ML®SM8175
SO_2 and NO Analyzer
Operation and Maintenance Manual

CE

TELEDYNE INSTRUMENTS
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Table of Contents

Table of Contents

Table of Contents

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1.1.0 Introduction

1.1 Purpose of the Manual

This manual is written for the control room operator, maintenance technician, and plant personnel who use the SM8175. It provides system description, function, theory, installation, operation, and maintenance information.

Note

This manual is intended to be used in conjunction with the *LS710 Control Unit Operation and Maintenance Manual*, which provides detailed information on the configuration and setup of the analyzer within the menu structure.

1.2 Purpose of the SM8175

The SM8175 SO_2 and NO process gas analyzer is a combined optical and electronic system that detects and measures sulfur dioxide (SO_2) and nitric oxide (NO) gas concentrations and temperatures in stack emissions.

By means of a fixed probe that protrudes through a stack wall into the gas/particle (effluent) stream, the SM8175 directly measures SO_2 and NO without disturbing or modifying the effluent. Gas concentration measurement is independent of the effluent flow rate.

Note

NO_X is the sum of NO and NO_2 in the gas stream. However, due to high temperatures, combustion processes produce 95% to 99% NO out of the total NO_X emission. The 1% to 5% difference is well within US EPA relative accuracy requirements and can be corrected using a 1.01 to 1.05 multiplier.

The instrument uses a UV (ultraviolet) analytical technique known as *second-derivative spectroscopy*. Use of this technique results in high measurement sensitivity to low SO_2 and NO concentrations and rejection of other stack gases that may cause interference with less sophisticated systems. The second derivative signal is further unaffected by changes in light level which may result from light source aging or the slow buildup of dust on the optical surface exposed to the stack gas.

1.3 Theory of Second-Derivative Spectroscopy

Two definitions basically describe the second-derivative spectroscopic measurement technique. Spectroscopy is the empirical observation of changes in light absorption caused by molecules absorbing light energy in specific wavelength regions (λ) around and including discrete wavelengths that are called peak absorption wavelengths (λ_o). Second-derivative spectroscopy is the measurement of the amount of curvature in a narrow wavelength band around λ_o.

1.3.1 General Explanation

The spectrum of interest is a continuous distribution of light wavelengths that is part of the total electromagnetic wave spectrum. The light spectrum extends from infrared through visible to the far ultraviolet, a wavelength range of about 5×10^{-2} cm (0.05 centimeter) to 5×10^{-7} cm (0.0000005 centimeter). Figure 1-1 below shows the light spectrum.

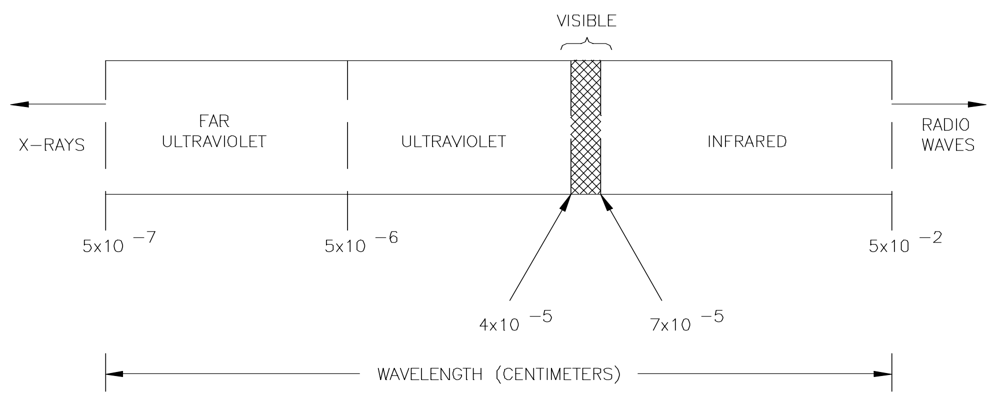
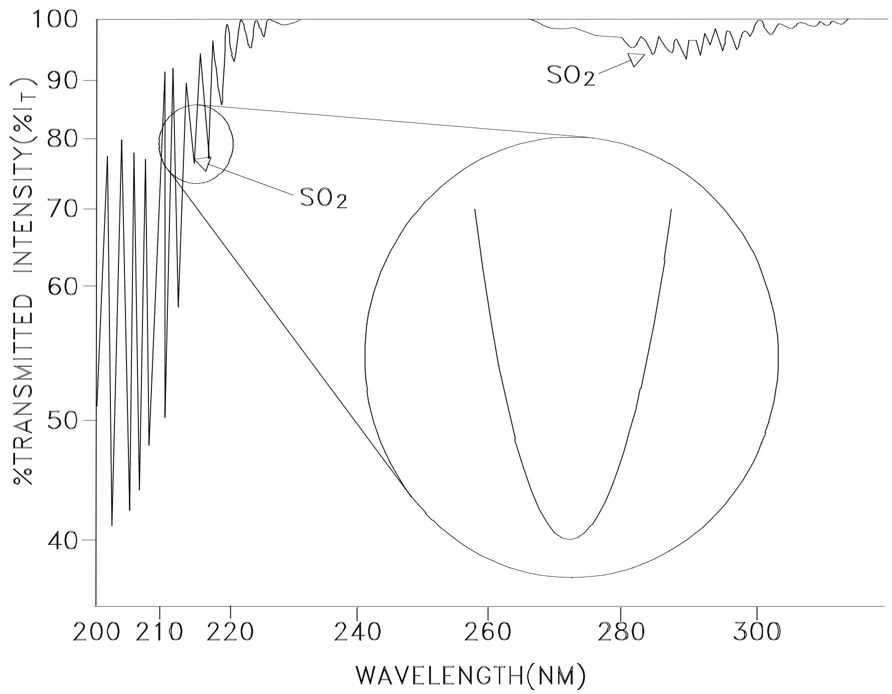


Figure 1-1. Light Spectrum

All atoms and molecules absorb incident light energy in many narrow wavelength regions throughout the light spectrum. The distribution of these regions of absorption wavelengths is called an absorption spectrum. Figure 1-2 below shows a partial SO_2 absorption spectrum. Transmitted light intensity is less at wavelengths around and including peak absorption wavelengths than in the spectrum between them. Each atom or molecule has a unique absorption spectrum that distinguishes it from others.



$$\%I_T = \left(\frac{I_O - I_A}{I_O}\right) 100\%$$

WHERE: I_O =incident UV light intensity on SO_2

I_A =absorbed UV light intensity on SO_2

I_T =transmitted UV light intensity through SO_2

Figure 1-2. SO_2 Absorption Spectrum

The SM8175 is *optically tuned* to detect two specific peak absorption wavelengths, one of them unique to SO_2 and the other unique to NO. Note that the SM8175 measures the *second derivative* of the absorption spectrum. A peak absorption wavelength (minimum transmitted intensity) is also a peak second-derivative wavelength (maximum curvature). The NO and SO_2 peak absorption wavelengths monitored are 2.265×10^{-5} cm (226.5 nanometers) for NO and 2.185×10^{-5} cm (218.5 nanometers) for SO_2. These values appear within the ultraviolet NO and SO_2 *second-derivative* spectrums shown in Figure 1-3 below.

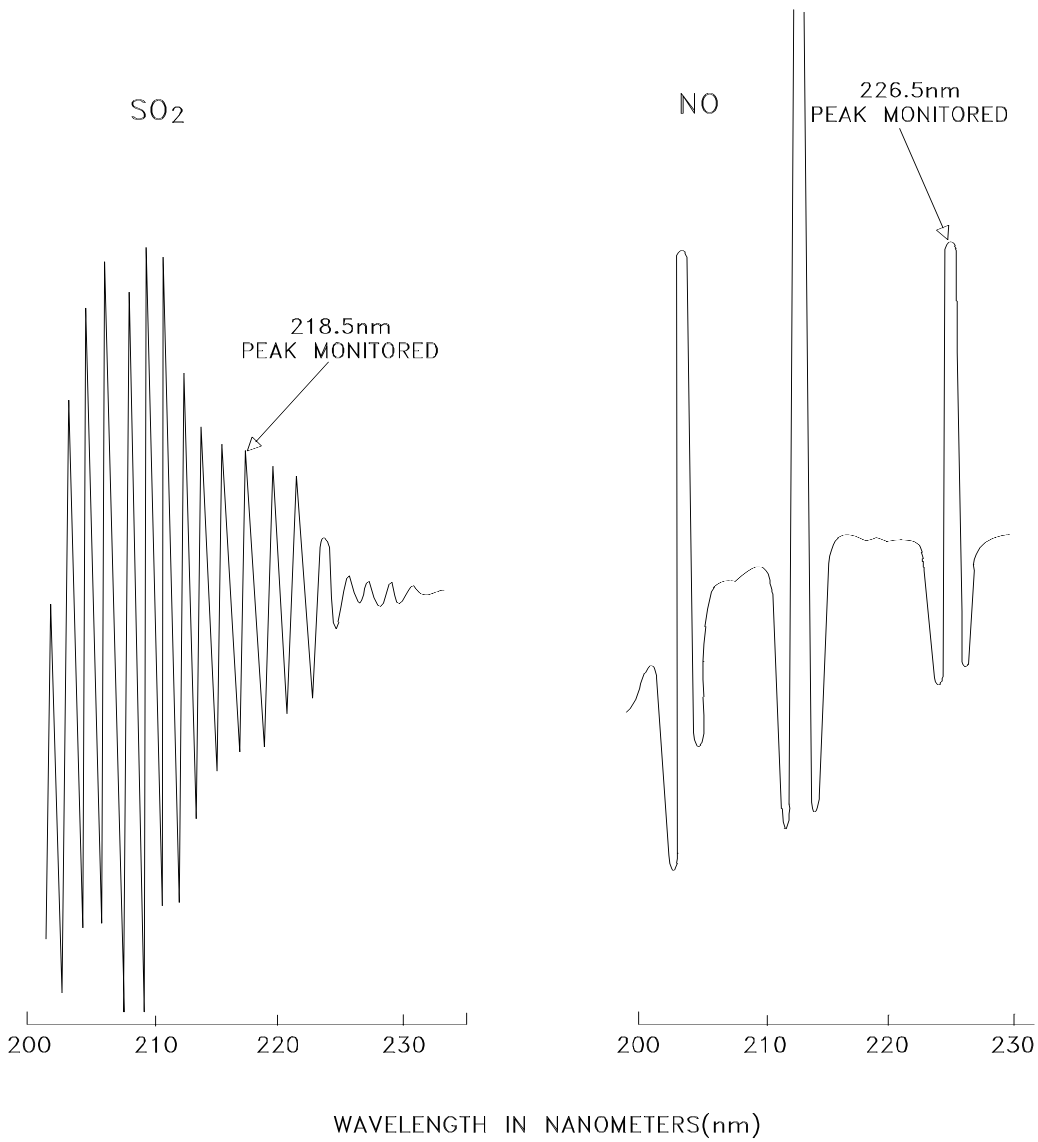


Figure 1-3. SO_2 and NO Second-Derivative Spectrums

Maximum curvature, maximum light absorption, and minimum transmitted light intensity all occur at peak absorption wavelength λ_o (see Figure 1-4 below). The amount of curvature (or second derivative) is directly proportional to gas concentration. See *Appendix B, Second-Derivative Spectroscopy Mathematical Theory*, for mathematical theory.

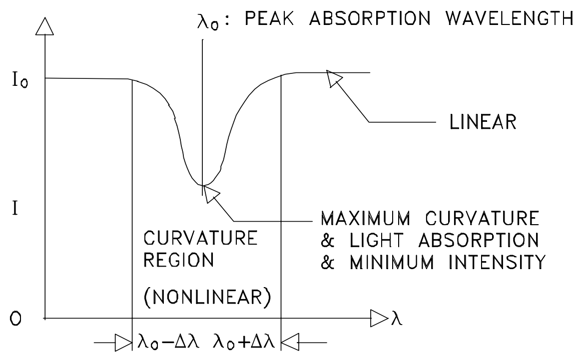


Figure 1-4. Absorption Spectrum Around Peak Absorption Wavelength (λ_0)

The SM8175 detects an AC signal corresponding to the second derivative of the absorption spectrum around a specific peak absorption wavelength. This signal is generated by wavelength modulation. In this process, the measured wavelength varies over time in accordance with a sinusoidal modulating waveform (F). The measurement signal induced by (F) is the second derivative, which varies at twice the modulating signal frequency (2F). The amplitude of the second-derivative signal is directly proportional the gas concentration (see *Appendix B*).

Figure 1-5 through Figure 1-8 below illustrate the generation of the AC second-derivative signal. A linear absorption curve showing light intensity (I) versus wavelength (λ) without peak absorption wavelengths present is illustrated in Figure 1-5. This type of response appears when there is neither NO nor SO_2, or at some band of wavelengths apart from any absorption wavelengths. The curve has a (negative) constant slope: a straight line without curvature. Because of this constant slope (absence of absorption curvature), the induced and modulating signal frequencies are equal.

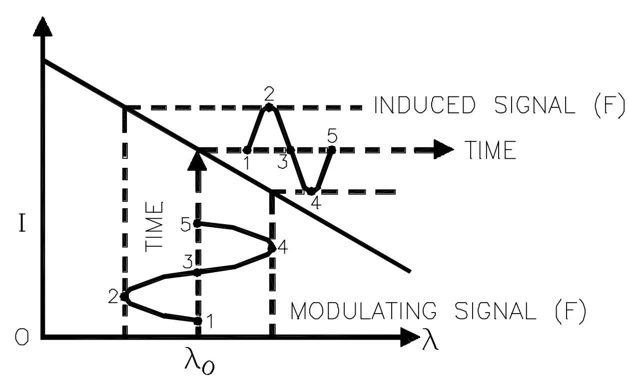


Figure 1-5. Absorption Curve: Modulated Without Curvature

In contrast, an absorption curve with a peak absorption wavelength (λ_o) and thus with curvature is shown in Figure 1-5. As the wavelength is modulated with frequency (F) about λ_o, the induced second-derivative signal (2F) can be traced point-by-point on the graph. Each identically-numbered point corresponds to simultaneous time between the two signals. By contrast, look at Figure 1-5 and Figure 1-6 and notice the difference in location of the induced signal points (1 through 5) for an identical (F) signal. Superimposing (2F) on (F) demonstrates that (2F) is twice (F) in frequency and is out of phase, except at 90° (see

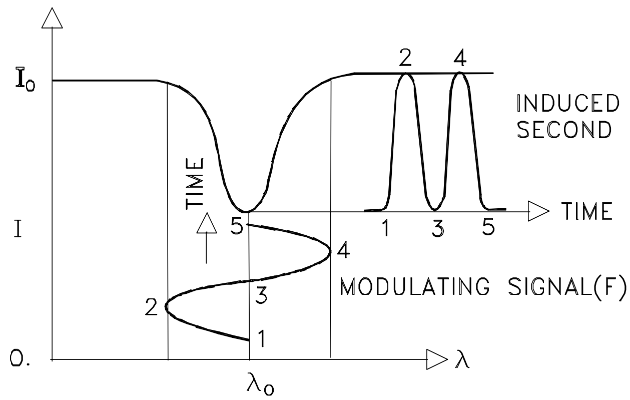


Figure 1-7).

Figure 1-6. Absorption Curve Modulated with Curvature

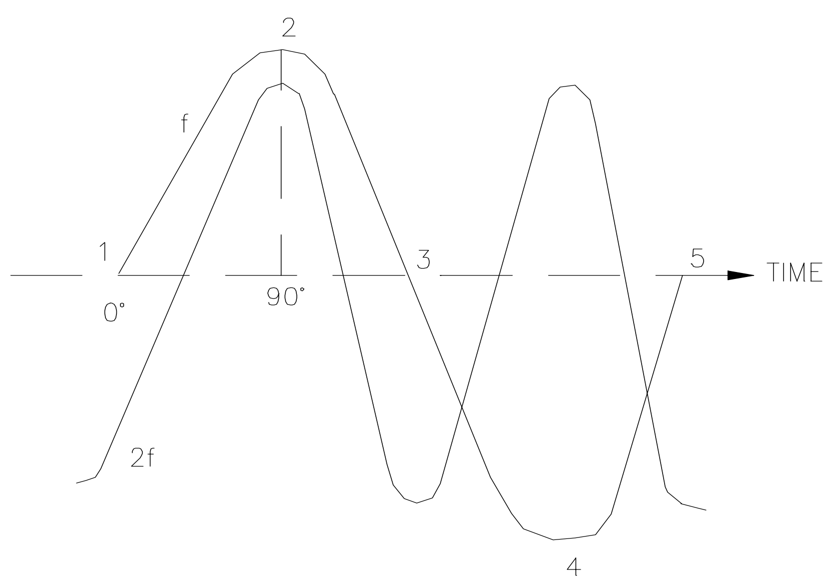


Figure 1-7. Induced Signal Superimposed on Modulation Signal

Figure 1-8 shows two absorption curves where curve 2 indicates greater light absorption and curvature caused by higher gas concentration than curve 1. This results in ($2F_2$) having greater light intensity amplitude than ($2F_1$).

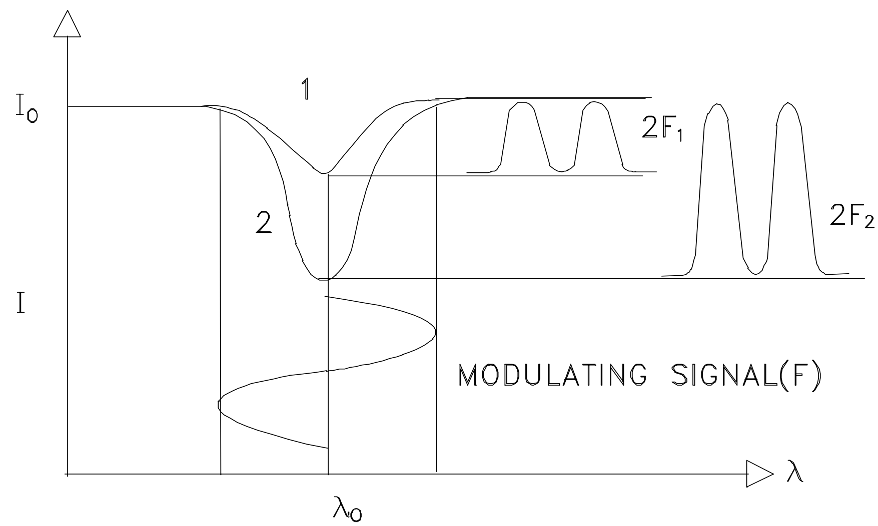


Figure 1-8. Two Absorption Curves with Different Curvatures Curve 2 Curvature Is Greater Than Curve 1 Curvature

Once the 2F second-derivative signal is established, it is processed using a ratiometric technique which ensures that measurement accuracy is unaffected by light level.

In summary, the second-derivative signal exists only when an absorption is present. The second-derivative signal amplitude increases or decreases relatively linearly with respect to increasing or decreasing gas concentration. The frequency of the second-derivative signal is twice the modulating frequency.

2.0 System Description

This section describes the SM8175 from a system point of view, relating to the System Block Diagram. Attention is focused on signal flow and functional blocks that can be used with the wiring diagrams included in *Chapter 9, Engineering Drawings*.

Figure 2-1 through Figure 2-7 follow section 2.1.

2.1 Basic Components

The SM8175 includes four basic components: probe, transceiver, J-box, and control unit (see Figure 2-1). The probe is physically joined to the transceiver. Signals flowing between the J-box and the transceiver are connected by the interconnect cable provided with the transceiver. The probe includes part of the optical system, the measurement cavity, the ceramic filter, and the thermal probe (see Figure 2-2). The interconnect cable to the controller is a variable-length RS422 communication link that transports signals between the J-box and the remote control unit.

The transceiver contains part of the optical system (UV lamp, monochromator, and PMT detector) and the electronics system (see Figure 2-3). The calibration access slot makes all electrical adjustments easily accessible so the cover does not have to be removed during a calibration adjustment. The electronics system is located on the transceiver printed circuit board (PCB) shown in Figure 2-4.

Figure 2-5 shows the front of the transceiver. The desiccant indicator shows the amount of moisture inside the transceiver. An external span cell can be inserted in the desiccant opening for performing a functional check. The purge tube passes air into the transceiver housing and exits through a hole in the lamp housing to expel ozone gases generated by the lamp. The thermal probe cable and purge tube connect to the transceiver. The thermal probe cable originates near the probe measurement cavity, and the purge tube comes from the J-box (see Figure 2-6).

The J-box is a terminal interface unit located between the transceiver and the controller. The J-box houses the serial data acquisition (SDA) board, pressure gauge and regulator, and lamp power supply board (see Figure 2-7). External AC power is connected to the transceiver at the J-box.

The controller is typically located in a control room away from the transceiver and J-box. It produces all of the system outputs (also displayed on the front panel of the unit). Chart recorders and other customer-supplied instruments can be connected to the back of the controller.

