system power supply.
2. Loosen the mounting nut and take off the transmitter unit and the receiver unit (Figure 6.2). Check the optical parts for cracks, dust or other contaminants. If damage or contamination is evident refer to section 6.1.2 to clean and maintain the optical parts.

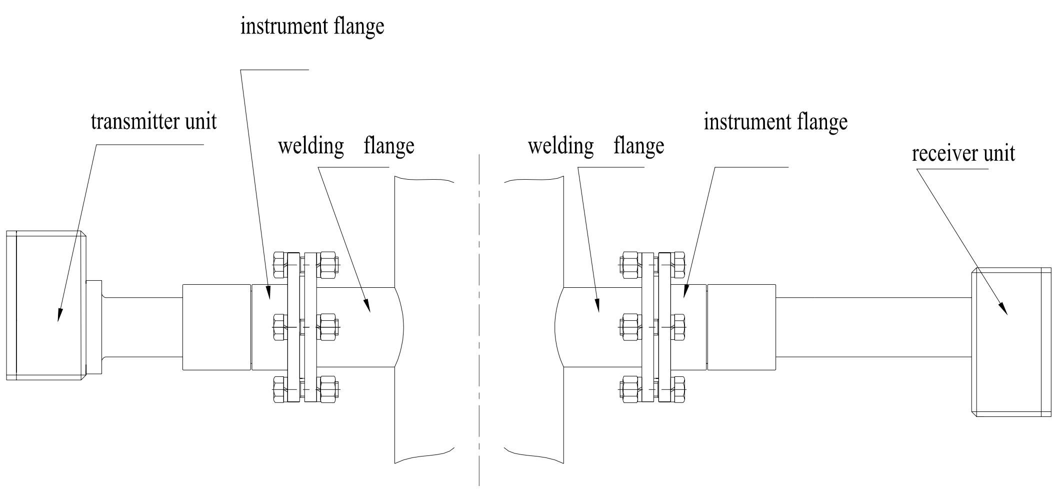


Figure 6.2 Removing the Transmitter Receiver Units

3. Mount the transmitter and receiver units to the flanges at the each end of the calibration devices, then and fasten the locknut (Figure 6.3)

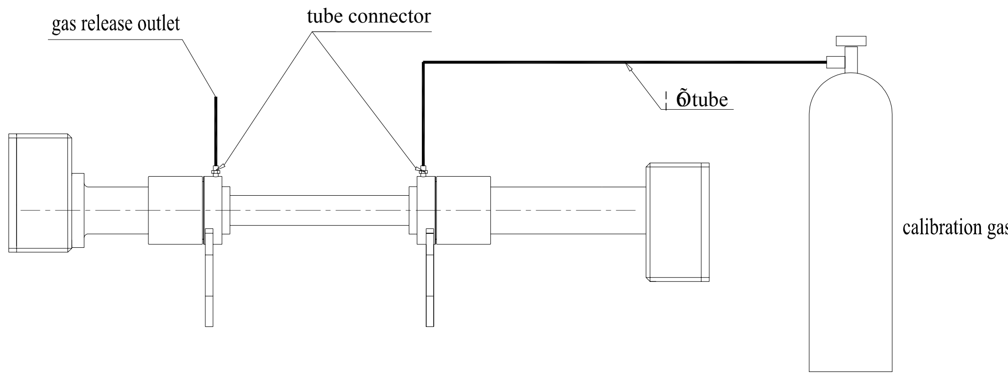


Figure 6.3 Schematic of the connection of calibration gas transport tubes

4. Before starting the calibration, turn on the system power and wait for at least an hour.

Note: The instrument and electronics must be thermally stable. If the temperature of the sample site (or where the receiver and transmitter and calibration tube are located) fluctuates, the stabilization period may be longer than one hour.

5. If you are using the PC service program to calibrate, run the PC service program. If you calibrate the system with the system front panel, go to the next step.
6. Start the zero gas flow into the calibration system. Wait until the gas concentration has stabilized then run the zeroing program in the PC service program or from the system front panel.
7. Set the optical path length of the calibration tube (refer to the calibration parameter table that comes with the system). Set the calibration gas concentration, temperature and pressure. For increased accuracy, the temperature and pressure of the calibration gas should be measured directly with temperature and pressure sensors.
8. Switch from zero gas to span gas (standard gas with a concentration that is recommended in the calibration parameter table). Once again, wait until the span gas concentration has

stabilized then run the calibration program in the PC service program or from the system front panel.

9. Remove the transmitter and the receiver units from the calibration devices and remount them onto the instrument flanges.

10. Reset the optical path length, environment temperature and environment pressure parameters for the environment under test.

CAUTION: **RESETTING THE OPTICAL PATH LENGTH IS NECESSARY. WITHOUT CORRECT PARAMETERS, THE SYSTEM CANNOT ANALYZE THE GAS CONCENTRATION CORRECTLY.**

CAUTION: **DO NOT CALIBRATE THE SYSTEM WHEN THERE IS AN ERROR OR WARNING ALARM MESSAGE ON LCD.**

CAUTION: **DO NOT CALIBRATE WHEN THERE IS GAS FLOW IN THE ENVIRONMENT UNDER TEST AND THE VALVE (IF INSTALLED) IS NOT CLOSED. THE PROCESS GAS COULD ESCAPE INTO THE ROOM OR AIR COULD ENTER THE PROCESS PIPE.**

6.2.2 Calibration Software

Calibration of the Model 3500 can be performed by using the front panel on the central processing unit or from a PC connected to the central processing unit through RS232 interface. When you choose the former method, please follow the instructions in section 4.3.4. If you choose the PC option, please follow the PC service program instructions in Appendix A. If you use the calibration tube available from TAI, please refer to the calibration parameter table that comes with the system.