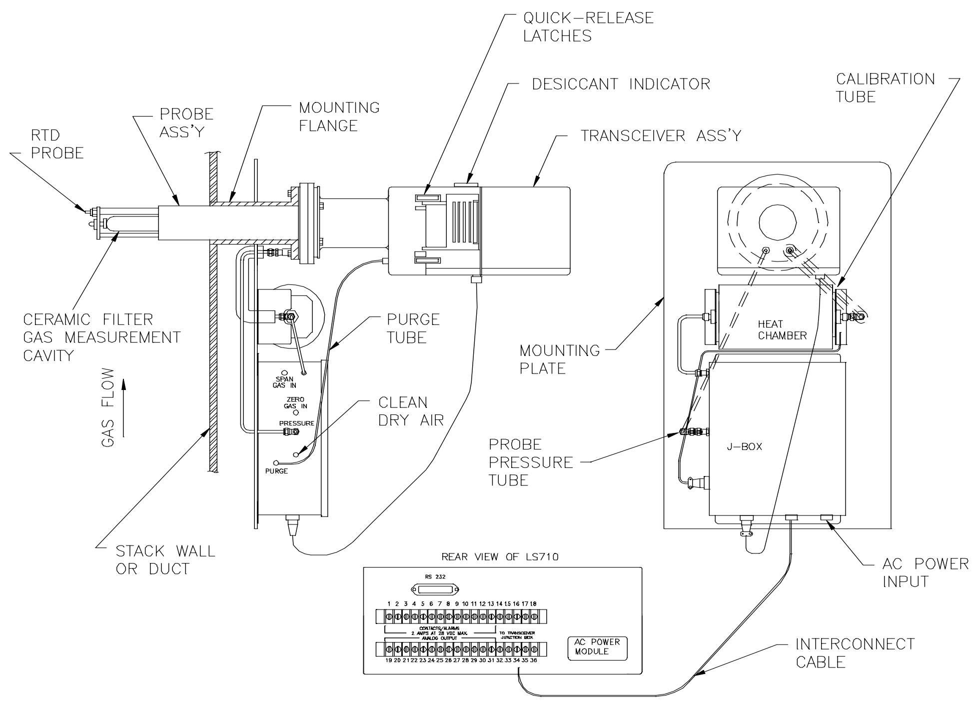


Figure 2-1. Basic Components, Side and Rear Views

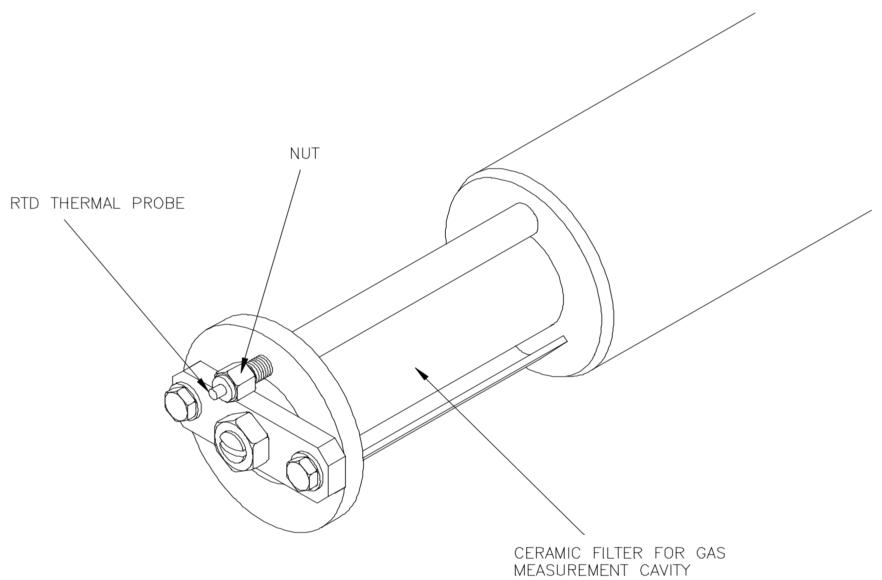


Figure 2-2. Standard SM8175 Probe for Measurement Cavities of 20 cm or Less

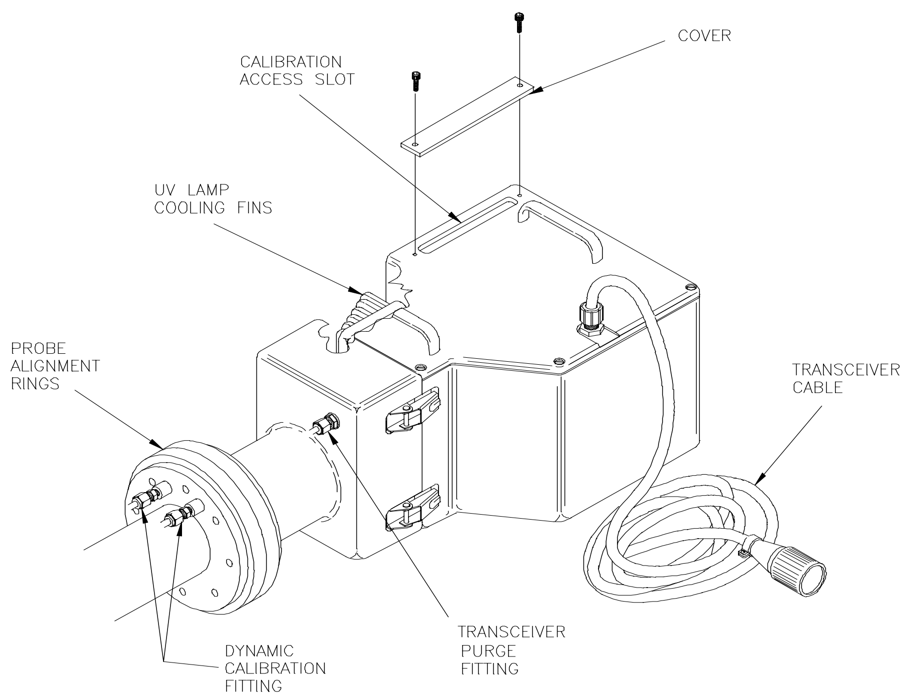


Figure 2-3. SM8175 Transceiver, External View

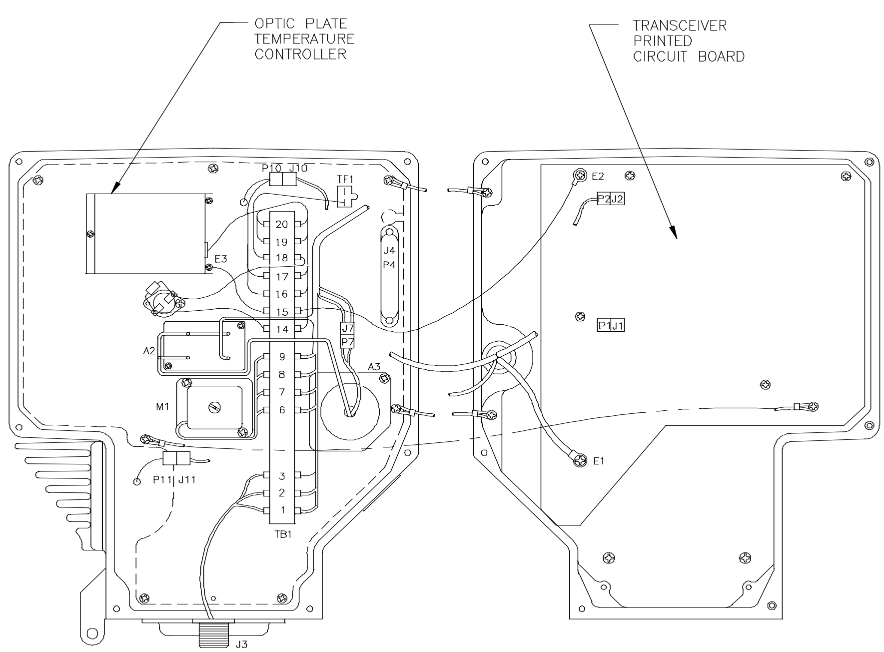


Figure 2-4. SM8175 Transceiver, Internal View

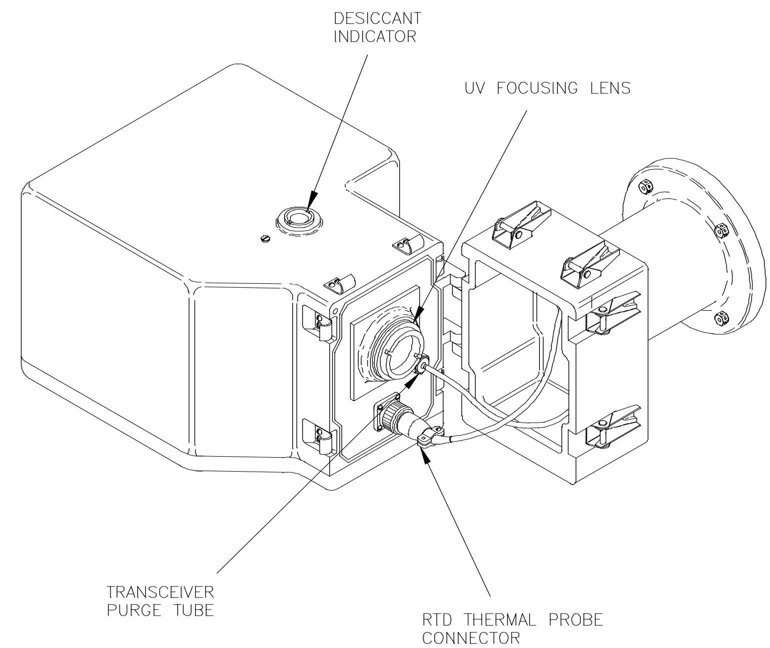


Figure 2-5. SM8175 Transceiver, Front View

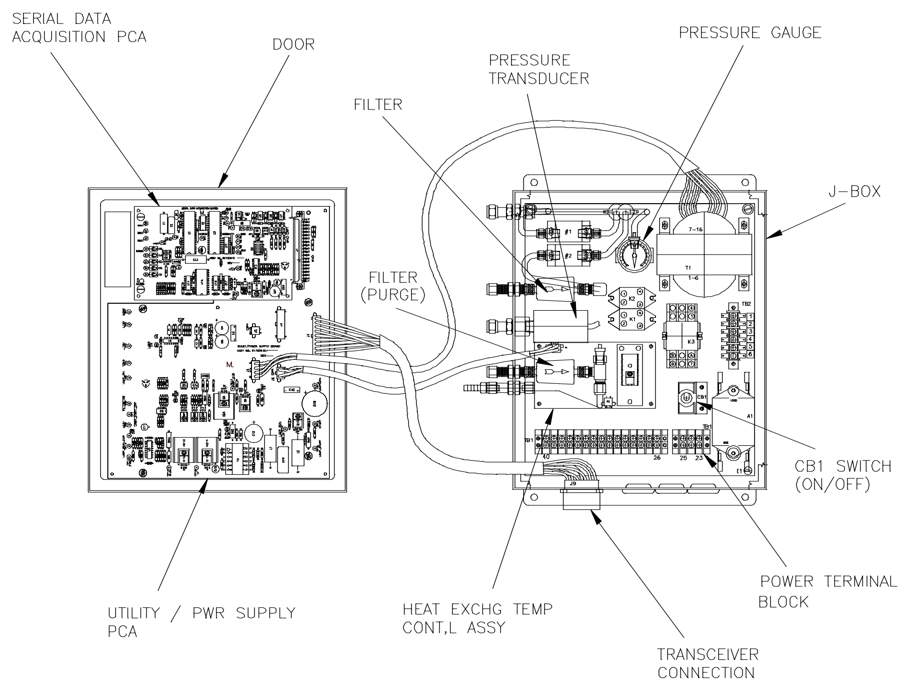


Figure 2-6. SM8175 J-Box, External View

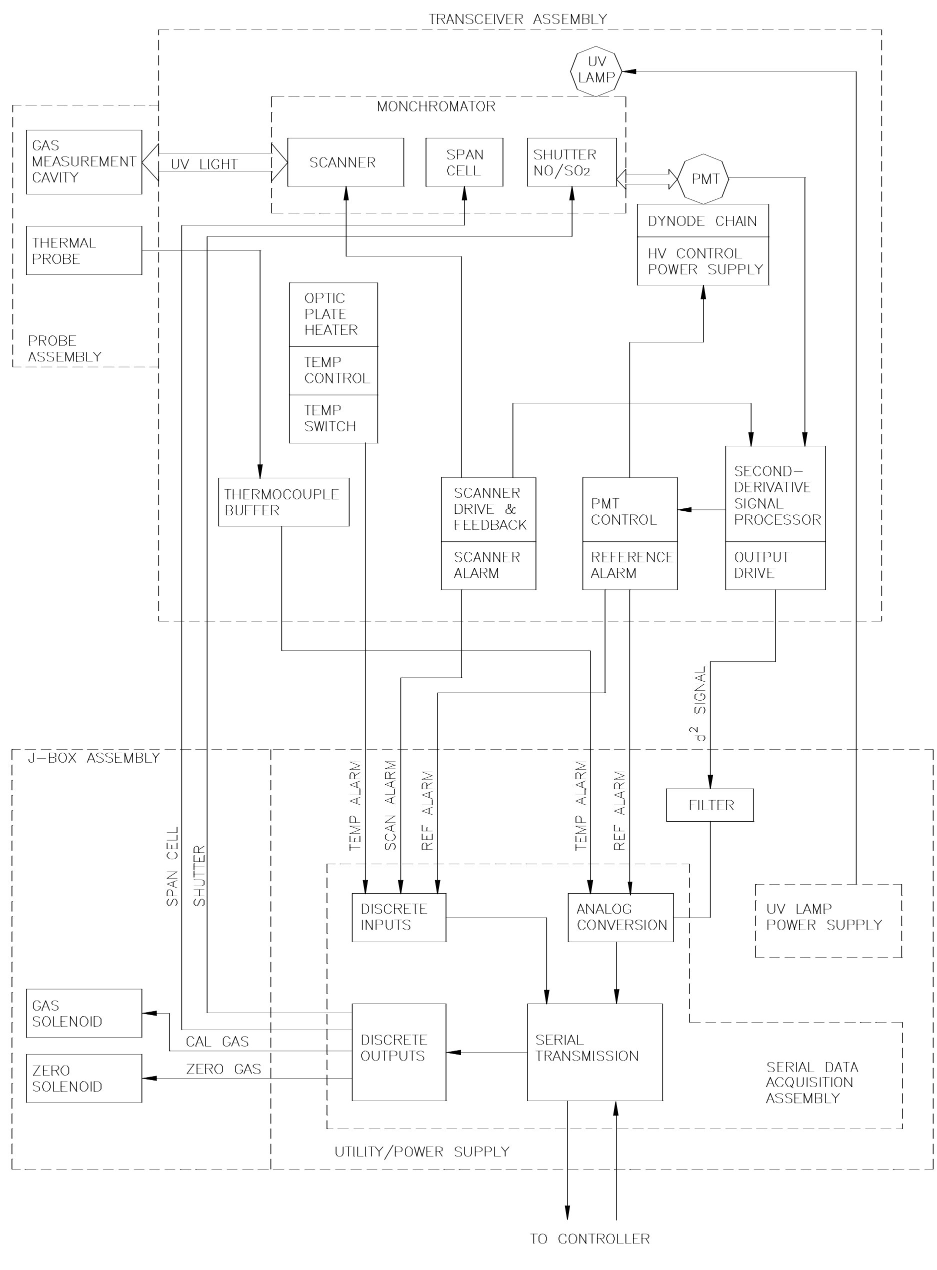


Figure 2-7. SM8175 J-Box, Internal View

2.2 System Overview

This section describes the system in general with a discussion of major signal paths. Reference is made to the functional blocks in conjunction with signal paths. The major signals and signal groups are:

1. second-derivative (d^2)
2. gas temperature
3. reference
4. system timing and control
5. alarms and faults.

2.2.1 Transceiver Signals

Light from the UV lamp travels along the probe to the gas measurement cavity where wavelengths unique to the gas are absorbed. The light is then reflected back through the monochromator inside the transceiver. The monochromator spatially separates the wavelengths of interest. A scanner within the monochromator modulates the wavelength around the absorption peak of interest   This absorption signature appears at the monochromator exit slit and is measured through a photomultiplier tube (PMT) detector. A second exit slit is present so that both SO_2 and NO signatures can be measured. For signal separation a two-position shutter blocks one of the exit slits and allows either the SO_2 or NO UV light signal to be projected onto the detector, depending on the logic state of the shutter control signal.

The photomultiplier tube (PMT) transforms UV light into an electrical signal current proportional to the high voltage applied across the tube. Operating voltage for the photomultiplier tube is controlled by a DC feedback through a high voltage (HV) power supply. This DC feedback representing available light forms an automatic gain control (AGC) which constant amplified (Io) signal levels with the deterioration of the UV light source or contamination buildup on exposed probe optics. The second-derivative signal (d^2) is extracted from the PMT signal in the second-derivative signal circuitry. It then goes to the output drive where d^2 is normalized by dividing by the DC level of PMT OUT.

2.2.2 J-Box Signals

The second-derivative signal, temperature, and PMT light level reference analog signals are converted to digital format for transmission to the control unit. Serial transmission to the controller also includes the transceiver status, which is:

1. optic plate over/under TEMPerature alarm (optical plate temperature not within specification)
2. SCANner alarm (the wavelength modulation device is not operating properly)

3. light level `REF`erence alarm (detected light level is inadequate to maintain specified performance)
4. pressure in mmhg (used to correct measurements to standard pressure conditions).

Communication from the controller to an SM8175 J-box includes selection of the analog measurement and sequencing of discrete outputs, which are:

1. shutter control for either NO or SO_2 measurements
2. span cell control for automatic calibration checks
3. zero solenoid control for automatic zero correction
4. calibration gas solenoid control for gas calibration corrections.

2.3 Specifications and Operating Envelope

2.3.1 System Measurement Accuracy

The SM8175 provides SO_2 and NO measurements that meet or exceed the US EPA requirements defined in *40 CFR Part 60, Appendix B, Performance Specification 2*, and the QA/QC requirements of *40 CFR Part 60, Appendix F*. Performance specifications are only applicable within the operating conditions listed below.

Calibration error (linearity): Within 5% of calibration gas value or 2 ppm, whichever is greater, for values greater than 20% of measurement cavity range after calibration at process temperature.

Zero calibration drift (24 hours): Within 2.5% of span.

Span calibration drift (24 hours): Within 2.5% of span or 2 ppm, whichever is greater.

Response time: Less than 4 minutes, typical.

Operational period: 3 to 6 months without maintenance, typical.

Relative accuracy: Within 20% of *US EPA 40 CFR Part 60, Appendix A* reference method values, and typically within 10% in applications where measurement values are at least 20% of the measurement cavity range. Consult the factory for guaranteed performance at lower measurement levels.

2.3.2 Span Values

That full scale concentration for which the analog outputs are set to provide full scale output. Specified performance is available for SO_2 span values between

75% and 150%, or NO span values between 75% and 125% of the measurement cavity range (see section 0 below). In regulatory compliance applications, the span value is an EPA-defined value which is used as the basis for defining calibration gas values, drift limits, etc. This regulation-based span value is not necessarily the same as the range of the analyzer.

2.3.3 Measurement Ranges

Measurement capabilities of the SM8175 are determined by the physical length of the optical measurement cavity. A selection of standard measurement cavities provides for nominal full scale concentrations (measurement cavity ranges) of 3000, 1500, 750, 500, 375, 208, and 100 ppm. Consult the factory for applicability of special cavities and ranges of 75000 (7.5%), 12000 (1.2%), 6000, and 1000 ppm for specific process conditions. Other ranges are available on request.

2.3.4 Process Gas Conditions

Temperature: Specified performance is available after calibration at nominal process temperature and within a range of normal process temperature variations of ±24° C (75° F) from nominal. Specified performance is available at process temperatures up to 232° C (450° F). Performance at higher temperatures or over larger temperature variations is dependent on specific application conditions; consult the factory. Temperature is measured over the range of 52° to 426° C (125° to 800° F). The probe can withstand operation over this temperature range without damage.

Pressure: Measurements are continuously corrected for the effects of ambient barometric pressure. Stack gas pressure must be restricted to atmospheric pressure ±101 cm (40 inches) of water column. Consult the factory for higher pressures.

Other: Standard configuration is not recommended for applications with substantial entrained water droplets. Consult the factory for special configurations.

Note

Guaranteed performance in any specific application is subject to factory review and approval of site-specific gas measurement conditions.

2.3.5 Calibration

Automatic on-stack zero and span calibration at selectable intervals up to 24 hours with manual activation at any time. Gas calibrations incorporate automatic correction of zero and span values at the completion of the calibration cycle. Electro-optical calibrations using zero gas and span cell only provide automatic zero correction. Calibration cycle length is selectable; typical length is 7 minutes.

2.3.6 Outputs

Controller: Eight 4-20 mA current sources that can be user-assigned to any selected variable. These current source outputs can be spanned to any integer value between 25 and 75,000 ppm (7.5%) for SO_2, or between 75 ppm and 7.5% for NO as long as that value is within the span capabilities of the analyzer described above. External current loop isolators are optional. Process temperature signal is linear with process gas temperatures from 52° to 426° C (125° to 800° F). RS232 serial printer and data communication port are also available.

Junction box: Provides electrically isolated RS422 communication link between the transceiver and controller via a cable containing two individually twisted, shielded pairs. Accepts one additional 4-20 mA input for transmission to the controller over RS422.

2.3.7 Optical System

Light source: Deuterium lamp, hollow cathode discharge, typical lifetime up to six months.

Measurement technique: Second derivative signal detection and processing, with SO_2 monitored at 218.5 nm and NO monitored at 226.5 nm.

2.3.8 Operating Temperature

Instrument ambient: -35° to 52° C (-30° to 125° F).

Controller ambient: 5° to 38° C (40° to 100° F).

2.3.9 Physical

Transceiver: (lxwxh) 38.1 cm x 30.5 cm x 25.4 cm (15 in x 12 in x 10 in); 22.7 kg (50 lb).

Junction box: (hxwxd) 35.6 cm x 30.5 cm x 15.2 cm (14 in x 12 in x 6 in); 15 kg (33 lb).

Probe assembly: 8.9 cm (3.5 in) OD x 1.8 m (6 ft) overall length; adapter flange, standard; 13.6 kg (30 lb).

LS710 controller: (wxhxd) 43.2 cm x 17.8 cm x 64.8 cm (17 in x 7 in x 25.5 in); 12.7 kg (28 lb). Rack or panel mount option.

Weatherproof protective housing: (lxwxh) 80 cm x 50.8 cm x 45.7 cm (31.5 in x 20 in x 18 in); 5.4 kg (12 lb) plus 3.6 kg (8 lb) for mounting plate.

2.3.10 Utility Requirements

Transceiver/junction box: 115/220/240 VAC ±10%, 50/60 Hz, 220 watts nominal, 500 watts maximum.

Controller: 115/220/240 VAC ±10%, 50/60 Hz, 30 watts nominal, 50 watts maximum.

Instrument air: Junction box and transceiver purge with transceiver gas calibration requires 2.8 to 20 lpm (6 to 42 SCFH) of clean, oil-free, dry air or N_2 at 70 to 100 psig.

2.3.11 Construction

Probe: 316L stainless steel. Hastelloy is available for special applications. Standard length 6 feet; also available 1.5, 4, and 8 feet lengths.

Transceiver: Cast aluminum alloy-NEMA 4.

Alignment: Alignment of in situ probe and transceiver is adjustable, and probe is factory-prealigned. Test points and alignment procedures are provided for field maintenance needs.

Weatherproof protective housing: Factory-supplied housing hinges to top of mounting plate; lock-open/lock-closed mechanism.

2.3.12 Installation Interfaces

Mounting flanges: Factory-supplied mounting flange is welded to pipe barrel for customer installation; 4 in (ID) schedule 40 pipe barrel cut to length by factory for standard applications. Larger flanges available for wet scrubber FGDs and other wet gas applications as required. Transceiver unit attaches to flange with four factory-supplied 3/8" NC bolts.

Mounting plate: Required for attachment of weatherproof housing and junction box. Attaches to stack/duct with 4 anchor bolts.

Note

Consult the *LS710 Operation and Maintenance Manual* for specifications related to the controller.

2.3.13 Compatibility with Previous Models

The difference between the SM8175 and the previously supplied SM8100 is the transceiver printed circuit board and constants ROM U3 located in the controller. If the SM8175 is to be used in sequence with other SM equipment on the same controller, consult your service representative for information on upgrading the existing equipment (or other alternatives).

If an EX4700A ($CO/CO_2/H_2O$ in situ analyzer) is used on the same controller with the SM8175, the EX4700A must be specified (with optics plate S/N) at the time the order is placed so that specific EX4700A table information can be included in the constants ROM.

2.4 Suggested Spare Parts List

81000450-4	Maintenance Kit including: - 81000161-1 UV lamp assembly - 80030213 lens cloth - 81000205 filter gasket - 16000053 desiccant - 81000790-2 Grafoil rings [4] - 53000093-2 thermal fuses [2].

There are four levels of recommended spare parts.

Level 1: General maintenance supplies and expendable such as fuses, filters, gaskets, lamp, etc.

Level 2: Critical items that are known from experience to have a higher failure rate such as motors, fragile optics, power supplies, and circuit boards.

Level 3: Other miscellaneous items not included in Level 1 or 2. This level includes other spare parts which are not expected to fail over a given time frame.

Level 4: All items that have been defined in the Levels 1, 2, and 3 kits with the quantity to be determined by a ratio to a quantity of 10 instruments.

SM8175 SO_2/NO Analyzer Spare Parts Requirements		
Description	**Part Number**	**Level**
Cartridge, Desiccant	16000053	1
Cloth, Transceiver Lens Cleaning	25000393	1
Filter, Ceramic, 2.5 to 7.5 cm Cavity	28000262	1
Fuse, Thermal	53000093-2	1
Filter, Ceramic, 36 cm Cavity	80340018-1	1
Lamp Assembly, Ultraviolet	81000161-1	1

SM8175 SO_2/NO Analyzer Spare Parts Requirements		
Description	**Part Number**	**Level**
Gasket, Ceramic Filter (except 36 and 75 cm Cavities)	81000205	1
Maintenance Kit	81000450-4	1
Ring, Grafoil	81000790-2	1
Seal, Grafoil, 36 cm	81000790-3	1
Filter, Ceramic, 15 to 20 cm Cavity	81000935-1	1
Filter, Ceramic, 75 cm Cavity	81001130	1
Gasket, Ceramic Filter, 36 cm Cavity	81001176	1
Gasket, Probe Mount	81750564	1
Printed Circuit Assembly, Lamp Power Supply	80410006-1	2
Beam Splitter Assembly	81000160-2	2
Scanner Assembly	81000164-4	2
Controller, Heater, Proportional, Transceiver	81000623-3	2
Dynode Chain Assembly	81000883-2	2
Printed Circuit Assembly, Serial Data Acquisition	81750012	2
Printed Circuit Assembly, Utility/Power Supply	81750015	2
Printed Circuit Assembly, Transceiver	81750045-1	2
Cube, Corner, 18 Inch Probe, 2.5 to 100 cm Cavities	20400-5007-2	3
Cube, Corner, 4 Foot Probe, 2.5 to 100 cm Cavities	20400-5007-3	3
Cube, Corner, 6 Foot Probe, 2.5 to 100 cm Cavities	20400-5007-4	3
Cube, Corner, 8 Foot Probe, 2.5 to 100 cm Cavities	20400-5007-5	3
Valve, NC Brass, 120 VAC, 60 Hz	22000096-3*	3
Valve, Solenoid, Stainless Steel, 120 V, J-Box	22000096-5*	3
Gauge, Pressure	28000344-1	3
Orifice, 0.025	28000984-2	3
Relay	45000129	3
Relay, S/S, J-Box	45000168	3
Sensor, Thermal, Close 120, Open 130	53000027	3
Sensor, Thermal, Close 170, Open 155	53000028	3
Probe, Thermal, RTD, 4 Foot, 36 cm Cavity	53000188-2*	3
Probe, Thermal, RTD, 6 Foot, 36 cm Cavity	53000188-3*	3
Probe, Thermal, RTD, 8 Foot, 36 cm Cavity	53000188-4*	3
Probe, Thermal, RTD, 4 Foot, 75 cm Cavity	53000188-5*	3
Probe, Thermal, RTD, 6 Foot, 75 cm Cavity	53000188-6*	3

SM8175 SO_2/NO Analyzer Spare Parts Requirements		
Description	**Part Number**	**Level**
Probe, Thermal, RTD, 6 Foot (except 36 and 75 cm Cavities)	53000188-9*	3
Probe, Thermal, RTD, 4 Foot (except 36 and 75 cm Cavities)	53000188-8*	3
Probe, Thermal, RTD, 18 Inch (except 36 and 75 cm Cavities0	53000188-7*	3
Probe, Thermal, RTD, 8 Foot (except 36 and 75 cm Cavities)	53000188-10*	3
Lens, Transceiver	81000157-3	3
Photomultiplier Tube Assembly (includes gasket)	81000284-1	3
Span Cell, Internal	81000409-1	3
Window Assembly (except 36 cm), 316L	81000789-2*	3
Solenoid, Span Cell	81000882-1	3
Sensor, Temperature	81000908-2	3
Solenoid Kit, Shutter	81000165SP	3
Window Assembly, 36 cm	81001007-1	3
Transducer Assembly, Pressure	81001227	3
Power Supply, Transformer, J-Box	81750016	3

* For 115 volt 316L stainless instruments only, use different numbers for 220 volt or Hastelloy instruments.

** Recommended quantity for 10 instruments.

3.0 Installation

3.1 Site Preparation

3.1.1 Stack Site Selection and Preparation

Select the transceiver/probe site according to procedures established by the appropriate regulatory agencies. The location should be selected where measurements of SO_2 and NO are representative of the SO_2 and NO concentrations at the stack exit (refer to *40 CFR Part 60, Appendix B, PS-2, paragraph 3*). If the instrument will be exposed to weather conditions, a protective housing is required. Each SM8175 is typically supplied with a fiberglass weather cover.

Clean, dry instrument air must be supplied with the following specifications:

- 70 psi minimum to 100 psi maximum air pressure
- -40° F maximum dew point
- less than 40 ppm hydrocarbon concentration.

The instrument air tube must be installed near the mounting plate for connection to the J-box.

3.1.2 Controller Site Preparation

Refer to the *LS710 Operation and Maintenance Manual* for information.

3.1.3 Electrical Site Preparation

Refer to *drawings 81750001-2, 80610023-1,* and *80610023-2*.

AC power to the transceiver and controller must be wired in compliance with local electrical codes. The power line carrying 115 VAC ±10%, 60 Hz AC power must be capable of supplying the following input powers:

- transceiver and J-box: 220 watts typical to 500 watts warmup
- controller: 30 watts typical to 100 watts startup.

3.2 System Installation

After completion of site preparation, install the transceiver and probe as described in the following steps.

Note

Cover the probe opening and transceiver lens when transporting the system to the stack.

3.2.1 Installing the Mounting Flanges and Pipe

1. If installation is on a metal stack, go to step 2.

   If installation is on a masonry stack, bolt the stack plate (customer-supplied) to the stack wall using six 0.5-diameter anchor bolts.

2. Perform this step ***only*** when a protective housing for the SM8175 is being installed. If no housing is to be installed, go to step 3.

   If installation is on a metal stack, fillet weld four mounting brackets to the stack, with dimensions as shown in *drawing 81750002-2*.

   If installation is on a masonry stack, fillet weld four mounting brackets to the stack plate, with dimensions as shown in view AA of *drawing 81750002-2*.

3. Cut a 4½" diameter hole in the stack wall for insertion of the mounting flange pipe (4 inch Schedule 40 pipe).

4. Insert the mounting flange pipe into the hole and position the face of the mounting flange not less than six inches away from the stack wall. One hole of the largest bolt circle ***must be*** in the twelve o'clock position.

5. Fillet weld the mounting flange pipe where it meets the stack wall (metal stacks) or stack plate (masonry stacks).

3.2.2 Installing the Protective Housing

If no protective housing is being used, install the J-box as described in 3.2.3 below.

Bolt the mounting plate assembly (including the housing and J-box) to the four mounting brackets welded to the stack by inserting four 1/2-13 UNC bolts with flat washers and lockwashers. Use the four 0.68-diameter clearance holes in the mounting plate.

Secure the cover in the raised position.

3.2.3 Installing the J-Box

Position the J-box with the three cable inlet holes facing downward. Bolt the J-box in place on the enclosure mounting plate. Inside the J-box, check for an orifice in the plumbing to the probe Cal port. When the probe is configured with a 1-meter cavity, this orifice is not used, and in some cases the orifice is not required with the 36 cm cavity.

3.2.3.1 Cable Installation

1. Open the J-box cover.

2. Push an external AC power cable (three wires) through one of the cable inlet holes at the bottom of the J-box. The holes allow for the use of ¾-inch conduit fittings. Make connections as listed below.

    - from AC high power line to TB1 pin 23
    - from AC low power line to TB1 pin 24
    - from ground line to TB1 pin 25.

    See Figure 2-7 and drawing 81750001.

3. Push the two twisted-pair 22 AWG cables with overall shields through another inlet hole at the bottom of the J-box.

    Note

    If conduit is not used, replace the supplied fittings with glands that maintain the NEMA 4 rating of the J-box. Terminate this interconnect cable so that terminal 32 of the controller connects to terminal 32 of the J-box. Similarly, terminal 33 of the controller connects to terminal 33 of the J-box. Connect the shield on both ends to terminal 34. Terminals 35 and 36 must also be terminated to like terminal numbers.

4. When applicable, install and connect the O_2 calibration J-box per *drawing 80390072*. Refer to *drawing 94200019* if YEW O_2 calibration J-box is used. Both O_2 J-box assemblies interface with the SM8175 J-box as indicated in *drawing 81750001*. Refer to *drawing 80390010-6* when the LS420 O_2 calibration J-box is used.

5. Close the J-box cover.

3.2.3.2 Plumbing Installation

1. Connect a purge tube from the J-box Purge fitting to the transceiver Purge fitting located on the bottom of the probe air flush housing. Connect instrument air to the J-box Air In fitting.

2. If the probe has a pressure-sensing port, connect a tube from the J-box Pressure fitting to the left Calibration fitting on the probe flange. If the probe port is not installed, point the elbow on the J-box pressure bulkhead downward.

3. Connect a cylinder of mixed NO and SO_2 calibration gas to the J-box Gas Cal fitting. Concentrations should be near that expected in the process, but not less than 20% of the instrument full scale.

Note

A pressure regulation adjustment of approximately 5 to 20 psi is required.

4. If the optional heat exchanger is used, connect the J-box Cal to Probe fitting to the left side of the heat exchanger. Using the insulated tubing provided, connect the right side of the heat exchanger to the probe Cal fitting (right Calibration fitting on the probe flange). Without a heat exchanger, connect the J-box Cal port to the probe Cal fitting.

3.2.4 Installing the Probe

1. Slide the probe (without the transceiver) through the hole at the top of the mounting plate until the probe flange meets the mounting flange.

Note

Be sure the dynamic calibration fitting slides through the large hole used for zero and gas calibration (in the five o'clock position). One hole in the probe flange must be at the twelve o'clock position.

2. From the stack side, insert five 3/8-16 x 1-inch LG hex bolts with split lock-washers through the mounting flange into the five threaded holes in the probe flange. Tighten the bolts.

3.2.5 Installing the Transceiver

1. Lower the transceiver onto the hinge pins of the probe.

2. Attach the thermal probe connector from the probe to the bulkhead connector just below the transceiver lens. Also, connect the purge tube.

Note

Ensure that the thermal probe connector and purge tube are not in the light path when making the connection, and when closing the transceiver against the probe.

3. Remove the lens cover and clamp the transceiver to the probe, ensuring that the pilot pins are properly aligned.

Note

The pilot pins ensure correct optical alignment between the transceiver and probe.

Do not:

- Connect the cable between the transceiver and the J-box. This will be done during checkout and startup by a Teledyne Monitor Labs service engineer.
- Attempt to extend the length of this cable. The junction box must be mounted within the factory fabricated distance.

3.2.6 Installing the Controller

Refer to the *LS710 Operation and Maintenance Manual* for installation information.

3.3 Purge

High gas concentrations can exist in the ambient air surrounding the transceiver and low levels of ozone are produced by the UV lamp, so instrument air is circulated through the transceiver and probe body. The resulting positive pressure keeps gases, dust, and other contaminants from entering the optical path and prevents ozone accumulation inside the transceiver.

Note

Ozone is highly corrosive. Always operate the transceiver with purge air.

3.4 Checkout and Startup Service

Teledyne Monitor Labs provides a checkout and startup service at additional cost. This includes a seminar on instrument operation, support, maintenance, and data interpretation. All personnel who will operate or maintain the SM8175 should attend this presentation.

Note

Startup cannot begin until the steps under *section 3.2, System Installation*, have been completed. Customers are charged at an hourly rate for additional time that Teledyne Monitor Labs' service engineer is required to spend at the site waiting for completion of the installation.

At startup, the *Transceiver Checklist and Installation/Startup Checklist* are completed by Teledyne Monitor Labs' service representative. Sample checklists are provided at the end of this chapter for your information.

The complete field test and calibration procedure used at startup and whenever instrument test or verification is needed can be found in *Chapter 4, Operation, Calibration, Maintenance*.

3.5 Transceiver Checklist (Sample)

1. Visually inspect the unit for any apparent damage and record below.

____

____

____

2. Check the mounting interface bolts for tightness . ______

3. Open the transceiver and visually inspect the lens and probe reflector. ______

4. Apply power to the instrument and wait one minute for the lamp to fire.
______

5. Verify that the lamp has fired (Ref LED on the SDA board in the J-box is not lit).
______

3.6 Installation/Startup Checklist

1. Factory setup values:

   SO_2 and NO gain from factory ____________________

   SO_2 range _______________________________________

   NO range ____

2. LS710 setup:

   Under the Calibration Menu:

   `INTVL` _______ calibration interval.

   `E/O DEG TEMP`_______Factory setup for the recorded Span Values.

   Under the `SO2/NO SETUP MENU`:

   `SO2 FS` and `NO FS` agree with SO_2 and NO ranges in 1 above.

   `SO2 C` and `NO C` agree with the calibration gas value plumbed into the J-box.

   `SO2 G`, and `NO G` agree with the factory setup or set to 1 for initial calibration.

   `NO&SO2` agrees with the factory setup.

   `TEMP` is set to `RTD` (`rtd, KTYPE,` and `ktype` are for older models).

   Under both the `SO2 PPM` and the `NO PPM MENUS`:

   `ALARM OFF` unless `HI LIMIT` and `LOW LIMIT` values are inserted.

   `COLUMN 0` unless required for RS232 output.

   `DISPLAY` ___ a value of 1 - 30 for position on display (must not duplicate another display position).

   `AVG`____Typically 1 min is selected for recorder and RS232 outputs.

   `RANGE`____Typically set to agree with SO_2 and NO ranges in 1 above.

3. Verify that the transceiver has been on for at least three hours before continuing checkout (warmup and settling time).

   Select `START` as `YES` under the `CALIBRATION MENU` on the controller and wait for the calibration to finish. Verify that `E/O` is selected under `CALIBRATION MENU` and `TYPE` submenu.

4. Verify that system fault alarms are off:

   `HEATER` ________________ `SCANNER` ____________ `REFERENCE` ___________

5. Verify that SO_2 and NO zero and span readings are correct:

   SO_2 zero ____________________ma

   NO zero ____________________ma

   SO_2 span cell value ____________________ppm

   SO_2 front panel span reading ________________________ppm

   NO span cell value _________________________ppm

   NO front panel span reading ______________________________ppm

   SO_2 S _____________________

   NO S __________________________

   Pressure _________________

   `SPAN SO2` _______________ppm reading, ____________bottle concentration

   `SPAN NO` ________________ ppm reading, ____________bottle concentration

6. Verify SO_2 and NO current loop output:

   If the `ZERO ADJ` (`RECORDER MENU`) is selected as 0, then:

   $$Io(mA) = 20\ mA\ \frac{(Front\ Panel\ Readings)}{(Range\ Setting)}\ \text{for 0-20 mA output}$$

= 16 mA (Front Panel Readings / Range Setting) +4 mA for 4-20 mA output

Repeat for all analog outputs.

7. Verify alarm levels according to the application requirements:

`SO2 LOW` level	___________	ppm	`SO2 HIGH` level	___________	ppm
`NO LOW` level	___________	ppm	`NO HIGH` level	___________	ppm

8. Verify contact closure outputs to any external devices.

9. Verify RS232 communication to the DAS or printer, as appropriate.

3.7 LS710 Menu Reference

PANEL	CALIB	CO/CO2 SETUP	SO2/NO SETUP	OPACITY SETUP	RECORDERS 1-4	RECORDERS 5-8	LS710 SETUP	SERIAL PORT	PARAMETERS	DIAGNOSTICS
ACCESS	START	CO Hi	SO2 FS	ZCOMP	RECORDER #	RECORDER #	HOURS	PG TOP	BARO FS	CLEAR
CODE	TYPE	CO2 Hi	NO FS	OP Hi	J-BOX	J-BOX	MIN	CAL LOG	BWA	V/R
MENU	INTVL	H2O Hi	SO2 Hi	OP G	SELECT	SELECT	MONTH	PG #	FUEL	HOURS
UNITS	NEXT	CO Low	NO Hi	SETUP-OPLR	TYPE	TYPE	DAY	PORT	FDX10	
TYPE	CONTIN	CO2 Low	SO2 Low	OPLR	MA	MA	SITE	BAUD	FWX10	
AGC	E/O DEG F	H2O Low	NO Low	SPAN OP	ZERO ADJ	ZERO ADJ	UNIT	PARITY	FC	
REF	PURGE	CO C	SO2 C				RECORDERS	MARGIN		
	ZERO	CO2 C	NO C				AUX	WIDTH		
	SPAN	CO G	SO2 G				AUX FS	LENGTH		
	TEMP CK	CO2 G	NO G					COLUM N		
	AUTOZER	H2O G	SO2 25%					EXCESS		
		CO2&CO	NO 25%							
		CO&CO2	SO2 55%							
		CD&H2O	NO 55%							
		CO&H2O	N&S25%							
		S/N EX	N&S55%							
		SPAN CO	SO2 & NO							
		SPAN CD	TEMP							
		CO FS	SPAN SD							
			SPAN NO							

CO PPM	RESET	ALARM	HI LIM	LO LIM	COLUMN	DISPLAY	AVG	RANGE
CO2 PERCENT	RESET	ALARM	HI LIM	LO LIM	COLUMN	DISPLAY	AVG	RANGE
CO-ST CALC	RESET	ALARM	HI LIM	LO LIM	COLUMN	DISPLAY	AVG	RANGE
H2O PERCENT	RESET	ALARM	HI LIM	LO LIM	COLUMN	DISPLAY	AVG	RANGE
DEW CALC	RESET	ALARM	ERROR	EXCESS	COLUMN	DISPLAY	AVG	RANGE
BWS CALC	RESET	ALARM	HI LIM	LO LIM	COLUMN	DISPLAY	AVG	RANGE
O2 PERCENT	RESET	ALARM	O2 MAX	O2 MIN	COLUMN	DISPLAY	AVG	RANGE
SO2 PPM	RESET	ALARM	HI LIM	LO LIM	COLUMN	DISPLAY	AVG	RANGE
SO2 MASS	RESET	ALARM	HI LIM	LO LIM	COLUMN	DISPLAY	AVG	RANGE
NO PPM	RESET	ALARM	HI LIM	LO LIM	COLUMN	DISPLAY	AVG	RANGE
NO MASS	RESET	ALARM	HI LIM	LO LIM	COLUMN	DISPLAY	AVG	RANGE
TEMPERATURE	RESET	ALARM	HI LIM	LO LIM	COLUMN	DISPLAY	AVG	RANGE
PRESSURE	RESET	ALARM	HI LIM	LO LIM	COLUMN	DISPLAY	AVG	RANGE
OPACITY %	RESET	ALARM	HI LIM	LO LIM	COLUMN	DISPLAY	AVG	RANGE
OPAC COMB %	RESET	ALARM	HI LIM	LO LIM	COLUMN	DISPLAY	AVG	RANGE
DENSITY	RESET	ALARM	HI LIM	LO LIM	COLUMN	DISPLAY	AVG	RANGE
AUXILIARY	RESET	ALARM	HI LIM	LO LIM	COLUMN	DISPLAY	AVG	RANGE

Figure 3-1. LS710 Version 3.03 Software Menus

CONFIGURATION MENU: PANEL	
ACCESS	Displays access to the front panel, OPEN or LOCK. Select LOCK to lock in data.
CODE	Code to access and alter parameters. Enter 3300 to change ACCESS to OPEN. Enter 666 to inhibit the current position of the shutter. Disabled next calibration cycle.
MENU	If OPER is selected, submenus will allow data entry to connected J-boxes. If SETUP is selected, all entry fields are available. After five minutes of no keyboard activity, MENU will revert to the OPER setting.
UNITS	Controls the display units. ENG displays 5-second English units; ENGAV displays average English units averaged over the period selected under each channel. MA displays process-mounted instrument output currents. CGS (centimeters/grams/seconds) indicates metric units and CGSAV displays metric 5-second and average data.
TYPE	Indicates EX for $CO/CO_2/H_2O$ analyzers, MC for opacity monitors, and SO_2 or NO for SO_2/NO analyzers, depending on the transceiver sequential shutter. Loss of J-box communication results in displaying NA, indicating Not Active.
AGC	AGC is a reading of automatic gain control current used for EX4700A and opacity analyzers only. See *Channel* and *Display* for setup.
REF	An indicator of the electro-optical condition. See *Display* under *Channel* for setup.

CONFIGURATION MENU: CALIBRATION	
START	When YES is selected, a manual calibration sequence is initiated.
TYPE	E/O means any automatic interval or manual calibrations will use internal span devices. GAS means any automatic interval or manual calibrations will use externally connected gas bottles and may correct gain values. Opacity monitors will always use internal zero and span devices, regardless of type.

INTVL	Allows selection of automatic calibration over interval, from 0 to 24 hours. A zero entry eliminates automatic calibrations.
NEXT	Indicates the hours until the next automatic calibration. This parameter cannot be changed during a calibration or when INTVL is set to zero.
CONTIN	Selects a continuous ZERO or SPAN calibration. Once ZERO or SPAN is entered, the calibration continues until OFF is entered. If TYPE in this menu is selected as E-O and CONTIN SPAN is selected, then a continuous E-O span will result. Otherwise, a continuous GAS span will result. OUT is used to identify an out-of-service instrument.
E/O DEG F	The entered factory value is the temperature where E-O span and zero will be evaluated.
PURGE	The entered value establishes the total time of purge before zero calibration.
ZERO	The entered value establishes the zero time in calibration.
SPAN	The entered value establishes the total span time in calibration.
TEMP CK	The entered value establishes the total time to purge from cal gas to process gas.
AUTO ZERO	Entered minutes for auto zero before cal sequence. 0 = disable.

CONFIGURATION MENU: GAS

XXS	Displays the last E-O span value for measurement XX, where XX = CO, CO_2, SO_2, NO.
XXZ	Displays the zero offset value for measurement XX, where XX = CO, etc.
XXC	Sets the concentration of NBS traceable standard gas (taken from C values from the supplier's cylinder tag) for gas XX, which can be CO, CO_2, etc.
XXG	A measurement gain to read XXC within 1%. Can be manipulated manually or automatically adjusted during gas calibrations. Automatic adjustments are limited to ±10%.

`XX & YY`	Defines the gain factor for interference between `XX` and `YY` (eg, CO_2 and CO, etc).

`CONFIGURATION MENU: CO/CO2 SETUP`

`S/N EX`	A display of the EX4700A calibration curve serial number. Set to `-1` if none are available.
`SPAN CO`	Sets the CO E-O span value.
`SPAN CD`	Sets the CO_2 E-O span value.
`CO FS`	Sets the CO full E-O scale value in ppm.

`CONFIGURATION MENU: SO2/NO SETUP`

`NO & SO2`	Defines the gain factor for interference between NO and SO_2.
`TEMP`	Selects both the temperature sensor type and the temperature curves. `SMXXXXR` specifies an RTD sensor, and `SMXXXXK` specifies type K sensor used on older probes. `SM8175` specifies 125° to 450° F curves. `SM8160` specifies 300° to 800° F curves.
`XX ?5%`	Defines gain factors used to trim out linearity variations (at the 25% and 55% points).
`SO2 FS`	Sets the SO_2 full scale value in ppm.
`NO FS`	Sets the NO full scale value in ppm.
`SPAN NO`	Sets the NO E-O span cell value.
`SPAN SD`	Sets the SO_2 E-O span cell value.

`CONFIGURATION MENU: OPACITY SETUP`

`Z COMP`	Displays the zero compensation value for opacity.
`OP S`	Displays the last E-O span value for opacity (S values).
`OP G`	The opacity gain factor used to trim out variations from instrument to instrument.
`OPLR`	Sets the optical path length ratio for an opacity monitor.
`SPAN OP`	Sets the opacity span cell value.

SETUP OPLR	A nonalterable factory installed value for the site installation dimensions. The SETUP OPLR along with the working OPLR will be printed at each calibration sequence.

CONFIGURATION MENU: RECORDER OUTPUT

RECORDERS 1-4	To enable display of this menu, the RECORDER entry under LS710 SETUP must be set to 4 or 8 to agree with the analog channel board installed.
RECORDERS 6-8	The above entry must be set to 8 with an 8 channel analog board installed.
J-BOX	Specifies the J-box that the above RECORDER # will be connected to.
SELECT	Assigns a measurement channel designation to a particular RECORDER # channel. ZERO and FS (full scale) can be entered here for recorder calibration.
TYPE	5-SEC uses a fundamental 5-second measurement. AVG uses the calculated average measurement. 5S-SH (sample/hold) means the last 5-SEC output is sampled and held through all calibration cycles or any time the instrument is placed in the manual mode. AV-SH likewise means the last averaged output is sampled and held.
MA	Sets the current loop output to 0-20 mA. (Reminder: The 8 recorder configuration allows only 4-20 mA output.)
ZADJ	1% to 10% offset in the recorder current output to accommodate negative data.

CONFIGURATION MENU: LS710 SETUP

Time and day must be entered whenever the system is powered up. DAS can set the current time and day through the RS232 port.

HOURS	Sets the current hour of the day.
MIN	Sets the current minute of the day.
MONTH	Sets the current month.
DAY	Sets the current day.

SITE	The site number to be printed on the top of each page.
UNIT	The unit number to be printed on the top of each page.
RECORDER	Sets the type of analog board installed into the LS710 to NONE (no analog board installed), 4, or 8 (8 analog board installed).
AUX	Selects the channel to be assigned to the auxiliary 4-20 mA input. A 4-20 mA input may be connected to the auxiliary connections of any J-box. This input may be assigned to O2 (O_2 monitor), VEL (velocity monitor), or AUX (any other linear 4-20 mA input) to be displayed, printed, or sent to a recorder output.
AUX FS	Sets the full scale value of the auxiliary input. To force a fixed velocity when there is no flow monitor, enter the desired value here and set the AUX entry to OFF.

CONFIGURATION MENU: SERIAL PORT

PG TOP	Sets the condition for advancing the RS232 output to the top of the next page before transmission of the next data output.
CAL LOG	All previous calibration data can be printed with time and date of the last calibration. Current faults are also printed. If there are no previous calibration data to be printed, no log will be printed. The cal log is disabled when a DAS is connected and sending clock sets.
PG#	Sets automatic page numbering. The number specified becomes the current page number.
PORT	Enables or disables the RS232 serial port. The OFF selection disables the port. The DAS selection is automatically selected when the time of day clock is controlled by the DAS. The PRN selection sets the port for a printer and enables the internal time of day clock. If the DAS selection is made and no external clock command is sent within approximately 1.5 minutes, the selection will automatically revert to PRN.
BAUD	Sets the transmission baud for the RS232 output.
PARITY	Determines the transmission of no parity, odd parity, or even parity.