Extended Communication Functions

The demand for networked, intelligent, and automated analysis systems is increasing. In addition to advanced remote data communication capabilities, users also want the systems to be equipped with remote communications and system management functions such as wireless data transmission, capability for setting system parameters and upgrading system software remotely through wireless networks. To meet our customers' needs, the Model 3500 series of instruments provide a GPRS based wireless remote data communications interface as a supplement to their 4-20mA output port and RS232 local communication port.

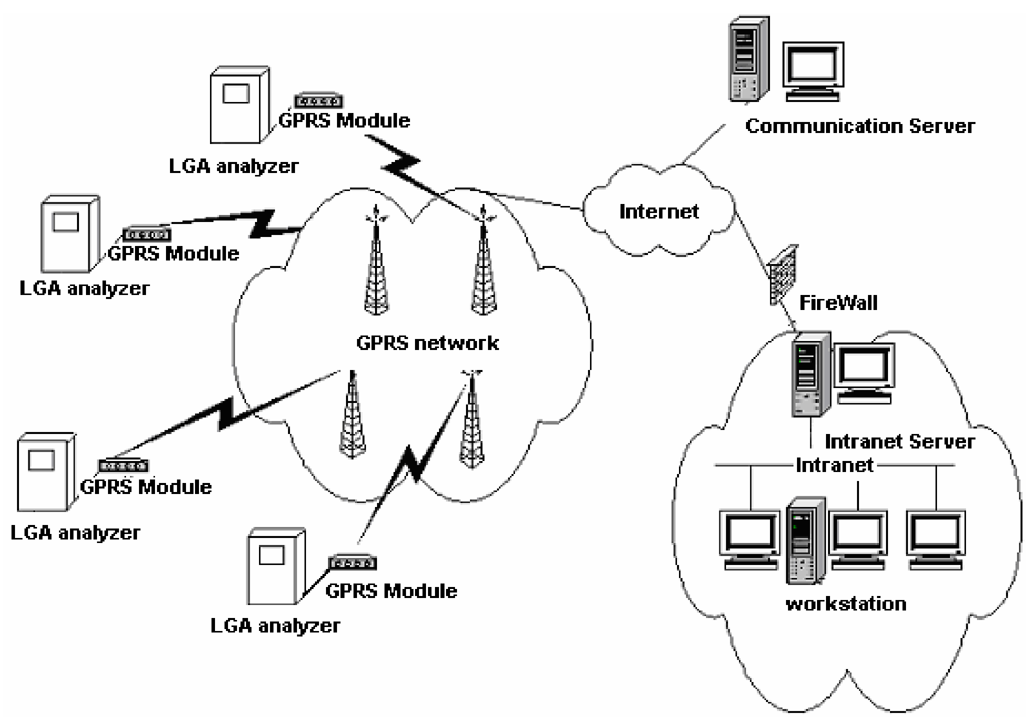


Figure 7.1 Schematic for Networked Multiple-point Remote Measurement on Model 3500 Systems

The main functions of this implementation are:

- **Remote data communications:** Data include the concentration, pressure, temperature, etc. of the gas under test.
- **Remote query and setting of system parameters:** Enables quick data analysis and remote system diagnosis. This greatly improves the turn-around time as well as the accuracy of after-sales technical support and services.
- **Wireless system software updating:** New versions of the system software and custom-made software can be uploaded into the system remotely through GPRS wireless networks.

Centralized monitoring of multiple measurement points: Using one single service program to collect data wirelessly from multiple measurement points.

Appendix

Specifications

Technical Features	Optical path length (OPL)	≤ 12m
	Response time	< 1s
	Linear accuracy	≤ ± 1% FS
	Span drift	≤ ± 1% FS (within maintenance interval)
	Zero drift	Negligible
	Warm-up time	< 1hour
	Maintenance interval	< 4 times/year (no replacement parts)
	Calibration interval	<4 times/year
Input & Output Signal	Analogue output	4~20mA current loop, 500Ω Max, isolated
	Digital output	RS232/GPRS
	Relay alarm	3-Channel (Relay Specification: 220V, 0.5A)
	Analogue Input	4-20mA environment gas temperature, pressure input (optional)
Operation conditions	Environment temperature	-20□—50□ (adjustable upon customer request)
	Protection class	Transmitter/ Receiver: IP65
	Power supply	220 VAC, 50Hz, <30W
	Purging gas	N_2, etc.

Installation	Mounting method	Use DN50/PN2.5 flanges to install transmitter and receiver
Dimension and Weigh	Transmitter/Receiver Unit	260×200×150mm, 10kg
	Connecting Unit	385×150×160mm, 10kg
	Central processing unit	400×320×170mm, 10kg

Recommended Spare Parts List

Qty.	Part Number	Description

A minimum charge is applicable to spare parts orders.

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

Orders should be sent to:

TELEDYNE Analytical Instruments

16830 Chestnut Street
City of Industry, CA 91749-1580

Phone (626) 934-1500, Fax (626) 961-2538

Web: www.teledyne-ai.com
or your local representative.

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