MARGIN	Sets the number of characters to be used for right, left, top, and bottom margins.
WIDTH	Sets the number of characters available across the page, excluding the margins.
LENGTH	Sets the number of rows available in the page length, excluding the margins. A typical page has 66 lines. The page length tells the RS232 when to advance to a new page.
COLUMN	Sets the number of six-character columns to be printed across the page. If more columns are specified than will fit on the page, the printer output will default to data logger format, where all parameters are identified uniquely in one 12 character column.
EXCESS	The selection ONLY prints only those measurements and calculations that exceed the specified high alarm level. The selection INCLD prints *all* measurements and calculations that are configured in the LS710.

CONFIGURATION MENU: PARAMETERS

BARO	Sets the full scale value for the pressure input sensor. If a sensor is not present (output less than 4 mA), the entered value becomes the barometric pressure used in calculations.
BWA	Sets the ambient moisture in percent H_2O (site average moisture level).
FUEL	Causes calculations to use the fuel factors appropriate for the selected fuel. ANTH = anthracite, BITUM = bituminous, LIQU = liquid, and OTHER = uses fuel factors entered below for any other fuel type.
FDX10	Fuel Factor (Dry). When entered, the numerical factor displayed times ten should equal fuel FD. FDX10 is entered only if FUEL is selected as OTHER.
FWX10	Fuel Factor (Wet). When entered, the numerical value displayed times ten should equal fuel FW. FWX10 is entered only if FUEL is selected as OTHER.

FC	Fuel Factor (CO_2). When entered, the numerical value displayed should equal fuel FC. FC is entered only if FUEL is selected as OTHER.

CONFIGURATION MENU: DIAGNOSTICS

CLEAR	YES clears all LS710 faults.
V/R	Displays the firmware version and revision number of your LS710.
HOURS	Displays the total number of hours that the LS710 has been in operation.

CONFIGURATION MENU: Channel Names

CO PPM	CO measurement.
CO2 PERCENT	CO_2 measurement.
H2O PERCENT	H_2O measurement.
O2 PERCENT	O_2 measurement or 20.9*((1-BWA)-((FW/FC)*(CO2/100)))
OPACITY %	Opacity measurement.
OPAC COMB %	Combined opacity of all non-zero velocity instruments.
DENSITY	Optical density measurement.
PRESSURE	Pressure measurement through auxiliary input #2.
NO PPM	NO measurement.
NO MASS	NO #/MBtu (GCM).

Note

Mass calculations are based on O_2 measurement. If O_2 measurement is not available for the specified J-box, then the calculation is based on J-box 1 CO_2.

If metric selected, computes grams per cubic meter:

(CONCEN)(MOL WT)(0.04087)

Else if O_2 selected, computes lb/Mbtu:

(CONCEN)(20.9/(20.9(1-BWA)-O2))(FW)(2.59E-9)(MOLECULAR WEIGHT)

Else if CO_2 selected, computes lb/Mbtu: (CONCEN)*FC*2.59E-9*(100/%CO2)*MOL WT

SO2 PPM — SO_2 measurement.

SO2 MASS — SO_2 #/MBtu or GCM TEMP temperature measurement.

AUXILIARY — Auxiliary measurement.

CO-ST CALC — CO-stoichiometric concentration (CO/CO2)*(FC/FW)*100.

DEW CALC — Calculate dew point.

BWS CALC — BWS = [(CO2/100)(FW-FD)/FC]+BWA.

CHANNEL:

RESET — LATCH holds an alarm in the active state until YES is entered. YES acknowledges and clears the alarm. AUTO causes the alarm to reset automatically when the value falls below the limit. An alarm is activated any time a value exceeds the high or low limit. In the case of O_2, an alarm is activated when the O_2 value falls below the O_2 minimum.

ALARM — Selects processing for the alarm signal. OFF deactivates the alarm processor. 5-SEC uses 5-second instantaneous values as the alarm variable. AVG uses the average values (averages over the time period entered for the specific channel menu, AVG entry) as the alarm variable. Both 5-SEC and AVG activate the alarm processor.

HI LIM — Sets the upper alarm limit value. For BWS channel, this entry is labeled EXCESS.

LO LIM — Sets the lower alarm limit value. For BWS channel, this entry is labeled ERROR.

O2 MAX — Sets the O_2 high alarm limit value.

O2 MIN — Sets the O_2 low alarm limit value.

COLUMN — Sets the RS232 column at which a channel value is to be printed. An entry of zero omits the measurement from printing. Each column is six characters long.

`DISPLAY`	When `0` is entered, the measurement for the channel is not displayed. The entered number indicates the display position. Numbers `1` to `15` are the first column and number `16` starts the second column in the upper middle of the display.
`AVG`	Sets the time over which measurements for a channel are to be averaged, from 1 to 60 minutes. `AVG` also sets the printing rate for this channel.
`RANGE`	Sets the full scale analog recorder range for a channel.

Teledyne Monitor Labs reserves the right to modify, alter, or enhance its software at its own discretion.

Periodically, software upgrades are made available for sale; call for standard upgrade price.

Customers who request upgrades accept all responsibility for installation and configuration of the upgrade, including costs and real or consequential damages related to the installation or use of the upgrade.

Factory service software upgrades performed by Teledyne Monitor Labs employees will include a charge for software installation.

In the event of a software upgrade covered by warranty, Teledyne Monitor Labs' liability is limited to provision of the software or firmware component in question on electronic media. Labor, travel costs, incidentals, and all other expenses resulting from the software upgrade are the sole responsibility of the customer.

4.0 Operation, Calibration, Maintenance

4.1 Operation

This section describes the basic operating steps for the SM8175. Operators must understand the operating procedure for the controller before attempting to operate the SM8175. Refer to the LS710 Operation and Maintenance Manual for details on headings and setup parameters pertaining to SM8175 operation and reporting. Refer also to section 4.3, *System Parameter Setup*.

The SM8175 has two control modes, manual and automatic. The manual mode is used during installation, maintenance, calibration, and servicing, and is controlled by the switches located on the Serial Data Acquisition (SDA) board in the J-box. These switches control the automatic and manual modes, Zero Cal solenoid, Gas Cal solenoid, internal span cell, and NO/SO_2 shutter position.

The automatic mode is used for normal operation and data collection of the SM8175, and is controlled by the controller.

In general, the following controller parameters and menu headings need to be taken into consideration for proper operation (see Figure 4-2).

Basic SM8175 setup with results displayed on controller front panel:

- `J-BOX` selection (1-4 corresponding to the SDA board switches)
- `SO2/NO SETUP` Full Scale (NO must be cavity full scale; SO_2 can be 20% to 125% of cavity full scale)
- `SO2/NO SETUP TEMP`erature (RTD, or K type used on older units)
- `CALIB` Menu `E/O DEG F`
- `SO2/NO SETUP` Gains for NO, SO_2, NO/SD interference
- `PANEL UNITS` (mA, eng=ppm)
- `PARAMETERS MENU BARO`metric pressure (mm Hg)
- `SO2/NO SETUPZ`(ero) for NO and SO_2.

Calibration verification and diagnostics:

- `PANEL TYPE` (NO or SO_2 for SM8175)
- `PANEL REF`
- `CALIBRATION MENU TYPE`
- `CALIBRATION MENU INTVL, NEXT`
- `CALIBRATION MENU CONT`

- SO2/NO SETUP NOS and SOS_2 (reported value used in E/O cal)
- SO2/NO SETUPS(pan) for NO and SO_2 (reference value used in E/O cal)
- SO2/NO SETUPC(oncentration) for NO and SO_2 (reference values used in GAS cal).

Process monitoring and reporting:

- SERIAL PORT heading and subheadings
- LS710 SETUP hours, minutes, site, unit, and RECORDER
- SO2 PPM heading and subheadings (alarms, limits, RECORDER)
- SO2 #/MBTU heading and subheadings (alarms, limits, RECORDER)
- NO PPM heading and subheadings (alarms, limits, RECORDER)
- NO #/MBTU heading and subheadings (alarms, limits, RECORDER)
- TEMPERATURE heading and subheading (alarms, limits, RECORDER).

4.2 Controller Configuration

The configuration menu includes all possible headings and subheadings, including headings and subheadings for all of the measurements and calculations the controller can process (see Figure 4-2). The controller can monitor up to four instruments and up to four auxiliary inputs, including opacity, SO_2, NO, O_2, and velocity. The configuration menu is generally used during instrument setup and when new instruments are added to the controller.

4.3 System Parameter Setup

This section contains setup instructions for the system operation parameters that do not affect or are not essential for calibration. Menu parameters pertinent to calibration are discussed in the calibration section of the manual.

1. Enter the calibration intervals and desired time of day for automatic calibrations. Access the CALIBRATION MENU, subheading INTVL and increment to the desired calibration interval (eg, 24 HOURS). Access subheading NEXT and enter the number of **minutes** from the present time to the desired time of day for the next automatic calibration.

2. Set up the measurement channels. Enter values for all appropriate subheadings (eg, ALARM, HI LIM, LO LIM) for each measurement channel (eg, SO2 CHAN, NO CHAN).

   Verify that each channel has a ***different*** column number if the controller uses the RS232 port for a printer or data acquisition system. No two channels can have the same column.

3. Set up the analog outputs under heading `RECORDER 1-4` (`5-8`). Set each DAC number for a specific J-box number, channel (eg, `SO2`, `NO`, `TEMPERATURE`), type, and mA (ie, `4-20` or `0-20`).

Note

The 8 DAC board offers 4-20 mA only. Go to step 6 if no oxygen analyzer is used with your installation.

4. Enter `O2` under heading `INSTRUMENT`, subheading `AUX` to identify the O_2 analyzer, if used.

5. Enter the O_2 analyzer full scale value (normally `25.0`) under heading `INSTRUMENT`, subheading `AUX FS`.

Note

If the controller *is not* connected to the printer, go to step 8.

6. Enter `HOURS` and `MIN` under heading `LS710 SETUP`.

7. Enter the printer parameters under heading `PRINTER`.

Note

(a) If you are using a data acquisition system, set the `MARGIN` to zero and the `WIDTH` to `12`. (b) Set `EXCESS` to `INCLUD`. (c) The number of columns must match the number of measurement channels. Each `COLUMN` is equal to a measurement output (eg, SO_2 ppm, O_2).

8. Make the following entries under heading `PARAMETERS`.

   a. Obtain barometric pressure for the day in mmHg. Call up heading `PARAMETERS`, subheading `BARO`. Increment to the correct full scale number, typically `780`. If `BARO` is not displayed, go to heading `PRESSURE`, subheading `DISPLAY` and increment to `9` (or an unused position on the front panel). This pressure must agree with the barometric pressure for the day. Adjust the above `BARO FS` (full scale value) as required until the displayed `BARO` value agrees with the correct ambient or stack pressure.

   b. If using `BWS CALC`, O_2 derived from CO_2, or SO_2/NO with O_2 and a diluent, enter the percent of ambient moisture under heading `PARAMETERS`, subheading `BWA`.

   c. If using `BWS CALC`, O_2 derived from CO_2, or SO_2/NO MASS, enter the type of fuel (ie, `ANTH`, `BITUM`) under heading `PARAMETERS`, subheading

FUEL. Select OTHER if the desired fuel factor is different than the fuel factors listed in the *LS710 Operation and Maintenance Manual*. Enter the correct fuel factors under subheading FD X 10 or subheading FW X 10. Keep in mind that the value you enter is automatically multiplied by 10.

9. Enter SITE and UNIT numbers under heading LS710 SETUP if you want these numbers to be printed with printer output.

4.4 Maintenance

This section provides a guide to scheduled maintenance procedures such as inspection, cleaning, and adjustments. The calibration section includes procedures for the adjustment of parameters used to maintain system operation within desired specifications.

4.4.1 Routine Maintenance

After initial installation, the SM8175 typically provides three months of low-maintenance operation. The table below summarizes the routine maintenance recommended to ensure ongoing trouble-free operation.

Refer to Chapter 6 for component replacement procedures.

Recommended Interval	Description	Materials Required
12 months*	Clean probe.	Ceramic filter and filter gasket (these are probe-dependent). Refer to appropriate probe list of materials for correct part numbers.
6 months	Replace UV lamp.	UV lamp assembly (P/N 81000161-1).
12 months	Perform field calibration procedure, section 4.5.	Refer to 4.5.1.
6 months*	Replace transceiver desiccant cartridge.	Desiccant cartridge (P/N 16000053).
6 months	Replace desiccant capsules in J-box air filter.	Desiccant capsules (P/N 80180305-2).

* If the transceiver desiccant cartridge requires more frequent replacement, the instrument air system may require more thorough drying.

Note

The transceiver optics are sealed from the electronics to prevent optical contamination during checkout, servicing, or calibration.

4.4.2 Junction Box

4.4.2.1 Serial Data Acquisition (SDA) Board Test Points

The following test points on the SDA are referenced throughout the maintenance procedures in this manual.

1	SO_2 Measurement
2	NO Measurement
3	Temperature Measurement
4	Reference Input
5	[not used]
6	[not used]
7	Auxiliary Input (typically O_2 measurement)
8	Pressure
9	Ground
10	Vref
11	A/D Status Pin
12	Isolated 5 VDC Return
13	Isolated 5 VDC
14	+5 VDC
15	-5 VDC

4.4.2.2 SDA Board Setup Switches

The SDA board dipswitches select the J-box associated with the instrument. Up to four J-boxes can be connected to a control unit. Switches S6-1 and S6-2 determine which J-box the control unit is addressing (see Table 4-1 below). Only one J-box address can be configured for a given J-box number. Communication conflict will result if two J-boxes have the same number. The socket that the SDA board is plugged into indicates the instrument type (EX4700A, SM8100A, or opacity). Switches S6-3 through S6-5 determine whether the source is a current loop or voltage measurement. For the SO_2/NO instrument, these are voltage inputs and should be switched off. All other instruments are current inputs and have these three switches positioned on.

Table 4-1. Serial Data Acquisition (SDA) Board Dipswitches

Switch	J-Box Number 1	J-Box Number 2	J-Box Number 3	J-Box Number 4
S6-1	On	On	Off	Off
S6-2	On	Off	On	Off

4.4.2.3 Adjusting the SDA Board A/D Converter

The following adjustment corrects all analog transceiver and auxiliary measurements that interface through the J-box.

1. Connect a DVM to TP4 with the return connected to TP9 on the SDA circuit board.
2. Configure the control unit to display `REFERENCE` for this J-box number.
   a. Select `REF` from the `PANEL` menu.
   b. Increment the `REF` choice to display on the panel.
3. Adjust R18 until the displayed value agrees with the DVM reading.
4. Return the `REF PANEL` display to its condition before this adjustment.

4.4.2.4 UV Lamp Current

Set the UV lamp current to 300 mA by adjusting R17 to 0.300 VDC. Make the adjustment at TP12 on the lamp power supply board in the J-box (see *Figure 2-7*). Ground is at TP11.

4.4.3 <u>Visual Inspection</u>

1. Release the six latches that secure the transceiver to the probe assembly and swing the transceiver to the side on its hinges.
2. Stand approximately two feet back from the probe assembly and look into the probe cavity. You should see a reflection of your eye at the end of the probe. If no image is visible, remove the probe from the stack and check the probe filter. Replace the filter if it is blocked, using the procedure in *section 6.2*.

Note

You may need to shine a flashlight down the probe.

Warning

Eye damage can result from looking directly at the UV lamp. Wear protective glasses.

3. Clean the outside surface of the transceiver lens with a clean, ***dry*** lens cloth.

Caution

Do not use solvents on the lens. Do not remove the lens from the transceiver. Do not turn the lens housing, because the focal point will be changed.

4. Swing the transceiver back into position. Be sure the thermal probe connector and purge tube are out of the light path. Ensure that the transceiver is properly aligned on the alignment pins opposite the hinged side. Secure the six latches.

5. Ensure that all mounting bolts at the probe/flange interface are secure.

Note

If the bolts and nuts that face the transceiver are loose, the transceiver/probe may require realignment (refer to the probe replacement procedure in *section 6.7* for alignment instructions). If the bolts can be tightened without changing the previously established alignment, no adjustment is necessary.

6. Check the desiccant indicator on top of the transceiver. The center spot of the desiccant capsule should be blue. If not, replace the desiccant cartridge.

Note

If the transceiver desiccant cartridge requires replacement more frequently than every six months, an air dryer may be required on the instrument air supply. Desiccant capsules are also located inside the air filter in the J-box.

4.4.4 Wiring Check

Inspect the wiring between the J-box and the controller for any irregularity. Verify the J-box number. (Refer to the Instrument # Table in drawing *81750011* for the positions of S6-1 and S6-2 on the SDA board in the J-box.)

4.5 Field Test and Calibration Procedures

The following procedures can be used for initial instrument startup and any time instrument verification is required. The complexity and interactive nature of the following procedures require that the operator have SM8175 training and experience before proceeding.

Operators must also be familiar with the procedures for entering and changing parameters in the controller. Thoroughly review the *LS710 Operation and Maintenance Manual* before starting these procedures.

4.5.1 Recommended Equipment

1. 4½ digit DVM (digital voltmeter), Fluke 80 Series or equivalent
2. Independent temperature monitor capable of measuring process temperature at probe sampling point (also required to simulate a 100 ohm RTD)
3. Oscilloscope
4. Untreated lens cleaning cloth
5. Flowmeter, 0 to 10 lpm or equivalent (recommended equipment)
6. Two-stage gas regulator
7. NO single gas, balance N_2
8. SO_2/NO blend, balance N_2.

Note

Select calibration gas values to be near the typical process values, or at least 70% of full scale.

4.5.2 Determining Zero Gas Flow

1. Put the SM8175 into continuous zero via the controller, or by placing the J-box in `MANUAL` and activating the Zero solenoid.
2. Set the flow rates for the zero gas by first adjusting the pressure regulator in the J-box for the lowest voltage at the SDA board TP1 (indicating that the process gas is being evacuated) .

Note

The voltage at TP1 changes with the position of the sequential shutter. NO is typically less than SO_2. Ground for voltage measurements on the SDA board is at TP9.

3. Reduce the pressure until the voltage at TP1 starts to increase (indicating process gas diffusing back into the cavity).
4. Increase the pressure until the lowest voltage is again obtained.

5. Increase the pressure by 1 to 2 psi to compensate for any minor changes in the process.

6. Record the pressure shown on the gauge in the J-box for future reference.

4.5.3 Determining Span Gas Flow

Two methods can be used to determine the optimum span gas flow. One method uses a flowmeter and the other uses the J-box pressure gauge. The method using a flowmeter is preferred over the method using gas regulator adjustment while monitoring J-box pressure. If more purge time is required (as with a 1-meter cavity), increase the purge time under heading `SETUP` in increments of 60 seconds.

4.5.4 Using a Flowmeter

Refer to the list of recommended equipment in section 4.5.1 above. The transceiver board d^2 signal must be peaked before this procedure (refer to paragraph 4.5.6.3 below).

1. Connect a span gas bottle through the flowmeter to the dynamic calibration port located on the front of the probe mounting flange. Do not use the Cal fitting on the J-box.

2. Verify the site barometric pressure displayed on the controller. Refer to section 4.3, step 8a for `BARO FS` calibration procedure if adjustment is required.

3. Establish calibration gas pressure to agree with the Zero gas pressure established in section 4.5.2 above. For high temperature calibration (above 500° F), establish the gas flow required by slowly increasing the flow rate while monitoring the controller or the voltage at TP1 on the J-box SDA card. The data will only be valid for the shutter position corresponding to the span gas being used. Allow 5 to 10 seconds for an update at the controller. Plot the response (ppm or voltage) against flow rate. There will be a plateau in the curve where further increases in gas flow do not increase system response. Set the flowmeter for a safe margin above the knee of the curve.

4. Optimum gas flow depends on both probe cavity size and site installation. Record the flowmeter setting for future reference.

4.5.5 Probe Tests

4.5.5.1 Light Level Down the Probe

Refer to the *LS710 Operation and Maintenance Manual* for information about setup and operation of the controller.

The light level down the probe should not cause an excess of 13 mA reference current in continuous zero. Check the light level using the following steps.

1. Display the reference value on the controller front panel or monitor TP4 of the J-box SDA using a DVM.

2. Put the SM8175 in continuous zero via the controller or by placing the J-box in `MANUAL` and activating the Zero solenoid.

Note

The Zero gas flow must be set in accordance with the paragraph titled *Determining Zero Gas Flow*.

3. Verify that the reference current is equal to or less than 13 mA (1.3 volts at TP4).

4. Return the controller and J-box to the normal operational mode.

If you have a problem with high reference current readings, check for the following:

- *Dirty or damaged window and/or corner cube.* Inspect the window and corner cube for damage. Clean the window and all reflective surfaces of the corner cube with an untreated lens cleaning cloth.
- *Damaged and/or dirty beam splitter.* Inspect and clean or replace the beam splitter if necessary.
- Defective photomultiplier tube (PMT). Inspect and replace if necessary.
- *Incorrectly adjusted or dirty focusing lens assembly.* The proper focus for probes that are four feet long or shorter is two turns counterclockwise from the fully clockwise position. Probes that are six feet long or longer are focused at 3/4 turn counterclockwise from the fully clockwise position.

Note

Clean the lens with an untreated cleaning cloth.

- *Incorrect probe alignment.* The probe must be removed from the stack for alignment. Position and clasp the probe on the transceiver in a vertical position. Loosen the three flange bolts, then rotate the two flange alignment rings independently and together in order to get the lowest voltage at TP4 on the SDA board in the J-box. Long probes may be subject to a significant change in alignment because of the effects of heat. In such cases, try alternate positions near the lowest voltage.
- *PMT alignment.* Lower the transceiver bottom cover for access to PMT adjustments. Switch the J-box SDA Manual and Shutter switches to the On position (NO measurement). With the equipment operating, record the voltage at TP4 on the SDA circuit board. Loosen the three PMT mounting plate screws approximately one turn. Position the Shutter switch Off (SO_2 measurement), grasp the PMT socket, and rotate the assembly for the lowest

voltage at TP4 on the J-box SDA circuit board. Return the SDA switches to Off and verify that the NO measurement recorded above has not increased in value. Button up the transceiver. Following the gas calibration procedure optimizes the SO_2 measurement. The NO measurement has a wider bandwidth and is not as sensitive to PMT alignment.

4.5.5.2 Probe Leaks

In some stack conditions, isolating probe leaks can be a challenge. A gas leak at the window in a negative stack can cause low gas readings, while the same leak in a positive stack can fill the probe body and cause high gas and light level readings. Verifying a leak-free probe is therefore very important. Use the following techniques to verify a leak-free probe.

Leak-testing the probe is best performed with the probe removed from the stack. Flow calibration gas into the dynamic calibration fitting at a much higher rate than required and verify that the readings do not continually increase. To verify that no gas leaked into the probe body, flow zero air into the probe and ensure that the reading is zero.

Gas can also leak into the probe body through the air filtration system. The air used to purge ozone from the transceiver is vented into the probe body through a small hole in front of the transceiver. Purge the transceiver with clean, dry, oil-free instrument air only.

Keep the transceiver access door and ports closed, especially when the atmosphere around the transceiver is suspected to be contaminated with gases.

When installing a probe in the stack, allow sufficient time for the entire probe to stabilize to process temperature (approximately one hour for shirt sleeve ambient conditions: 60° to 90° F).

4.5.6 Transceiver Test and Electronic Alignment

Note

Do not attempt to calibrate the transceiver until it has reached full operating temperature. A cold transceiver requires a minimum of three hours with all access doors and ports sealed to reach a stable temperature. When possible, allow the transceiver to warm up overnight.

When the transceiver temperature has stabilized, use the following procedures to test and calibrate the transceiver.

4.5.6.1 Optics Plate Temperature

Optics plate temperature affects the stability of the optics and the accuracy of readings. To verify this temperature, connect a thermocouple or other temperature measurement device under the temperature controller and tighten for good thermal contact. Using the temperature measurement device, verify that the temperature is 143° ±3° F. Adjust the coarse and fine potentiometer(s) on the temperature controller, if required. Turn the bandwidth potentiometer fully clockwise. Close the transceiver housing when the procedure is complete.

4.5.6.2 Oscillator/SO_2 Scan Offset

The oscillator/SO_2 scan offset adjustments work together to peak the instrument for SO_2. In normal operation, the oscillator operates at a period of approximately 28 milliseconds when observed at TP3 on an oscilloscope. The transceiver is peaked when a positive symmetrical half-wave d^2 signal is present at TP5 while in the span mode (see Figure 4-3).

The span mode is activated by switching S5 on the SDA board in the J-box to the `MANUAL` position (to the left). Activate Zero and Span switches S1 and S2 (to the left). If peaking is required, adjust R3 (SO_2 scan offset) for the best half-wave signal possible. Using R2 as a fine adjustment, turn R2 as necessary to bring both halves of the waveform to ground.

Move the oscilloscope to TP6 and observe the scanner drive signal. The signal should be a 0.6 ±0.25 volt peak-to-peak triangular waveform with slightly rounded peaks (refer to Figure 4-4).

Note

If the d^2 signal is not discernible, adjusting R2 to obtain a square wave at TP 3 of 28 milliseconds and centering the scanner drive triangular waveform at 0 VDC at TP6 using R3 may help.

4.5.6.3 NO Scan Offset

The NO scan offset adjustment is required if the NO peak is not a good symmetrical half-wave signal while in the span mode. SO_2 must be satisfactorily peaked before NO can be adjusted. Activate Shutter switch S3 (to the left) on the SDA board in the J-box. Adjust R88 if necessary. Failure to obtain a good NO peak could indicate a problem with the optics alignment. If this occurs, contact Teledyne Monitor Labs for assistance.

When scan offset adjustments are complete, deactivate switches S1, S2, and S3 (to the right).

4.5.6.4 Scanner Feedback

Scanner feedback is tested at TP7. The waveform should be a half-wave with a negative peak of -7 ±1 VDC that does not go above ground (refer to Figure 4-5). Major irregularities in this signal could indicate a defective scanner motor. The scanner feedback signal is derived from a coil on the scanner motor that represents what the motor is doing.

4.5.6.5 Scanner Level Detect

The scanner level detect circuitry may need adjustment if a scanner alarm is present but the scanner feedback procedure in paragraph 4.5.6.5 above shows it to be normal. Adjust R4 for 0 ±50 mVDC at TP12.

4.5.6.6 Stack Temperature Adjustment

Disconnect the RTD at the transceiver and connect the RTD simulator for the length of the probe being tested. Switch the simulator to Low Temp. Connect positive lead of the DVM to TP3 on the SDA board. Adjust R72 on the transceiver board so that the meter reads the low temperature recorded on the simulator. Switch the simulator to Hi Temp. Adjust R137 on the transceiver board so that the meter reads the high temperature recorded on the simulator. Repeat both adjustments until the LS710 displays both temperatures as recorded on the simulator. Reconnect the RTD to the transceiver.

Note

The simulator is simply a three-terminal RTD simulator with the RTD lead resistance in series with all three leads. The series resistance can be measured between pins B and C on the RTD connector (the resistance per lead will be half the measured value). The Low Temp is the RTD platinum resistance at some low temperature (the lowest temperature of interest for the process). Similarly, the high temperature is the highest process temperature expected.

Note

Even though the temperature can read to 0° F, the temperature will default to the lowest table temperature in the LS710. When the SM8260 curves are selected, the lowest table temperature is 200° F. All other tables have entries down to 0° F.

This completes the transceiver alignment (excluding pressure and gain adjustments).

4.5.7 Gas Calibration

Two different gas calibration methods are described below, one using flowmeters to monitor span gas flow and the other using the `GAS CALIB` sequence. The preferred method is to use flowmeters.

The following assumptions are made before performing gas calibrations:

- The transceiver test and electronic alignment has been completed.
- Optimum zero gas flow has been determined for the installed system.

Note

The operator must be familiar with the controller operating procedures and parameters before beginning this procedure. Refer to the *LS710 Operation and Maintenance Manual*.

4.5.7.1 Manual Gas Calibration Using a Flowmeter

1. Ensure that power to the controller is on and that a communication link exists between the controller and the J-box. Indicate either NO or SO_2 for the SM8175 under subheading `PANEL TYPE` on the controller. The appropriate J-box number must be selected.

2. Enter the calibration gains for each gas. Access heading `GAS CALIB,` subheading `SO2 G` and enter `1.000.` Access subheading `NO G` and enter `1.000.` If a blended gas is available, enter `1.000` for `GAS CALIB NO&SO2` interference gain; otherwise, leave it at its previous setting.

3. Enter the full range of the instrument under heading `SM8160`, subheading `SO2 FS` and subheading `NO FS`. `NO FS` is determined by the measurement cavity size (ie, 188, 208, 375, 750). `SO2` may be 150% of the cavity size and `NO FS` may be 75% to 125% of the cavity size.

4. Verify the ***site*** barometric pressure on the controller display. Refer to section 4.3, step 8a above if adjustments are required.

5. Verify the temperature of the thermal probe. Select the correct temperature detector type (`STD R, 8100R`, or `HI R`, where `R` denotes `RTD`). Note that `K` denotes the Type K thermocouple used on older instruments. The `STD` curve selection covers 125° to 450° F, the `HI` curves cover 300° to 800° F, and the SM8100 is the older instrument with a lower degree of accuracy and linearity. If the `HI` curve set is not installed in the LS710 (U3 chip), the selection of `HI` will default to the prior selection.

   Use the independent measurement device at or near the probe measurement point and record the temperature. Select the temperature channel to be displayed on the controller front panel. If the displayed temperature does not agree with the independent measurement, refer to *paragraph 4.5.6.6* above for adjustment.

Note

If only R72 is used to adjust temperature, temperature tracking with process temperature changes will not be accurate.

6. Put the SM8175 in continuous zero. Verify that the J-box pressure gauge is at the value obtained in the paragraph entitled *Determining Zero Gas Flow.*

7. Take the SM8175 out of continuous zero (return to normal operation).

8. Set the SO_2 and NO zero currents by starting an E/O calibration cycle. Refer to the *LS710 Operation and Maintenance Manual.* Allow the instrument to complete the E/O calibration.

9. If a flowmeter is used, connect the NO span gas bottle to the Cal to Probe line from the J-box using a flowmeter and two-stage regulator. If a flowmeter is not used, connect the NO gas to the J-box Cal Gas inlet port and set `CONT`inuous Span under the `CALIBRATION MENU` to flow gas. Flow the NO span at the rate established under the paragraph entitled *Determining Span Gas Flow*. With the controller `NO G` set to `1.000`, adjust R15 on the transceiver PCA so that the controller display is the same as the named gas.

10. Set divider such that the display is 50% to 60% of scale. Change the value of heading `SO2/NO SETUP` subheading `NO 55` such that the display shows the NO concentration times the divider setting.

11. Set divider such that the display is 20% to 30% of scale. Change the value of heading `SO2/NO SETUP` subheading `NO 25` such that the display shows the NO concentration times the divider setting.

Note

A shutter inhibit function has been added to the LS710. When `666` is entered into the `PANEL` menu under `CODE`, the current state of the shutter will be maintained until `666` is reentered. A power interruption will cancel this inhibit function. Because the `PANEL` menu only updates when it is rewritten, the best way to determine the shutter state is to keep sequencing the <Select> then <Exit> or <PgUp> pushbuttons to view the current shutter state in the `TYPE` part of the `PANEL` menu. When the shutter is inhibited, a message will appear on the main menu status line and be sent out on the RS232 port.

Note

Calibration errors will not be generated when the shutter is in the inhibit state.

12. Remove the NO gas and connect the mixed SO_2/NO cal as in step 9 above. Adjust R5 so that the controller display is the same as the named SO_2 gas. `SO2 G` must be set to `1.000` before final trim adjustment. Verify that the pre-determined flow is maintained.

Note

R5 and R15 do not interact.

13. Change the value of the controller `NO&SO G` interference gain so the displayed value of NO agrees with the mixed NO gas concentration. Verify flow gas is at the optimum rate.

14. Set divider such that the display is 50% to 60% of scale. Change the value of heading `SO2/NO SETUP` subheading `SO2 55` such that the display shows the SO_2 concentration times the divider setting.

15. Change the value of heading `SO2/NO SETUP` subheading `N&S 55` such that the display shows the NO concentration times the divider setting.

16. Set divider such that the display is 20% to 30% of scale. Change the value of heading `SO2/NO SETUP` subheading `SO2 25` such that the display shows the SO_2 concentration times the divider setting.

17. Change the value of heading `SO2/NO SETUP` subheading `N&S 25` such that the display shows the NO concentration times the divider setting.

18. Disconnect the span gas bottle and flowmeter, and set `CONT`inuous to off if set in step 9 above. This completes manual gas calibration using a flowmeter. Run the internal span verification in paragraph 4.5.7.3 below at this time.

4.5.7.2 Gas Calibration Using the GAS CALIB Sequence

1. Ensure that power to the controller is on and that a communication link exists between the controller and the J-box. Indicate either NO or SO_2 for the SM8175 under subheading `PANEL TYPE` on the controller. The appropriate J-box number must be selected.

2. Enter the calibration gas gains for each gas. Access heading `GAS CALIB`, sub-heading `SO2 G` and enter `1.00`. Access subheading `NO G` and enter `1.00`. If a blended gas is available, enter `1.00` for `SO2/NO SETUP` Menu `NO&SO2` interference gain; otherwise, leave it at its previous setting.

3. Enter the full range of the instrument under heading `SO2/NO SETUP`, subheading `SO2 FS` and subheading `NO FS`. `NO FS` is determined by the measurement cavity size (ie, 188, 208, 375, 750). `SO2 FS` may be 50% to 200% of `NO FS`.

4. Verify the ***site*** barometric pressure on the controller display under heading `PARAMETERS`, subheading `BARO`. Refer to section 4.3, step 8a above for `BARO FS` calibration procedure if adjustment is required.

5. Verify the temperature of the thermal probe. Select the correct temperature detector type (`8175R`, `8100R`, or `8260R`, where `R` denotes RTD). Note that `K` denotes the Type K thermocouple used on older instruments. The SM8175 curve selection covers 125° to 450° F, the SM8260 curves cover 300° to 800° F, and the SM8100 is the older instrument with a lower degree of accuracy and linearity. If the 8160 curve set is not installed in the LS710 (U3 chip), the selection of SM8160 will default to the last selection.

   Use an independent measurement device at or near the probe measurement point and record the temperature. Select the temperature channel to be displayed on the controller front panel. If the displayed temperature does not agree with the independent measurement, refer to *paragraph 4.5.6.7* above for adjustment.

   Note

   If only R72 is used to adjust temperature, temperature tracking with process temperature changes will not be accurate.

6. Put the SM8175 in continuous zero, then start a timer to determine the time it takes to drop the voltage at TP1 to a zero condition (near 0.04 volts = 4 ma). Verify that the J-box pressure gauge is at the value obtained in the paragraph entitled *Determining Zero Gas Flow*. If the time to obtain a consistent zero is near or greater than 1 minute, change the entry under heading `CALIBRATION` and `PURGE` to a value that is greater than the above measured time.

7. Take the SM8175 out of continuous zero (return to normal operation), then start a timer to determine the time it takes to increase the voltage at TP1 to a stack condition. If the time to obtain a consistent stack condition is near or greater than 1 minute, change the entry under heading `CALIBRATION` and `TEMP` to a value that is greater than the above measured time.

8. Set the SO_2 and NO zero currents by starting an E/O calibration cycle. Refer to the *LS710 Operation and Maintenance Manual*.

9. Enter the calibration gas concentrations for each gas. Access heading `SO2/NO SETUP`, subheading `SO2 C` and enter the value of SO_2 in the gas bottle. Access subheading `NO C` and enter the value of NO in the gas bottle.

10. To set flow rate for the NO calibration gas, connect the calibration gas bottle to the Cal Gas In fitting on the J-box and perform the following steps:

    a. Switch S5 on the SDA board to the MANUAL position (to the left). Activate Gas switch S4 (to the left).

    b. Adjust the regulator on the calibration gas bottle for the same pressure shown on the J-box pressure gauge as the pressure obtained in the paragraph entitled *Determining Zero Gas Flow*. Record the voltage at TP1 that represents the NO response.

    c. Deactivate switches S4 and S5 (to the right).

    d. Select heading `CALIBRATION`, subheading `TYPE` to `GAS`. Put the SM8175 in continuous span, then start a timer to determine the time it takes to increase the voltage at TP1 to a steady condition. Verify that the J-box pressure gauge is at the value obtained in the paragraph entitled *Determining Zero Gas Flow*. If the time to obtain a consistent up scale value is near or greater than 1 minute, change both entries under heading `CALIBRATION` and `SPAN` and `ZERO` to a value that is greater than the above measured time.

    e. ***Do not turn the calibration gas bottle regulator off at this time, as calibration gas will be used later in this procedure.***

11. Perform a GAS CALIB sequence. Refer to the *LS710 Operation and Maintenance Manual* for details. Allow the calibration sequence to complete.

Note

SO_2 will fail the gas calibration because there is no SO_2 in the gas bottle.

12. If `NO G` is greater than `1.00`, adjust R15 clockwise. If `NO G` is less than `1.00`, adjust R15 counterclockwise. Initially, adjust R15 one turn to see how much effect it has.

Note

You will not see the effect of R15 adjustment until the end of the next GAS CALIB sequence.

13. Set `NO G` back to `1.00`. Perform steps 12 and 13 until no further adjustment of R15 is needed to keep `NO G` as close as possible to `1.00`.

Note

NO will now pass the gas calibration.

14. To make the SO_2 adjustment, connect the mixed SO_2/NO calibration gas to the Cal Gas fitting on the J-box and repeat step 10.

15. Initiate GAS CALIB and allow the sequence to complete.

16. If SO_2 is more or less than 1.00, adjust R5. Initially, adjust R5 only a little to determine the effect. You will not see the effect until the calibration sequence has completed.

17. Repeat steps 15 and 16 until SO_2 G remains as close as possible to 1.00.

18. Connect the NO gas bottle to the Cal Gas fitting on the J-box and repeat step 10. If a blended gas is not available, leave subheading `NO&SO2` at the previous setting and go to step 22.

19. Initiate GAS CALIB and allow the sequence to complete.

20. If `NO G` is less than `1.00`, increase the value under subheading `NO&SO2`. If `NO G` is greater than `1.00`, decrease the `NO&SO2` value.

Note

`NO&SO2` is an adjustment that compensates for SO_2 interference with NO.

21. Repeat steps 19 and 20 until no further adjustment of the value under subheading `NO&SO2` is needed and `NO G` remains as close as possible to `1.00`.

22. Disconnect the span gas bottle. This completes gas calibration using the GAS CALIB sequence. Run internal span verification at this time.

4.5.7.3 Verification of Internal Span

1. Find the internal span cell value and E/O TEMP on the SM8175 factory data sheet.

Note

If the internal span value has been revised, refer to the last recorded value.

Note

Even though the E/O temperature entry can be set to 75° F, the temperature will default to the lowest table temperature in the LS710. When the SM8260 curves are selected, the lowest table temperature is 200° F. All other tables have entries at 75° F.

2. Begin an E/O CALIB sequence.

3. Allow the sequence to finish.

Note

The controller may produce a fault and display SPAN ERR at this time. It will clear shortly.

4. Record the span values under heading CALIB, subheading SO2 S and subheading NO S.

5. Clear the SPAN ERR by entering ALL under heading DIAGNOSTICS, subheading CLEAR.

6. Repeat steps 2 through 5 at least ***five*** times.

7. Enter the SO_2 and NO internal span values averaged in step 6 under heading INSTRUMENT, subheading SPAN SD and subheading SPAN NO, respectively.

8. Repeat steps 2 and 5 to verify that there is no SPAN ERR message and that no faults occur.

If significant changes have been made to both previous span values, perform the probe leak test in paragraph 4.5.5.2 above.

4.5.7.4 Recorder Adjustments

1. Refer to *Chapter 6* in the *LS710 Operation and Maintenance Manual* for recorder output calibration, if required.

2. To set recorder zero adjustment, record the menu settings under heading RECORDER, subheading SELECT associated with each subheading DAC # (recorder output currently being used). Select ZERO under subheading SELECT for each DAC #. Adjust the recorders for zero.

3. To set recorder span adjustment, select FS under subheading SELECT for each DAC #. Adjust the recorders for full scale.

4. Return all SELECT assignments to the original menu settings.

5. For ease of reading the recorder output, verify that the recorder full scale is divisible by the graduation of the chart paper. Recorder full scale is found under the heading for each of the selected recorder assignments in step 4 and under subheading RANGE.

4.6 Waveforms

See Figure 4-3 through Figure 4-9.

These waveforms occur with an external SO_2 span cell of typical ppm concentration. Because of variations among different systems, the amplitude values and repetition rates illustrated are only typical. Figure 4-3, Figure 4-6, and Figure 4-7 are directly related to the concentration of measured gas.

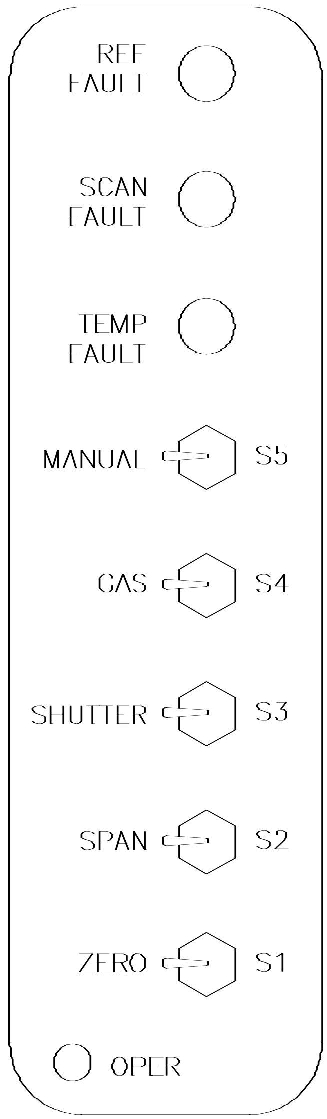


Figure 4-1. SM8175 J-Box Serial Data Acquisition Switches and Indicators

PANEL	CALIB	CO/CO2 SETUP	SO2/NO SETUP	OPACITY SETUP
ACCESS	START	CO Hi	SO2 FS	ZCOMP
CODE	TYPE	CO2 Hi	NO FS	OP Hi
MENU	INTVL	H2O Hi	SO2 Hi	OP G
UNITS	NEXT	CO Low	NO Hi	SETUP-OPLR
TYPE	CONTIN	CO2 Low	SO2 Low	OPLR
AGC	E/O DEG F	H2O Low	NO Low	SPAN OP
REF	PURGE	CO C	SO2 C	
	ZERO	CO2 C	NO C	
	SPAN	CO G	SO2 G	
	TEMP CK	CO2 G	NO G	
	AUTOZER	H2O G	SO2 25%	
		CO2&CO	NO 25%	
		CO&CO2	SO2 55%	
		CD&H2O	NO 55%	
		CO&H2O	N&S25%	
		S/N EX	N&S55%	
		SPAN CO	SO2 & NO	
		SPAN CD	TEMP	
		CO FS	SPAN SD	
			SPAN NO	

RECORDERS 1-4	RECORDERS 5-8	LS710 SETUP	SERIAL PORT	PARAMETERS	DIAGNOSTICS
RECORDER #	RECORDER #	HOURS	PG TOP	BARO FS	CLEAR
J-BOX	J-BOX	MIN	CAL LOG	BWA	V/R
SELECT	SELECT	MONTH	PG #	FUEL	HOURS
TYPE	TYPE	DAY	PORT	FDX10	
MA	MA	SITE	BAUD	FWX10	
ZERO ADJ	ZERO ADJ	UNIT	PARITY	FC	
		RECORDERS	MARGIN		
		AUX	WIDTH		
		AUX FS	LENGTH		
			COLUM N		
			EXCESS		

CO PPM	RESET	ALARM	HI LIM	LO LIM	COLUMN	DISPLAY	AVG	RANGE
CO2 PERCENT	RESET	ALARM	HI LIM	LO LIM	COLUMN	DISPLAY	AVG	RANGE
CO-ST CALC	RESET	ALARM	HI LIM	LO LIM	COLUMN	DISPLAY	AVG	RANGE
H2O PERCENT	RESET	ALARM	HI LIM	LO LIM	COLUMN	DISPLAY	AVG	RANGE
DEW CALC	RESET	ALARM	ERROR	EXCESS	COLUMN	DISPLAY	AVG	RANGE
BWS CALC	RESET	ALARM	HI LIM	LO LIM	COLUMN	DISPLAY	AVG	RANGE
O2 PERCENT	RESET	ALARM	O2 MAX	O2 MIN	COLUMN	DISPLAY	AVG	RANGE
SO2 PPM	RESET	ALARM	HI LIM	LO LIM	COLUMN	DISPLAY	AVG	RANGE
SO2 MASS	RESET	ALARM	HI LIM	LO LIM	COLUMN	DISPLAY	AVG	RANGE
NO PPM	RESET	ALARM	HI LIM	LO LIM	COLUMN	DISPLAY	AVG	RANGE
NO MASS	RESET	ALARM	HI LIM	LO LIM	COLUMN	DISPLAY	AVG	RANGE
TEMPERATURE	RESET	ALARM	HI LIM	LO LIM	COLUMN	DISPLAY	AVG	RANGE
PRESSURE	RESET	ALARM	HI LIM	LO LIM	COLUMN	DISPLAY	AVG	RANGE
OPACITY %	RESET	ALARM	HI LIM	LO LIM	COLUMN	DISPLAY	AVG	RANGE
OPAC COMB %	RESET	ALARM	HI LIM	LO LIM	COLUMN	DISPLAY	AVG	RANGE
DENSITY	RESET	ALARM	HI LIM	LO LIM	COLUMN	DISPLAY	AVG	RANGE
AUXILIARY	RESET	ALARM	HI LIM	LO LIM	COLUMN	DISPLAY	AVG	RANGE

Figure 4-2. Controller Configuration Menu

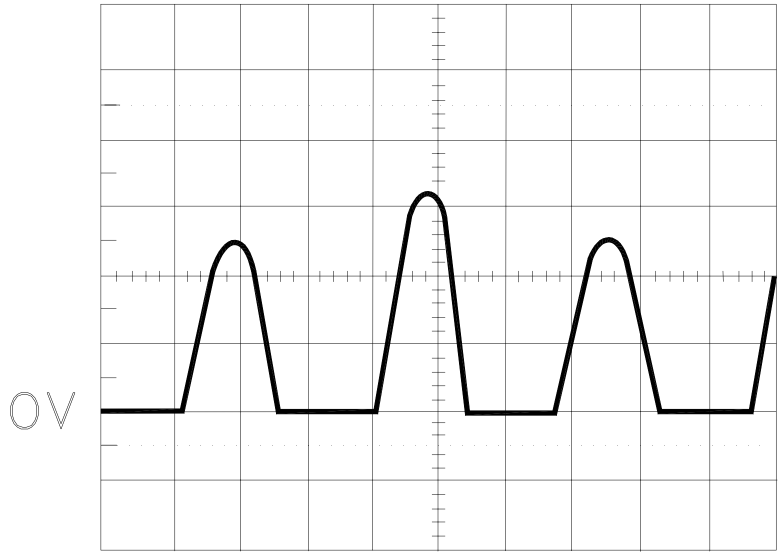


Figure 4-3. Transceiver Board, TP5: Time/Box = 20 ms Volts/Box = 0.5 V

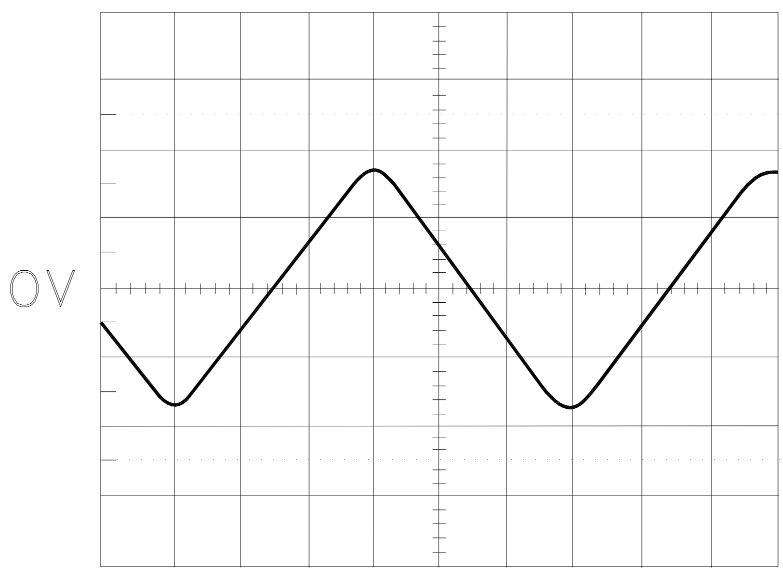


Figure 4-4. Transceiver Board, TP6: Time/Box = 20 ms Volts/Box = 0.2 V

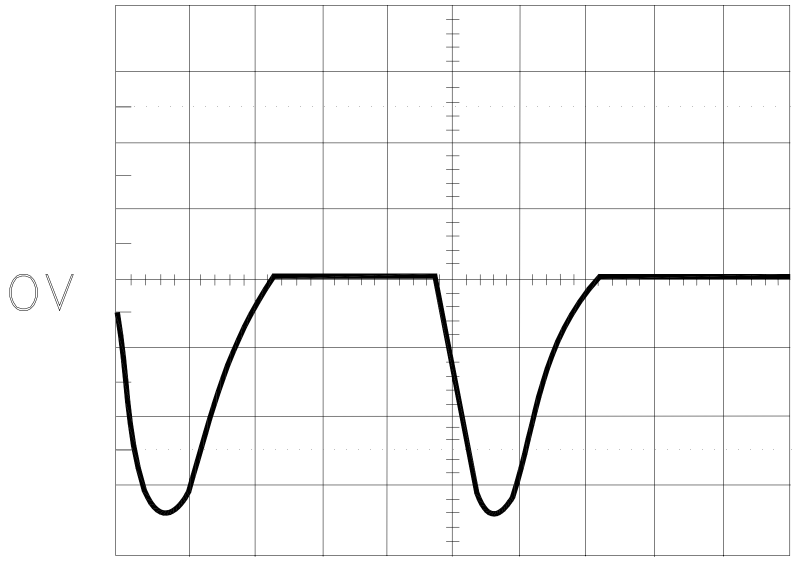


Figure 4-5. Transceiver Board, TP7: Time/Box = 20 ms Volts/Box = 2 V

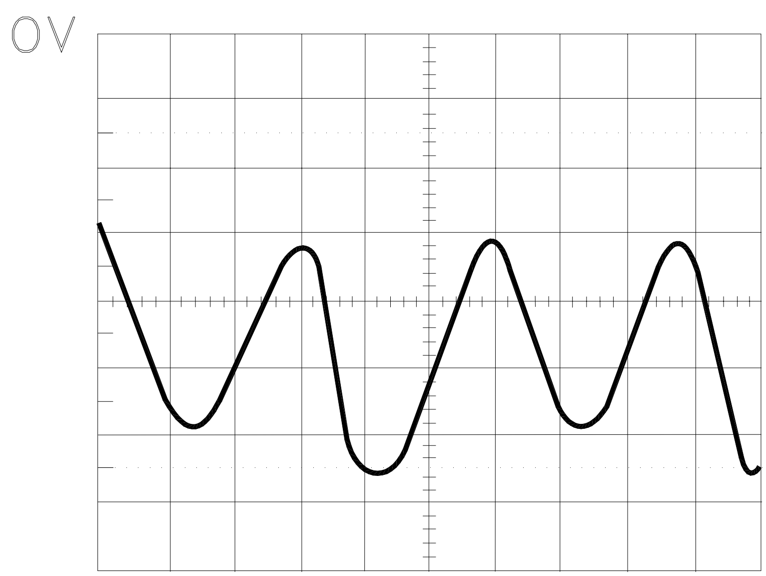


Figure 4-6. Transceiver Board, TP2: Time/Box = 20 ms Volts/Box = 0.2 V

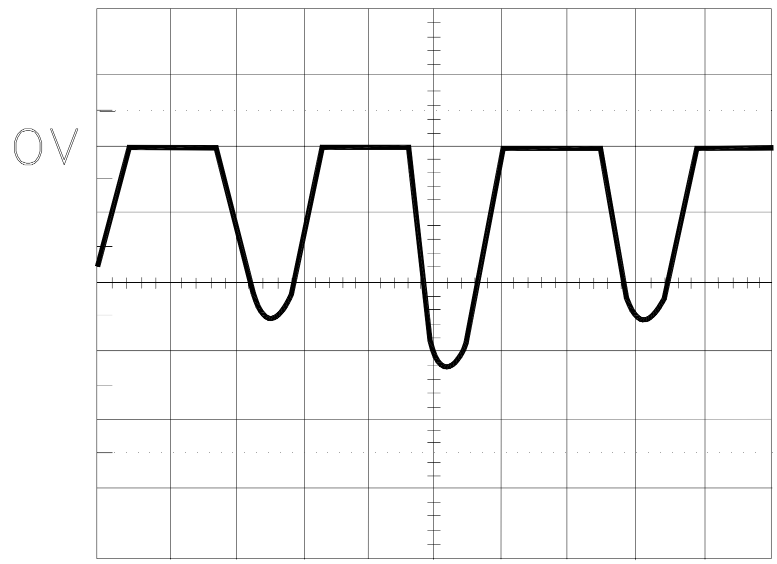


Figure 4-7. Transceiver Board, TP1: Time/Box = 20 ms Volts/Box = 1 V

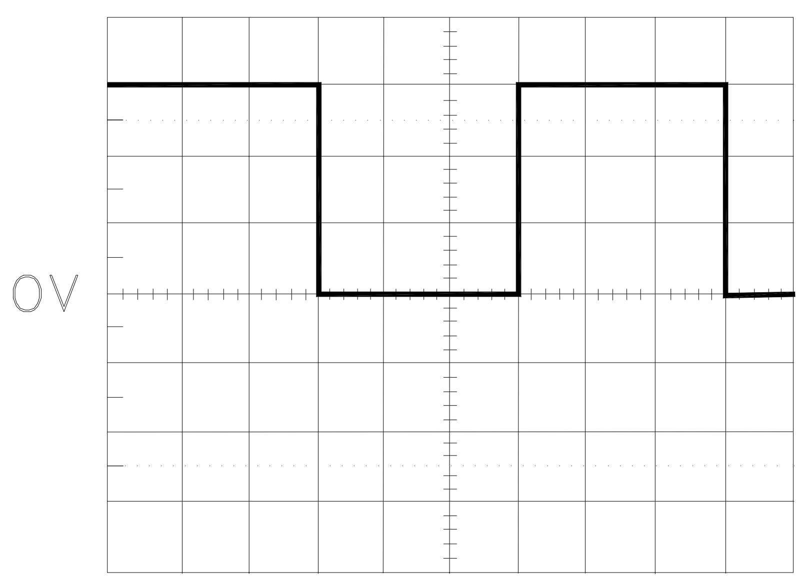


Figure 4-8. Transceiver Board, TP3: Time/Div: 5 ms Volts/Div: 5 V

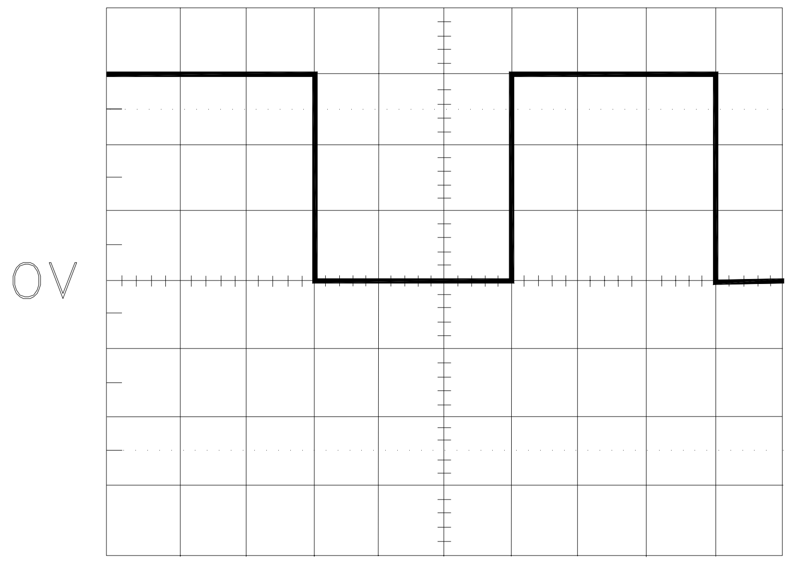


Figure 4-9. Transceiver Board, U8-1: Time/Box = 10 ms Volts/Box = 5 V

5.0 Diagnostics/Troubleshooting

5.1 Controller Diagnostics

Refer to the *LS710 Operation and Maintenance Manual* for complete information on the instrument.

5.1.1 Instrument Diagnostics

Instrument diagnostics are performed at power-up and during each E/O calibration sequence. *Table 5-1* lists possible instrument failures and maintenance situations, including the message that is displayed and a brief description. If an instrument failure is detected, the message is displayed on the controller front panel and the Fault indicator lights.

Refer also to the descriptions of the status messages and diagnostics that occur during an E/O calibration sequence in the *LS710 Operation and Maintenance Manual*.

5.2 Instrument Status

Table 5-1. Instrument Status

Instrument Status	`SM REF`
Description	Indicates insufficient UV light levels in the transceiver.
More Information	See items 1, 5, 6, and 7 in the *Troubleshooting Symptom/Action Chart*.
Instrument Status	`SM TEMP`
Description	Appears when the optic plate temperature is out of tolerance. This fault indicates a failure in the transceiver electro-optical system that could result in an erroneous output.
More Information	See item 2 in the *Troubleshooting Symptom/Action Chart*.
Instrument Status	`SM SCANNER`
Description	Appears when a failure has been detected in the transceiver scanner system.
More Information	See item 4 in the *Troubleshooting Symptom/Action Chart*.
Instrument Status	`FAILURE`

Description	Appears on the lower display line (status line) when the controller diagnostics detect a fault.
More Information	Refer to the *LS710 Operation and Maintenance Manual* for details about each fault code.

Instrument Status	`OUT OF SERVICE`
Description	Appears with J-box number when a J-box and instrument have been taken out of service with heading `E/O CAL`, subheading `CONTIN`.
More Information	Refer to the *LS710 Operation and Maintenance Manual* for more information about out-of-service instruments.

Instrument Status	`SM MANUAL`
Description	Appears with J-box number when J-box Manual switch S5 is in the manual mode.
More Information	The manual mode transfers instrument control from the controller to the J-box switches, and is only used temporarily during installation, maintenance, and servicing.

Instrument Status	`J-BOX UART`
Description	Indicates a bad transmission of RS422 to J-boxes. Appears with J-box number when the J-box transmission is faulty.
More Information	Remove and replace the SDA board, or replace U6 and/or U7 on the SDA board.

System Troubleshooting Table

Symptom	Possible Cause	Fault Isolation/Solution
1. `SM REF` alarm.	Deficient light level.	See symptom 5 (below).
	Lamp is off.	If the lamp does not fire after a complete 4 minute measurement cycle, refer to *Chapter 7* UV lamp power.
	Faulty lamp.	See the *UV Lamp Replacement* procedure in *Chapter 6*.
	Stack gas concentration wrong.	Calibration gas not at process temperature or pressure. Refer to *Chapter 4* for calibration.

System Troubleshooting Table		
Symptom	**Possible Cause**	**Fault Isolation/Solution**
2. SM TEMP alarm.	Ambient temperature at the transceiver is out of limits.	Limits are -30° to +125° F.
	Internal temperature of the transceiver is out of limits.	To verify this temperature, connect a thermal probe under the temperature controller and tighten for a good contact. Temperature range is 143° ±3° F. Adjust the potentiometers on the temperature controller, if needed.
	Thermal fuse TF1.	TF1 is located on the transceiver optic plate in the lower right corner, with the transceiver door open. Replace, as required.
3. Power failure in the transceiver.	No power into the J-box.	Check main power.
	J-box circuit breaker.	If the breaker won't stay set, troubleshoot the transceiver. Check the thermal fuse (TF1) on the transceiver optic plate in the lower right corner with the transceiver door open.
4. SM SCANNER alarm.	Incorrect signals transceiver board on: 1) TP3 2) TP5 3) TP6, drive signal 4) TP7, feedback signal.	Perform the following: 1) Check TP3 to verify the oscillator is working. 2) See Figure 4-3. 3) See Figure 4-4. 4) See Figure 4-5. If there is no feedback signal or there are major irregularities in this signal, the scanner motor is faulty. Replace the motor (see *Chapter 6*). If signals are okay, contact the factory for assistance.
5. Deficient light level (or high REF).	Lamp not firing.	See symptom 6.
	Fogged lens.	See *Incorrectly adjusted or dirty lens* procedure.
	Dirty window procedure.	See *Dirty or damaged window or corner cube level*.
	Dirty corner cube.	See *Dirty or damaged window or corner cube* procedure.
	Probe misalignment.	See *Incorrect probe alignment procedure*.
	Probe misalignment due to high stack temperature.	See *Incorrect probe alignment procedure*.
	Excessive stack gas concentration.	See *Chapter 2* specifications.
	Probe gas leak.	See *Probe Leaks* procedure.
5. Cont'd	Thermal probe cable or purge tube in the light path.	Unlatch the transceiver from the probe. Swing the transceiver open slowly and verify that the thermal probe cable and purge tube are not blocking the light path.

System Troubleshooting Table		
Symptom	**Possible Cause**	**Fault Isolation/Solution**
	Gas leak in the transceiver.	See the *Probe Leaks* procedure.
	Inoperative air purge in the transceiver.	Verify instrument air to the J-box and purge air flow to the probe.
	Shutter hang-up or vibration.	Consult the factory for assistance.
	PMT malfunction.	Replace the PMT.
	Dynode chain malfunction.	Replace the dynode chain.
	High voltage power supply malfunction.	Replace the high voltage power supply.
	Dirty beam splitter.	Clean or replace, as needed.
	Incorrect scanner position.	Consult the factory for assistance.
	Lamp current too low.	Check the lamp current and power supply circuit. See the *UV Lamp Current* procedure.
	Loose lamp assembly.	Tighten the screws on the UV lamp cooling fan assembly.
	Fogged lamp.	Remove and clean the lamp or replace, if needed.
6. Lamp not firing.	Pinched lamp wires.	See the *UV Lamp Replacement* procedure in *Chapter 6*.
	Open lamp filament circuit (lamp not heating up).	Replace the lamp.
	Low AC line voltage.	
	Faulty lamp.	See the *UV Lamp Replacement* procedure in *Chapter 6*.
	Faulty lamp power supply board in the J-box.	Replace the utility/power supply board.
	Filament voltage is less than 2.5 VAC.	
	Lamp start is less than 360 VDC.	
7. Lamp firing flashing.	Retriggering when lamp fires.	
	Improper adjustment of lamp current.	See the *UV Lamp Current* procedure.
7. Cont'd	Sustaining voltage too low.	Replace the lamp power supply board in the J-box.

System Troubleshooting Table		
Symptom	**Possible Cause**	**Fault Isolation/Solution**
	Low AC input voltage or varying outside limits.	
	Lamp fired in either glow or arc discharge.	Remove J-box power for approximately 1 minute.
	Faulty connection, intermittent AC line noises.	See the *UV Lamp Replacement* procedure in *Chapter 6*.
8. Lamp fires immediately.	Low impedance path of lamp cathode to ground.	Replace the utility/power supply board in the J-box.
9. d^2 signal not optimum.	Scanner offset shift.	See the *Scanner Offset* test in *Chapter 5*.
	Oscillator shift.	
	Faulty connection on scanner quick-disconnect terminals.	Check signals at transceiver board TP5 (Figure 4-3).
10. Random or varying output readings.	Transceiver too hot.	See symptom 2.
	Heater controller on transceiver allowing wide temperature variations.	See symptom 2.
	Process gas in and around the transceiver.	See the *Probe Leaks* procedure in *Chapter 4*.
	Improper shutter position.	Consult the factory for assistance.
	Incorrect lamp intensity or current variations.	See symptoms 6 and 7.
	Unstable scanner.	Replace the scanner motor.
11. Temperature is not tracking process.	Faulty thermal probe.[1]	See the *Thermal Probe Replacement* procedure in *Chapter 6*.
11. Cont'd	Open or intermittent connection between thermal probe plug and the transceiver.	Tighten the thermal probe plug.

[1] A temperature versus resistance table for RTD probes is found in *Appendix C*. **Caution:** ***Do not*** **make any monochromator adjustments.**

System Troubleshooting Table		
Symptom	**Possible Cause**	**Fault Isolation/Solution**
	Faulty solder joints on the thermal probe receptacle on the transceiver or the thermal probe plug.	Resolder the connections with silver solder.
	Heat exchanger not operating properly.	Replace J-box heat exchanger temperature controller.
	Wrong temperature device selected.	Refer to the *LS710 Controller Operation and Maintenance Manual, Chapter 2* on RTD or KTYPE selection.
	Faulty U16 on the transceiver printed circuit board.	Replace the transceiver board.
	Incorrect input selected on the transceiver printed circuit board.	Select correct input using jumpers.
	RTD temperature gain adjustment.	Calibrate gain for high temperature and R72 for low temperature.
12. Output readings ramp.	Transceiver heater controller not regulating properly.	
	Thermal sensor on optic plate is defective.	
	Probe leak.	See the *Probe Leaks* procedure
13. Unable to linearize unit.	Excessive 11 cycle modulating signal waveform (ratio of maximum to minimum signal greater than 2/1).	See symptom 15.
	Lens has no aperture.	
	Calibration incorrect.	Follow the *Chapter 4 Linearity Calibration* procedure.
14. Low frequency modulation of signal.	Excessive scanner offset.	See the *Scanner Offset* test.
15. Excessive 11 cycle modulating signal waveform.	Improper optics alignment.	
	Excessive scanner offset.	See the *Scanner Offset* test.

System Troubleshooting Table		
Symptom	**Possible Cause**	**Fault Isolation/Solution**
16. Unable to reassemble cavity properly.	Probe not positioned correctly.	The probe must be vertical to assembly the grafoil ring/window assembly.
17. Leaky probe.	Cracked window.	
	Grafoil ring not sealed.	See the *Probe Leaks* procedure.
	Internal calibration gas tubing is leaking.	Replace the probe. See the *Probe Replacement* procedure in *Chapter 6*.
	Calibration gas inlet not plugged or connected to the J-box.	
	Loose thermal probe fitting at the measurement cavity end of the probe.	
18. 8-foot or 9-foot probe out of alignment.	Cantilever action due to the weight of the probe versus the transceiver.	If possible, do not bolt the probe to the stack. Allow it to rest in its sleeve in the stack. Internal stack support is required.
19. Abnormal instrument readings.	High gas concentrations in the ambient air surrounding the transceiver.	See the *Probe Leaks* procedure in *Chapter 4*.
	Calibration probe mounting flange not secured tightly.	Use the *Probe Leaks* procedure.
	Leak at grafoil ring separating the probe body from the measurement cavity.	Use the *Probe Leaks* procedure.
	Blockage of the ceramic filter at the probe tip.	Use the *Probe Filter Replacement* procedure in *Chapter 6*.

6.0 Component Replacement

Note

For this chapter, probes are categorized into four general groups according to basic cavity size: standard, 20 cm, 36 cm, and 100 cm. Each group may contain several measurement cavity sizes.

6.1 UV Lamp Replacement

Caution

Switch the transceiver power off (CB1) in the J-box before beginning any transceiver maintenance or component replacement procedures.

Caution

Avoid touching any glass surfaces (lens, window, corner cube reflector, lamp) when cleaning and/or servicing the SM8175.

1. Switch the transceiver power off and wait 15 minutes for the lamp to cool.

2. The black-finned lamp housing is secured to the side of the transceiver with four captive screws. Release the two screws that secure the electrical connector. Loosen the two screws that secure the lamp assembly to the lamp housing and remove the lamp assembly.

3. Remove the new lamp assembly from its container. Avoid touching the quartz envelope of the lamp and handle it only by the wires or by the block at the base of the lamp. Be certain that the envelope is clean.

4. Place the new lamp assembly in the lamp housing and secure it with two screws. Secure the electrical connector to the side of the lamp housing with two screws.

5. Place the lamp housing back in position. Verify that the lamp housing is properly aligned on the alignment pins. ***Be sure that the lamp wires are not caught under the housing***. Secure the four captive screws. Ensure that the face of the lamp housing lies flush against the mating transceiver surface.

6. The lamp does not require further adjustment. If, however, the adjustment locknuts have been changed or if peak performance is desired, proceed to step 7.

7. To adjust the lamp, first notice the two threaded cams secured with locknuts. Using a screwdriver and a small wrench, loosen the locking nut counterclockwise 1/2 turn while keeping the cam from turning with the screwdriver. Loosen the four lamp housing mounting screws a few turns. Switch the J-box

SDA Manual switch to the ON position and shutter switch to the OFF position. With the equipment operating, simultaneously rotate both adjustments for the lowest voltage at TP4 on the J-box SDA circuit board (note that the measurement return is TP9). Return the SDA switches to OFF and button up the transceiver.

6.2 Probe Filter Replacement

Note

This procedure is a guideline based on the standard probe configuration. Steps 3 through 6 are probe-dependent. Refer to the appropriate probe drawings to determine the filter replacement procedure for nonstandard probes.

1. Release the six latches that secure the transceiver to the probe. Swing the transceiver to the side and disconnect the purge tube and thermal probe connector below the transceiver lens. Lift the transceiver off the hinge pins and set it aside.

2. Release the mounting flange bolts on the ***stack side only***. Carefully draw the probe from the sampling port. Allow the probe to cool to room temperature.

3. Use an Allen wrench to back off the adjustment cup and screw until the ceramic filter is loose. Remove the two screws securing the adjustment cup support.

4. Remove the ceramic filter. Use a small screwdriver to remove the filter gasket from its seat in the probe end plate.

5. Carefully press a new filter gasket into place. Lower the new ceramic filter over the measurement cavity and onto the gasket. Replace the adjustment cup support and tighten the two screws.

Note

If the probe is used with a wet scrubber, thoroughly wet the gasket and pack it in the gasket seat.

6. Hold the ceramic filter firmly against the gasket and advance the adjustment cup down onto the center of the ceramic filter end until the filter is held firmly against the gasket.

7. Carefully insert the probe back into the sampling port and secure it in place with the mounting flange bolts.

8. Place the transceiver on the hinge pins. Attach the thermal probe connector and purge tube. Close and latch the transceiver to the probe.

6.3 Transceiver Lens Replacement or Cleaning

1. Release the six latches that secure the transceiver to the probe. Swing the transceiver to the side and disconnect the purge tube and thermal probe connector below the transceiver lens. Lift the transceiver off the hinge pins and set it aside.

2. With the transceiver in a vertical position (lens up), remove the lens assembly by rotating it counterclockwise.

Caution

Do not touch any glass surfaces when cleaning or servicing the SM8175. Remove the lens only in clean, dry air.

3. Before inserting the new lens assembly, clean both sides of the lens with a lens cloth. Ensure that an O-ring is located below the threads on the outside of the lens assembly (refer to the old lens assembly as an example). ***Do not use the new lens assembly without an O-ring*.** Insert the new assembly by rotating it clockwise.

4. Once the assembly is fully seated, back off the applicable number of turns as follows:

18 inch probe	2 turns out
4 foot probe	2 turns out
6 foot probe	3/4 turn out

5. Place the transceiver on the hinge pins**.** Attach the thermal probe connector and purge tube**.** Close and latch the transceiver to the probe.

6.4 Grafoil Ring and/or Window Cleaning or Replacement

Note

This procedure is a guideline based on the standard probe configuration. Steps 3 through 6 are probe-dependent. Refer to the appropriate probe drawings to determine the ring/window replacement procedure for nonstandard probes. Whenever the window is replaced, the Grafoil ring must be replaced.

Note

Any time the probe end is disassembled, the filter gasket must be replaced. If a wet scrubber is used, thoroughly wet the gasket before packing it into the gasket seat.

1. Release the six latches that secure the transceiver to the probe. Swing the transceiver to the side and disconnect the purge tube and thermal probe connector below the transceiver lens. Lift the transceiver off the hinge pins and set it aside.

2. Remove the probe from the stack.

3. Remove the ceramic filter.

4. Remove the complete measurement cavity assembly by placing a screwdriver or other strong instrument horizontally through the measurement cavity for leverage. Turn the complete assembly counterclockwise until it is disengaged.

5. Lift the window assembly out of the probe.

6. Pry the Grafoil ring out of its seat with a small screwdriver and clean the seat.

Caution
Avoid touching any glass surfaces.

7. Place the new Grafoil ring in its seat.

8. Clean the window assembly and place it on top of the Grafoil ring.

9. Ensure that the key on the window assembly is aligned with the keyway in the probe body.

10. Replace the complete measurement cavity by turning it clockwise until solid resistance is felt. Measure the length of the measurement cavity extending from the probe and tighten with a torque wrench until it moves 0.25 to 0.32 inch. Do not exceed 25 foot-pounds.

11. Replace the ceramic filter and reinstall the probe.

6.5 Retroreflector (Corner Cube) Replacement

Note

This procedure is a guideline based on the standard probe configuration. Steps 3 through 6 are probe-dependent. Refer to the appropriate probe drawings to determine the retroreflector replacement procedure for nonstandard probes. The retroreflector is determined by probe length rather than cavity size.

Caution
Avoid touching any glass surface when cleaning and/or servicing the SM8175.

1. Release the six latches that secure the transceiver to the probe. Swing the transceiver to the side and disconnect the purge tube and thermal probe connector below the transceiver lens. Lift the transceiver off the hinge pins and set it aside.

2. Remove the probe from the stack.

3. Remove the ceramic filter.

4. Hold the measurement cavity securely and loosen the jam nut. Do not move the main body of the measurement cavity during this procedure.

Note
If the main body of the measurement cavity does move, perform the Grafoil ring and/or window cleaning or replacement procedure.

5. Turn the retroreflector housing counterclockwise and remove it.

6. Remove the old retroreflector. Verify that the spring and plate remain within the end of the retroreflector housing.

7. Clean the new retroreflector and insert it in the retroreflector housing.

8. Position the probe with the measurement cavity downward, then place the retroreflector housing on the end and turn clockwise until there is contact. Turn one turn after contact (preload).

Warning
Overtightening will crack the retroreflector.

9. Tighten the jam nut.

10. Replace the ceramic filter and reinstall the probe.

6.6 Thermal Probe Replacement

Note
This procedure is a guideline based on the standard probe configuration. Steps 3 through 6 are probe-dependent. Refer to the appropriate probe drawings to determine the thermal probe replacement procedure for nonstandard probes. The engineering drawings in *Chapter 9* are for probes with RTDs. If you are upgrading to an SM8175, replace the thermocouple with an RTD and change the transceiver jumper configuration.

Note

Any time the probe end is disassembled, the filter gasket must be replaced. If the probe is used with a wet scrubber, thoroughly wet the gasket and pack it in the gasket seat.

1. Release the six latches that secure the transceiver to the probe. Swing the transceiver to the side and disconnect the purge tube and thermal probe connector below the transceiver lens. Lift the transceiver off the hinge pins and set it aside.

2. Remove the probe from the stack.

3. With the probe in a horizontal position, remove the thermal probe Swagelock nut at the end of the probe. Remove the ferrule.

4. Insert the new thermal probe into the probe until approximately one inch protrudes through the end of the probe.

5. Insert the new ferrule.

6. Replace the Swagelock nut and tighten securely until thermal probe movement is totally restricted.

7. Reinstall the probe and reattach the transceiver to the probe.

8. Attach the thermal probe connector at the transceiver.

6.7 Probe Replacement

1. Release the six latches that secure the transceiver to the probe. Swing the transceiver to the side and disconnect the purge tube and thermal probe connector below the transceiver lens. Lift the transceiver off the hinge pins and set it aside.

2. Release the mounting flange bolts on the ***stack side only***. Carefully draw the probe from the sampling port. Allow the probe to cool to room temperature before transporting it.

3. Align the new probe. The probe must be out of the stack for alignment. Position and clasp the probe on the transceiver in a vertical position. Loosen the three flange bolts, then rotate the two flange rings independently and together in order to get the lowest voltage at TP4 on the SDA board in the J-box. Long probes may be subject to significant changes in alignment because of the effects of heat. In such cases, try alternate positions near the lowest voltage.

4. Carefully insert the new probe into the sampling port and secure it in place with the mounting flange bolts.

5. Place the transceiver on the hinge pins. Attach the RTD connector and purge tube. Ensure that the correct type of thermal probe is selected by the jumpers on the transceiver board. Close and latch the transceiver to the probe.

6.8 Transceiver Replacement

1. Release the six latches that secure the transceiver to the probe. Swing the transceiver to the side and disconnect the purge tube and thermocouple connector below the transceiver lens. Lift the transceiver off the hinge pins.

2. Place the new transceiver on the hinge pins. Ensure that the correct type of thermal detector is selected with the transceiver board jumpers. Attach the thermal probe connector and purge tube. Close and latch the transceiver to the probe.

3. Perform the transceiver test and calibration procedures.

4. Ensure that the transceiver lens is focused for the proper probe length (see *6.3.4* above).

6.9 Span Cell Replacement

Caution

Switch the transceiver power off (CB1) in the J-box before beginning any transceiver maintenance or component replacement procedures.

Caution

Expose optical components only in a clean area.

Caution

Avoid touching any glass surfaces when cleaning and/or servicing the SM8175.

1. Release the six latches that secure the transceiver to the probe. Swing the transceiver to the side and disconnect the purge tube and thermal probe connector below the transceiver lens. Lift the transceiver off the hinge pins.

2. Position the transceiver with the black-finned lamp housing up.

3. Loosen the six screws on the transceiver access door and open the access door.

4. Remove the Allen screw located near the bottom of the photomultiplier tube (PMT) assembly, which has a lanyard to the access cover attached to it.

5. Disconnect the two plugs to the dynode chain.

6. Remove the three Allen screws that secure the PMT assembly. (It may be necessary to disconnect several wires from TB1 to allow clearance for removal of the assembly.)

7. Carefully remove the PMT assembly by pulling outward (see Figure 6-1 and Figure 6-2).

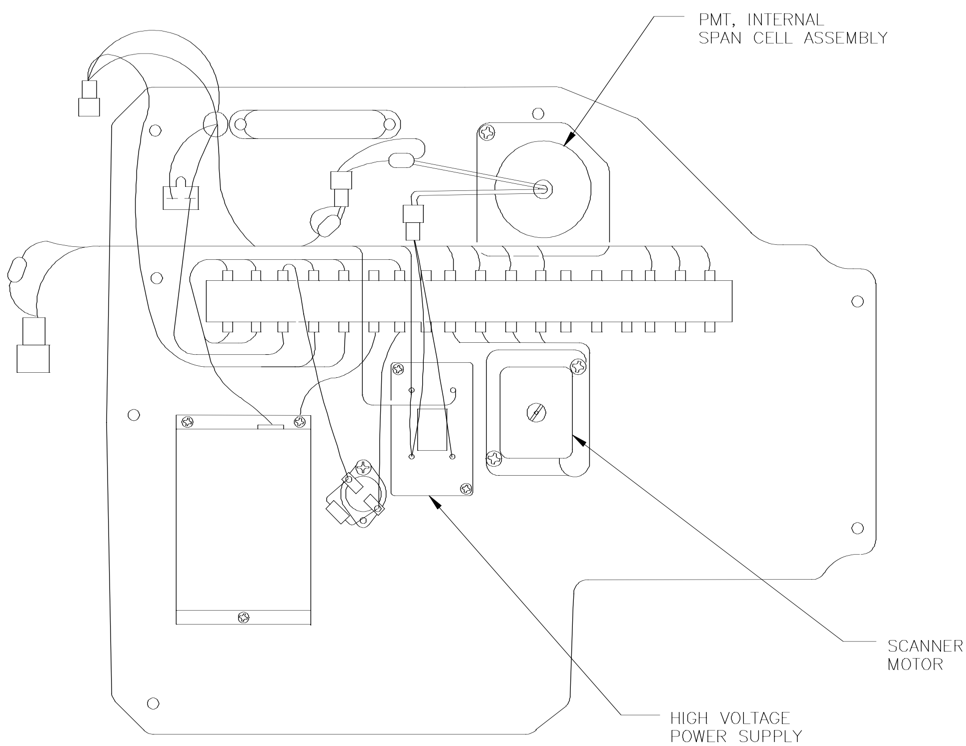


Figure 6-1. Optic Plate Assembly, Bottom View

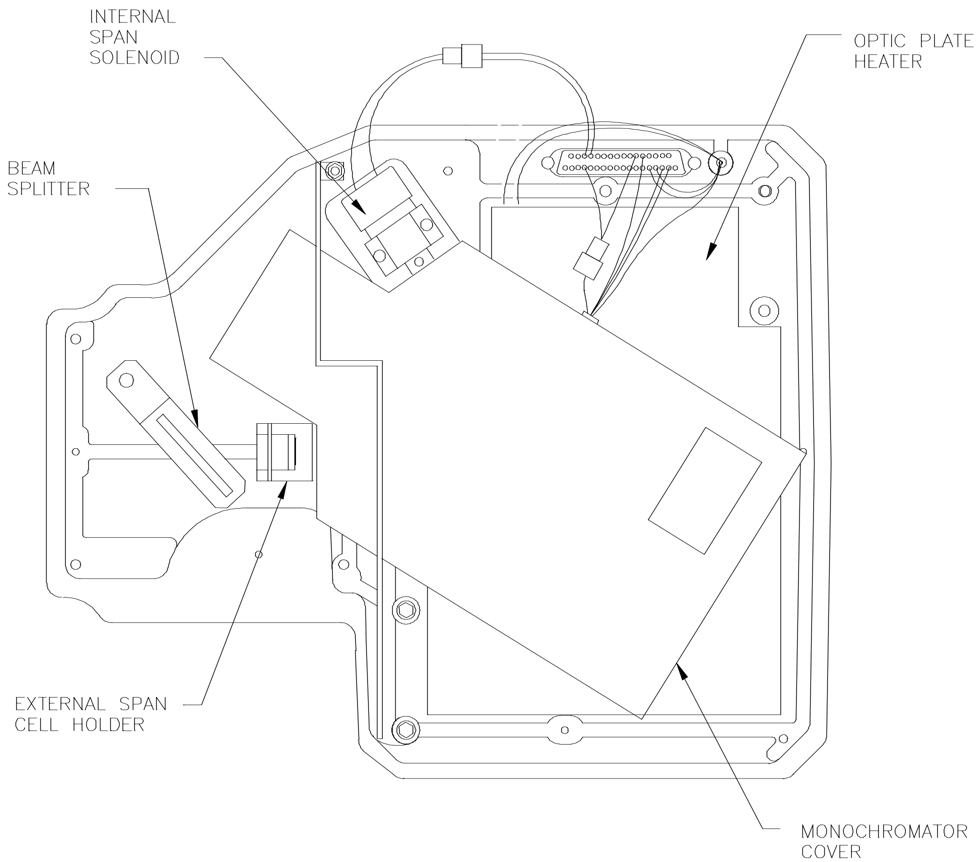


Figure 6-2. Optic Plate Assembly, Top View

8. Loosen the Allen set screw on the span cell and remove the span cell.
9. Install a new span cell and tighten the Allen set screw.
10. Perform steps 1 through 8 in reverse order and reverse action to reassemble the transceiver.
11. Correct the `SPAN` values and `E-O TEMP` value under the `SO2/NO SETUP` menu.

6.10 Span Cell Solenoid Replacement

1. Remove the span cell using the span cell replacement procedure.
2. Remove the two Allen screws that secure the span solenoid to the PMT assembly.

3. Remove the two nuts that secure the span solenoid to the bracket. Remove the solenoid.

4. Install the new span solenoid.

Note

Once the new span solenoid with the span cell attached is installed, verify that it moves back and forth freely without dragging.

5. Perform steps 1-4 in reverse order and reverse action to reassemble the transceiver.

Note

If replacing the optic plate, turn the transceiver on its back and verify that the optic plate is firmly seated on its alignment pins.

6.11 Photomultiplier Tube and/or Dynode Replacement

Caution

Switch the transceiver power off (CB1) in the J-box before beginning any transceiver maintenance or component replacement procedures.

Caution

Expose optical components only in a clean area.

Caution

Avoid touching any glass surfaces when cleaning and/or servicing the SM8175.

1. Release the six latches that secure the transceiver to the probe. Swing the transceiver to the side and disconnect the purge tube and thermal probe connector below the transceiver lens. Lift the transceiver off the hinge pins.

2. Position the transceiver with the black-finned lamp housing up.

3. Loosen the six screws on the transceiver access door and open the access door.

4. Remove the two smaller screws on the PMT assembly (see Figure 6-1 and Figure 6-2).

5. Remove the PMT by pulling outward.

6. Replacement of:

   PMT. Place the gasket on the seat (refer to the old PMT as an example). Disconnect the old PMT from the dynode and connect the new PMT to the dynode.

   Dynode. Remove the wires from the old dynode and remove the dynode. Connect the new dynode and reconnect the wires.

7. Carefully slide the PMT and dynode chain back into the optic plate, aligning the PMT grids with the hole inside the housing. Replace and tighten the two Allen screws.

8. Perform steps 1 through 7 in reverse order and reverse action to reassemble the transceiver.

6.11.1 PMT Base Plate Replacement

1. Remove power from the transceiver by tripping the J-box circuit breaker.

2. Drop the transceiver bottom cover for access to the PMT mounting hardware.

3. Remove the two screws securing the PMT socket.

4. Remove the PMT, being careful not to expose the tube to excessive light. (Direct sunlight will saturate the PMT, after which it takes several hours to recover.)

5. Remove the three screws securing the PMT assembly and remove the assembly. (The assembly will still be attached with wires to the span solenoid, but it can be dropped far enough to replace the plate.)

6. Remove the two screws attaching the mounting plate to the assembly and replace with the new mounting plate.

7. Reassemble in reverse order.

8. The PMT does not require further adjustment. If, however, peak performance is desired, proceed to step 9.

9. Loosen the three PMT mounting plate screws about a turn. Switch the J-box SDA Manual and Shutter switches to the ON position. With the equipment operating, grasp the PMT socket and rotate the assembly for the lowest voltage at TP4 on the J-box SDA circuit board (note that the measurement return is TP9). Return the SDA switches to OFF and button up the transceiver.

6.12 Scanner Assembly Replacement

6.12.1 Scanner Offset Test

Activate MANUAL switch S5 and SHUTTER switch S3 on the J-box SDA board (to the left for both switches). Transceiver board TP6 (*Figure 4-4*) shows a perfect scanner offset because the waveform is evenly centered around zero volts with the scope DC coupled at ground potential. The measurement technique is to DC-couple the scope, center the waveform as shown in *Figure 4-4*, and switch the scope to ground. The DC level above or below ground is the measured scanner offset voltage.

The SM8175 optical system is laser-aligned in the factory so that the scanner offset does not exceed 200 millivolts. However, reliable operation may be experienced with scanner offset as high as 400 millivolts. The criteria for proper scanner operation is that SO_2 d^2 and NO d^2 adjust properly, the scanner offset is within 400 millivolts, and no scanner alarm exists.

If the scanner offset is suspected, by the above criteria, to be contributing to a transceiver malfunction, replace the scanner motor using the replacement procedures in Chapter 6 or contact the factory for assistance. If replacing the motor does not correct the problem, contact the factory.

Caution

Switch the transceiver power off (CB1) in the J-box before beginning any transceiver maintenance or component replacement procedures.

Caution

Expose any optical components only in a clean area. Avoid touching any glass surface when cleaning and/or servicing the SM8175.

1. Remove the four nuts from the probe studs that retain the transceiver. Unplug the RTD bulkhead connector and disconnect the purge plumbing from the transceiver. Remove the transceiver from the probe. Note if the transceiver to J-box umbilical is too short to set the transceiver down, disconnect it from the J-box.

2. Position the transceiver with the black-finned lamp housing up.

3. Loosen the six screws on the transceiver access door and open the access door.

4. Remove wires #6 (green), #7 (yellow), #8 (black), and #9 (red) on the PMT side of the terminal strip.

5. Remove the two countersunk slotted screws on the scanner assembly

6. Remove the scanner assembly by pulling outward. This step may require some manipulation.

7. Insert the new scanner assembly. Be sure the new assembly is seated on the alignment pins. This procedure may be difficult. If it is, start the two screws, which should pull the assembly into place.

Caution

Do not pound on the scanner assembly or use any kind of tool to force it or alter the position of the scanner window.

8. Perform steps 1 through 7 in reverse order and reverse action to reassemble the transceiver.

6.13 Transceiver Printed Circuit Board Replacement

Caution

Switch the transceiver power off (CB1) in the J-box before beginning any transceiver maintenance or component replacement procedures.

Caution

Expose optical components only in a clean area.

Caution

Avoid touching any glass surfaces when cleaning and/or servicing the SM8175.

1. Release the six latches that secure the transceiver to the probe. Swing the transceiver to the side and disconnect the purge tube and thermal probe connector below the transceiver lens. Lift the transceiver off the hinge pins.

2. Position the transceiver with the black-finned lamp housing up.

3. Loosen the six screws on the transceiver access door and open the access door.

4. Disconnect the two connectors on the transceiver printed circuit board.

5. Remove the six screws that secure the PCB.

6. Remove the PCB and replace it with a new PCB.

7. Replace and tighten the six screws. Replace the two connectors.

8. Perform steps 1 and 2 in reverse order and reverse action to reassemble the transceiver.

9. Reconnect power and perform the transceiver test and calibration procedures. Ensure that the correct type of thermal detector is selected by jumpers 3 through 5 on the transceiver board.

6.14 Transceiver Sequential Shutter Replacement

Caution

Switch the transceiver power off (CB1) in the J-box before beginning any transceiver maintenance or component replacement procedures.

Caution

Expose optical components only in a clean area.

Caution

Avoid touching any glass surfaces when cleaning and/or servicing the SM8175.

1. Release the six latches that secure the transceiver to the probe. Swing the transceiver to the side and disconnect the purge tube and thermal probe connector below the transceiver lens. Lift the transceiver off the hinge pins.

2. Position the transceiver with the black-finned lamp housing up.

3. Loosen the six screws on the transceiver access door and open the access door.

4. Remove the bulkhead thermal probe connector from the transceiver casting and disconnect the wires after marking their leads for replacement. Remove the green lanyards that support transceiver bottom casting from the optic plate. Mark and disconnect all wire harness in-line connectors except those associated with the PMT. Remove the six screws attaching the optic plate to the transceiver casting (these are located near the edge of the optic plate). Remove the optic plate (note that the plate is slightly pressed onto two alignment pins, one under the thermal probe bulkhead connector and one on the other end of the optic plate).

Caution

Do not pound on the optic plate or use any kind of tool to force it or alter its position.

5. Remove the monochromator cover secured with a screw on either side.

6. Remove the two screws securing the solenoid mounting bracket.

7. Cut the grommet to remove the solenoid wires from the harness.

8. The solenoid bracket exhibits a tight fit, pinned to the monochromator plate. Don't remove the pin. A slight force will be required, but don't force it with hammer blows that can upset the monochromator alignment. Remove the solenoid bracket.

9. Remove the shutter arm by loosening the two set screws securing the arm to the solenoid shaft.

10. Replace the solenoid using the spacer and screws provided. Longer screws than provided will bind the solenoid.

11. If a 24 VAC supply is available, energize the solenoid and install the arm against the energized stop. If the arm chatters against the stop, it must be installed so that the solenoid asserts more force against the stop. If the supply is not available, assemble so that the solenoid asserts a force against the stop (when the transceiver is powered up and operating, there should be an audible sound when the shutter is positioned into the NO position without indications of excessive reference). Remove the power supply.

12. There should be a visible space between the arm and bracket so that the arm will not drag on the bracket.

13. Mount the solenoid bracket but do not tighten the screws. Be sure the new assembly is seated on the alignment pin. This procedure may be difficult. If it is, start the two screws, which should pull the assembly evenly into place.

14. Sight over the top of the mirror that is perpendicular to the exit slits. Rotate the solenoid bracket so that the exit slit to the right is well covered by the shutter arm and the space between the slits is evenly divided.

15. Tighten the solenoid bracket mounting screws. Feed the solenoid wires through the split grommet and install the monochromator cover.Plug solenoid the. Perform steps 1 through 4 in reverse order and reverse action to reassemble the transceiver.

7.0 Functional Description

The following is a general description of the SM8175 optical and electronic subsystems, including what they are and what they do. Each narrative section is associated with a functional block diagram so that the two can be used together. In the diagrams, active circuits are represented by blocks with names that identify their functions. Blocks that relate to a single operation are grouped together. In the text, reference is made to the blocks. Emphasis is placed on signal input and output names and their connections to other places.

7.1 Optical System

The optical system uses a second-derivative absorption spectrometer, an instrument that optically generates and extracts the second-derivative signal of the NO or SO_2 absorption spectra.

The optical system is contained within the probe and transceiver assemblies and includes a beam splitter, lens, corner cube (retroreflector), mirrors, and a diffraction grating. The functional diagram for this system shows the optical device configuration (see Figure 7-1). Progression of the light path envelopes are indicated by straight lines with arrows, referred to as light rays or beams.

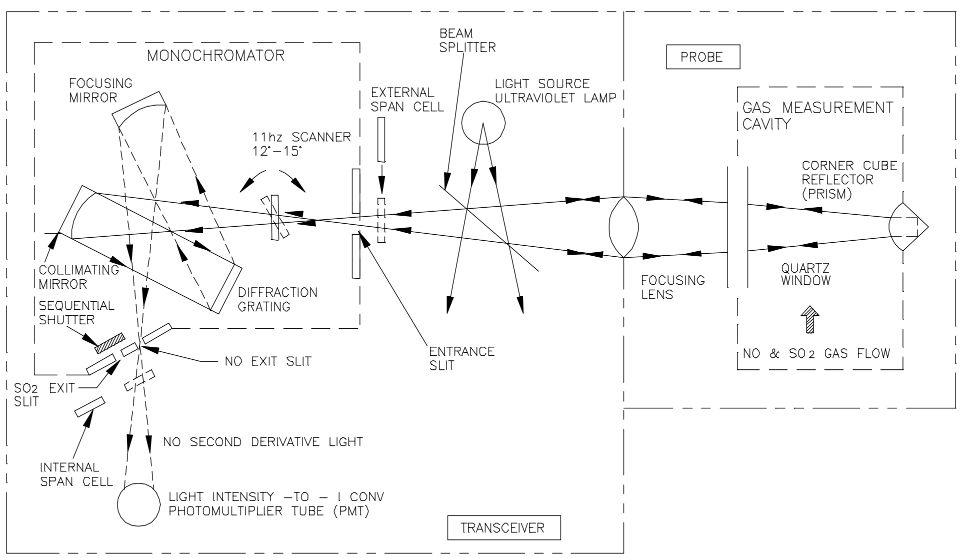


Figure 7-1. Optical System Functional Diagram

7.1.1 Transceiver Optics

The SM8175 functions when an electronically-controlled UV lamp emits a broadband UV light spectrum that impinges on the partially transparent surface of a beam splitter. The light reflects off the surface of the beam splitter towards a focusing lens located at the probe entrance. The lens converges light rays along the probe length toward the gas measurement cavity. The UV light passes through a quartz window and traverses the cavity. Any NO or SO_2 gas present in the cavity absorbs some UV light, thereby reducing the light intensity at the absorption wavelengths.

A focused corner cube reflector (a prism with a curved front surface to maintain the light beam shape) at the opposite end of the cavity returns the UV light along a different path by the principal of total internal reflection at two prism sides. The reflected light traverses the cavity again, passes back through the quartz window, and travels the probe length to strike the focusing lens, which converges the light towards the beam splitter.

After passing through the beam splitter, the UV light converges to a focal point at the monochromator entrance slit.

7.1.1.1 Monochromator

The monochromator is a self-contained unit that optically generates the second-derivative signals for NO and SO_2 from the focused UV light that passes through the entrance slit. In the monochromator, the light passes through a quartz plate scanner that periodically oscillates at 9 Hz through a 12° to 15° angle. The scanner motion continuously changes the incident angle of the light striking it, thereby displacing the light beam. This changing angle periodically shifts the UV spectrum, including the absorption wavelengths, in time and position, which results in wavelength modulation. The scanner induces second-derivative signals by wavelength-modulating the absorption wavelengths.

After the light passes through the scanner, it is reflected by a concave, collimating mirror that forms parallel (collimated) rays that impinge on a diffraction grating. The grating is a plane reflection-type with 2180 lines per millimeter. It is a device that diffracts, or bends, incident light at angles that are a function of the light wavelengths. This is called dispersion. It means that light is angularly separated according to wavelength in a manner similar to a prism separating visible white light into its rainbow of colors.

After dispersion, the light rays are reflected from the grating. The angle of the light rays is determined by their wavelength. They are directed to a concave focusing mirror that reflects and converges the dispersed light into a continuous spectrum across two exit slits. The fixed position and width (0.1 millimeter wide) of the exit slits select only the NO and SO_2 absorption wavelengths from the continuous spectrum.

Note

The functional diagram depicts only the NO light rays being focused at and exiting from a slit.

A sequential shutter operated by electronics system timing selects either the NO or SO_2 absorption wavelength for measurement

7.1.1.2 Light Intensity-to-Current Converter

A photomultiplier tube (PMT) converts the intensity of light exiting the monochromator to an equivalent electrical current. This cyclic current varies according to the second-derivative frequency (2F). In the SM8175, the second-derivative frequency equals 18 Hz, twice the 9 Hz modulating frequency (F) of the scanner. The principal photomultiplier tube output signal components are a DC level corresponding to the average UV light intensity and the modulated frequency (2F). The electrical output from the photomultiplier tube goes to the PMT input in the second-derivative signal processor section of the transceiver board, located in the transceiver.

7.2 Electronic System

7.2.1 Transceiver

The transceiver performs the following functions:

- processes the PMT signal to produce the second-derivative signal
- controls the UV lamp
- controls the scanner motor
- controls the high voltage (HV) power supply for the PMT
- receives and processes the thermal probe signal.

The devices and circuits that implement these functions are:

- dynode chain and HV control power supply for the PMT
- UV lamp
- scanner motor
- thermal probe
- transceiver board
- output drive.

7.2.2 Second-Derivative Signal Processor

The second-derivative signal processor processes the PMT signal, which includes the second-derivative signal from the PMT, into appropriate PMT OUT and d^2

signals (see Figure 7-2). The PMT current is converted into an equivalent voltage called PMT OUT. This signal branches in two directions; to a low-pass, active filter and into PMT DC control.

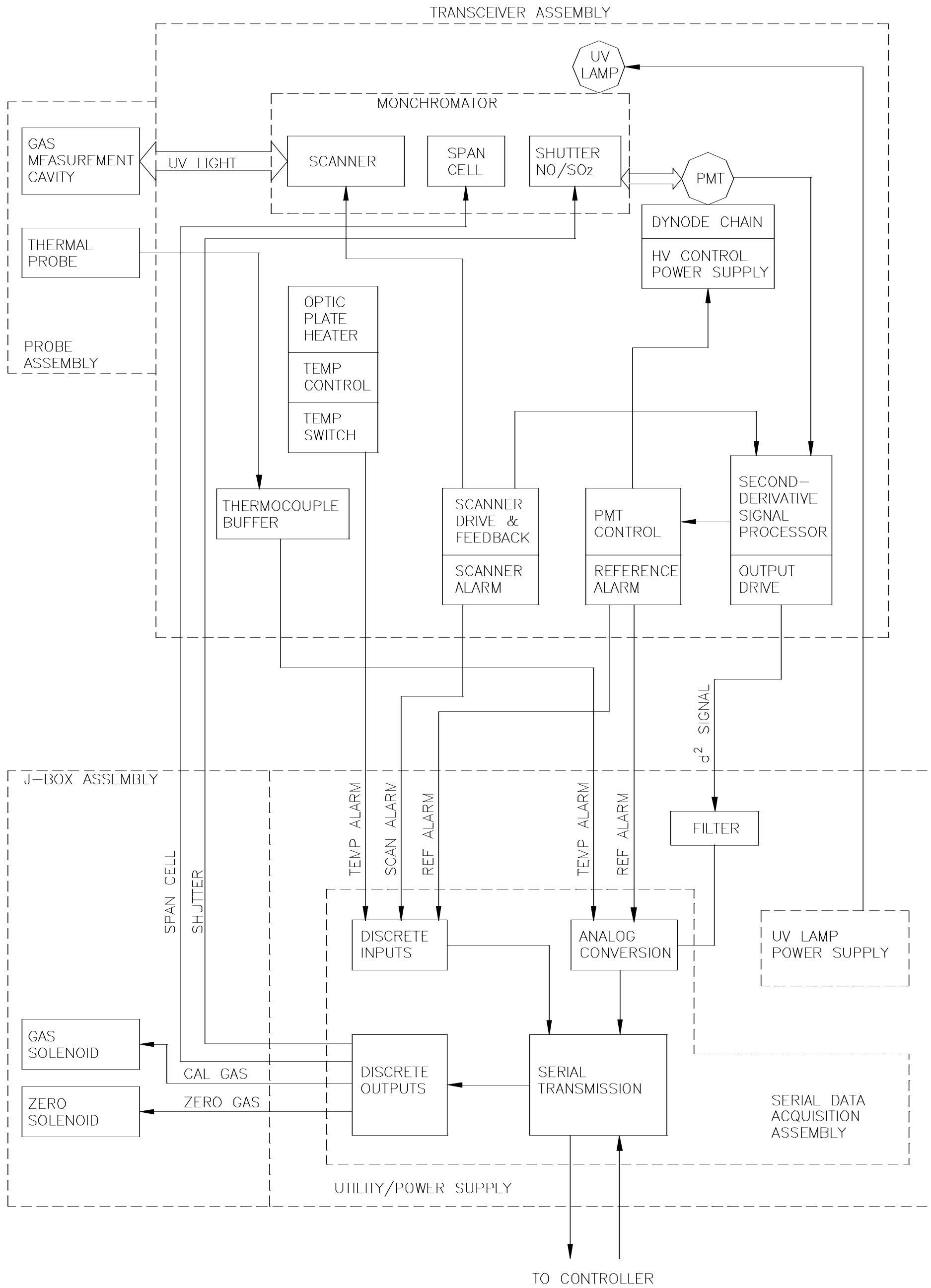


Figure 7-2. Block Diagram

After low-pass filtering and gain adjustments, the 18 Hz second-derivative signal is detected by a half-wave demodulator. A control signal from the scanner drive circuit switches the demodulator at a rate of 18 Hz. This rate is synchronized with the 9 Hz scanner drive signal to keep a correct phase relationship between them.

The signal is then divided by the available light level to remove variations caused by an aging lamp or detector. The signal is then filtered to form a DC voltage. Finally, the output driver converts the signal to a current for transmission to the J-box.

7.2.3 Photomultiplier Tube DC Control

The photomultiplier tube (PMT) DC control compensates for UV lamp aging and contamination of the optics. As the UV lamp ages and the optics become contaminated, the light intensity received by the PMT decreases. This change is detected by monitoring the PMT output current. If the current decreases, the HV CONT signal increases to increase the PMT high voltage, which results in higher PMT gain. This causes an increase in PMT current that restores the desired 1 microamp level. HV CONT is available as a reference voltage (REF).

REF ALARM is a signal that activates when the PMT high voltage increases to a level that affects measurement accuracy. The signal goes to the J-box for transmission to the controller as a fault diagnostic.

7.2.4 Thermal Detector Buffer Amplifier

The thermal detector buffer amplifier is a voltage-to-current converter. The type of detector input, RTD (or thermocouple used on older SM8100s), is selected by means of jumpers on the transceiver board. The output of a thermocouple is a small DC voltage characteristic of temperature. The output of the RTD is a resistance characteristic of temperature which is converted to a voltage by a bridge network.

The detector output, which is proportional to thermal probe temperature, is converted into an equivalent current output (TEMP +). The output goes to the J-box for transmission to the controller.

7.2.5 Scanner Drive

The scanner drive operates the scanner motor in conjunction with a feedback signal that stabilizes scanner operation. The basis of operation is the timing reference: a 36 Hz oscillator. A frequency divider divides the oscillator frequency by 2 to produce an 18 Hz control signal that operates the half-wave demodulator. It also divides the oscillator signal by 4 to produce a 9 Hz signal that operates the scanner motor. The phase relationship between the two signals remains constant. Variable DC offset voltages (NO scan and SO_2 scan offset) are added to the 9 Hz signal to properly set the drive level for scanner motor operation. The 9 Hz signal is converted by the driver from a voltage to a buffered current drive signal (scanner drive) that operates the scanner motor.

A feedback loop from the scanner is rectified and filtered by the scanner feedback circuit. It is then added to the 9 Hz drive signal to compensate for amplitude fluctuations in the scanner drive. This maintains correct scanner rotation amplitude.

7.2.6 Scanner Alarm

The scanner alarm circuit produces an alarm signal on the scanner alarm output whenever the scanner feedback voltage does not compensate enough for incorrect scanner amplitude.

7.3 J-Box

7.3.1 UV Lamp Power Supply

This supply is designed to drive a Deuterium lamp. After the lamp has been warmed up by its filaments, the lamp requires a high voltage drive at low current to strike an arc, then a lower voltage drive at the operating current. When the shutter signal changes state, the lamp start supply turns on. This supply ramps up toward 450 VDC, and the lamp fires when its firing potential is reached. The current regulator circuit then accurately maintains the current at 300 mA.

7.3.2 Serial Data Acquisition

The control unit retrieves transceiver status and analog measurements on a data acquisition basis. Acquisition starts when the control unit sends out a J-box identification code, along with the code for the required measurement and status. The control unit can then communicate with another instrument J-box until the requested data from the first J-box is ready.

When the data is ready, the serial data acquisition circuitry waits for the control unit to request the next measurement or status. When the request is received, the serial data acquisition circuitry transmits the last measurement or status and then starts on the next request, while the control unit again communicates with another J-box.

The control unit only communicates with a given J-box long enough to transmit its request and to receive the measurement or status from the last request. The control unit request can also set up the required discrete outputs. When calibration is required, the control unit operates the proper solenoid.

Transceiver diagnostic switches are also available on the serial data acquisition (SDA) board (see *Figure 1-2*). The switches are enabled when Manual switch S5 is activated (switched to the left). Activating Zero switch S1 (to the left) floods the measurement cavity with zero calibration gas. Zero conditions can then be monitored on the J-box test points.

With both Zero switch S1 and Span switch S2 activated (to the left), the transceiver span cell is placed in the zero-gas-filled optic path, allowing the span cell measurement to be monitored on the test points. With S1 and S2 deactivated (to the right) and Gas switch S4 activated (to the left), the Gas Cal solenoid is activated to fill the measurement cavity with calibration gas, and the conditions of a gas calibration can be monitored on the test points. In the active position (to the left), Shutter switch S3 forces NO measurements; in the deactivated position (to the right), S3 forces SO_2 measurements. The three status LEDs indicate the status of the reference alarm, the scanner alarm, and the temperature alarm.

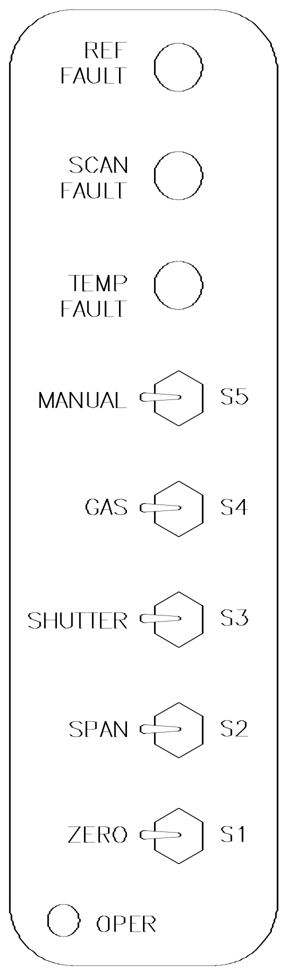


Figure 7-3. Serial Data Acquisition (SDA) Board Switches and Indicators

8.0 Technical Description

This chapter discusses how the transceiver printed circuit board sections work. Emphasis is placed on signal processing by circuits. Each circuit explanation relates to its associated printed circuit board (PCB) schematic. See *Figures 4-3* through *4-9* for representative waveforms from board test points.

8.1 Transceiver Printed Circuit Board

8.1.1 Second-Derivative Signal Processor

See *drawing 81750044*.

U5 is a current-to-voltage converter that converts the PMT signal current from the photomultiplier tube (PMT) to a voltage (PMT OUT). The output at U5-6 branches into three directions. PMT OUT goes to the divider IC though U19. Another branch goes to integrator input U7-2. The third branch goes to the input of a low-pass, dual-pole, active filter U8. R38 and C13 form the first filter section and R59, R57, R58, C14, and C22 form the second filter section.

After filtering, the signal goes to U15, which is an adjustable gain amplifier. The U15-1 output connects to analog switch U13-2, U13-7, and U13-11. The U13 outputs switch on and off at an 18 Hz rate determined by the logic states of the control signals coming from flip-flop U12-1 and U12-2. Because the 18 Hz control signals are synchronized with the 9 Hz scanner drive signal, they properly select the 18 Hz second-derivative signal from the input to U13.

The U13 output is a half-wave demodulated signal at TP1 (*Figure 4-7*). The divider U16 Z input is multiplied by 10 and divided by the available light on the X input. The normalized output is then converted to DC current by the circuitry associated with U19.

8.1.2 Photomultiplier Tube (PMT) DC Control

See *drawing 81750044*.

The U5-6 output signal is a small AC voltage (<10 mV) with a +1 VDC offset. Signal current from U5-6 goes through R53 to integrator U7-2. A reference voltage of +1.035 volts, derived from the junction of R55 and R56, is applied to the noninverting input of U7.

Variations above or below +1 VDC at U7-6 indicate a change in the operating point of the PMT. This variation is compared to the setpoint voltage at U7-3. As a result, the charge on C23 changes to alter to the U7 output and Q5 emitter voltages at TP4. TP4 should be 4 to 10 VDC. This voltage (HV CONT) goes to the power supply A2 for the PMT.

If the U5-6 offset increases, it causes the output at U7-6 to decrease. Thus, the voltage output on the emitter of Q5 decreases. This voltage decrease, going to the HV CONT power supply at J2-14, decreases the PMT voltage, which reestablishes the proper operating point.

Conversely, if the signal offset from U5-6 decreases, U7 and Q5 will increase the voltage at TP4. As a result, an increase of the PMT voltage reestablishes the proper operating point.

Emitter-follower Q3 transfers HV CONT at its base to REF at its emitter. The REF signal goes to the J-box and the controller where it can be displayed.

To produce a REF ALARM the HV CONT from Q5 goes to integrator U15-5. If U15-5 has a higher voltage than the junction of R77 and R71 (8.3 volts), the output of U15 rises to forward-bias emitter-follower Q6. Relay K2 is energized and closes the contacts between REF ALARM J1-23 and ALARM RET J1-24. As a result, REF ALARM is pulled low to illuminate the REF LED on the SDA board in the J-box and a REF ALARM is transmitted to the controller.

8.1.3 Thermal Detector Buffer Amplifier

See *drawing 81750044*.

The RTD produces a resistance dependent on probe temperature (≈ 100 ohms at 0° C). This resistance is converted to a millivolt signal with a bridge circuit at the input to U3. A three-wire RTD configuration is used to help balance out part of the lead resistance in the probe. U3 and Q4 comprise a circuit that converts the millivolt DC voltage from the thermal probe to a current-source signal. This is a low-impedance drive that permits transmission of the signal over the cable between the transceiver and the J-box.

Note

Curve fit for the RTD is accomplished in the controller firmware.

8.1.4 Scanner Drive

See *drawing 81750044*.

Oscillator U11 sends a 36 Hz signal to dual flip-flop U12-3. The first part of U12 divides the oscillator signal down to 18 Hz, and the second part further divides it down to 9 Hz. The 9 Hz signal goes from U12-13 to the base of emitter-follower Q8. It is then coupled by C41 and integrated by R46 and C25 to form a triangular wave before going to adder U10, which adds this signal to SO_2 scan offset.

TP6 (*Figure 4-4*) typically has a 0.6 volt peak-to-peak signal that is transmitted through U6, then to Q1 and Q2 where these push-pull transistors produce a current drive signal (scanner drive) that operates the scanner. Potentiometer R3 (SO_2 scan offset) moves the scanner position to the proper SO_2 absorption wavelength. R3 voltage goes through R61 to the positive input at adder U10-3. R3 is adjusted to produce a DC bias current that is necessary for proper scanner position when the system measures SO_2 and/or NO.

R88 is the NO scan offset potentiometer. It is connected into the circuit when relay K1 is activated. R88 voltage is applied to U10-2, where it is used to adjust the wavelength separation between the SO_2 and NO peaks. Usually, any wavelength shift is correctable by adjusting SO_2 scanner offset.

Feedback circuitry consisting of U4, U17, and Q8 compensates for any circuit variations or changes in scanner amplitude (typical ±3° allowed movement) that can cause erroneous second-derivative signals. The scanner drive amplitude originates from the peak-to-peak voltage transition of the square-wave output at Q8. When the scanner operates properly, the Q8 output range is +4 to +10 volts.

For example, if the SO_2 scanner amplitude is too great, the scanner angle exceeds +3° and scanner feedback increases. This signal is half-wave-rectified by U17, filtered by integrator U18, and then applied to the emitter of Q8, which is a summing junction. The emitter voltage rises to a higher DC level. This diminishes the peak-to-peak square-wave voltage going to U10. Therefore, if instead of a 5 volt square-wave amplitude there is a 4.5 volt amplitude, it produces less current drive to the scanner. Scanner amplitude is reduced to reestablish the proper ±3° scanner angle movement. If the scanner angle is less than the desired angle, the feedback signal decreases and the feedback increases the scanner drive current. Proper scanner amplitude is then reestablished.

8.1.5 Scanner Alarm

See *drawing 81750044*.

U17 output voltage is added to voltage from potentiometer R4 (scanner alarm reference) at adder input U9-2. R4 adjusts the U9-6 output to equal 0 VDC with a small AC signal added to it. If the scanner operates at an improper angle and the feedback system is unable to compensate for it, the output at U9-6 goes positive or negative, depending on the direction of scanner variation. U9-6 goes to D5 and D8, which steer the respective positive or negative outputs to integrator input U17-5 or U17-6. The output at U17-7 forward-biases emitter-follower Q7, which energizes relay K3. When the K3 contacts close, they allow scanner alarm J1-20 to illuminate the scanner alarm LED on the SDA board in the J-box, and a scanner alarm is transmitted to the controller.

8.2 J-Box

8.2.1 UV Lamp Power Supply

Refer to *drawing 81750014*.

The UV lamp power supply is designed to drive a Deuterium lamp. Initial lamp heating is achieved with lamp filaments and then maintained by the power dissipated by the arc discharge. After the lamp has been warmed up by its filaments (approximately 20 to 30 seconds), the lamp requires a high voltage drive at low current to strike an arc, then a lower voltage drive at the operating current. Lamp starting uses the shutter signal to turn on the filaments when SO_2 is selected. Because the lamp is initially off, the other input to the AND gate is high, allowing the filaments to turn on. The shutter signal changes state about every 60 seconds, so the lamp has more than enough time to warm up.

When the shutter signal changes state, the lamp start supply turns on. This supply ramps up toward 450 VDC, and the lamp fires when its firing potential is reached (about 350 VDC). The current regulation circuit attempts to deliver 300 mA by driving the anode toward ground, so its output holds the lamp cathode near 0 volts. The lamp anode attempts to draw 300 mA, which loads down the lamp start supply, and the lamp anode voltage drops to the level of the lamp run supply (about 120 VDC). The anode current increases until the lamp current equals the current regulation circuit output. The lamp run supply detects that the cathode voltage is above its setpoint of 3 volts and decreases the anode voltage until the cathode voltage is at its setpoint.

The Lamp On detector detects that the lamp cathode is above 1.5 volts and turns off the lamp start supply. Once the lamp is on, the Lamp On detector and the lamp start logic hold off the lamp start supply and the filament switch. If for some reason the lamp goes out, the lamp starting sequence repeats and restarts the lamp.

The current regulation operational amplifier is configured as a voltage follower driving a MOSFET. The amplifier turns on the MOSFET until the voltage drop across R34 is equal to the R17 setpoint. Because little current is drawn through the MOSFET gate, the MOSFET drain current equals the current flowing through R34. The circuit requires that the load be connected to a positive supply. The drain voltage rises toward this supply until the load current equals the current through R34.

The current regulator circuit accurately maintains the current through R34 once it has achieved steady state. However, when the lamp is being fired, the op amp output is at the positive stops of +15 volts, attempting to increase the current through R34. With this gate bias, the MOSFET is fully on and looks like a 2 ohm resistor. When the lamp turns on, the surge current would be approximately several amps until the op amp output could slew to its steady state output. However, transistor Q5 with its base emitter across R34 limits this surge current to 0.7 amps. When the voltage across R34 reaches 0.7 volts, the transistor turns on and stops any further increase in the gate voltage of the MOSFET. This limits the current to 0.7 amps. Under normal running conditions where the drop across R34 is 0.3 volts, this transistor is off.

The filament heater is driven by a triac, rated for 12 amps at 80° C case temperature. However, the heat sinking on this assembly limits the current to 4 amps. This limitation occurs under fault conditions when the lamp does not fire and the filaments are turned on continuously. The gate current required to turn the triac on is 125 mA at -40° C. The gate current for the triac flows through the MOSFET, which is the output of the current regulator circuit. Consequently, the current regulator circuit must be functional before the triac turns on.

The lamp start supply uses the energy stored in an inductor to charge capacitor C19 to about 450 volts. Each time the MOSFET Q10 turns on, energy is stored in inductor L2 and transferred to the capacitor due to flyback action. This action pumps up the capacitor voltage until the voltage feedback to the comparator turns off the MOSFET. The maximum output voltage from this circuit is limited by either the rate of change of current through the inductor or the feedback to the comparator. Each cycle of energy into the inductor is sufficient to charge the capacitor about 15 volts. When the output exceeds 450 volts, the comparator turns off the MOSFET, driving the inductor until the output voltage bleeds down below 450 volts.

The lamp run supply uses a pulse-width modulator (PWM) driving two MOSFETs, Q13 and Q14, in a push-pull configuration. The output filter is an LC filter, so the output voltage is the average of the full-wave rectified signal. The period is fixed at about 15 μs and the on time is variable, controlled by the PWM integrated circuit. As the on time changes, the average output voltage changes.

The circuit has two control loops controlled by two different error amplifiers within U5. The amplifier outputs are designed so that the amplifier trying to decrease the output has control. Amplifier U5-5, 16 is normally active and amplifier U5-1, 2 is inactive. Amplifier U5-15, 16 is designed to hold the voltage across the current regulator to 3 volts. A feedback resistor from pin 3 to pin 15 of the PWM U5 reduces the control loop gain, making the loop easier to stabilize. A parallel capacitor decreases the gain with frequency to ensure stabilization.

Current-sensing resistor R64 is in the current return leg of the lamp run circuit output. This resistor limits the short circuit current in the event the lamp anode is shorted to ground. This resistor is 1 ohm and the current-limiting op amp (U5-1, U5-2) is biased to 0.5 volt, so the short circuit current is limited to 0.5 amp. Note that the voltage fed back from the current-sensing resistor is negative.

8.2.2 Conditioning

The input to d^2 circuit U1 is a current of 20 mA full scale. This input is terminated by a 200 ohm resistor to convert this to 2 volts full scale. The resistor is chosen to have a 25 ppm per °C temperature coefficient to minimize temperature drift. A precision zener limiting circuit is added to the output of the filter to avoid driving the SDA A/D converter into overload. This circuit clamps the filter output to 2.5 volts ±1%. The low pass filter is a second order filter that attenuates at 40 dB per decade. The filter time constant is 1 second, which yields a cutoff frequency of 0.159 Hz. This circuit should reduce a 16 Hz signal by 10,000:1.

8.2.2.1 Serial Data Acquisition

See *drawing 81750011*.

Communication from the controller to the J-box is by means of an RS422 differential line transceiver U7/U6. Communication from the J-box to the controller is disabled by U6-3 until data is requested by the controller. The controller transmitted setup data is received through U7 by U3. U3 is a Universal Asynchronous Receiver Transmitter (UART) hardwired for the data format required by the controller (8 bits, even parity, one stop bit). The controller data is available on pins U3-5 through U3-12.

Pins U3-5 and U3-6 are the selection code for the J-box. The unique identification code for each J-box is established through S6-1 and S6-2 as shown in the Instrument # Table in drawing 81750011. S6-1 and S6-2 are configured so that U17-10 and U17-11 will go low when the J-box identification code has been selected. When selected, U16-10 and hence, U6-3, allow any data residing in U3 to be transmitted. When U6-3 is low, the transmission line to the controller is released for use by another J-box.

When selected, U13 latches and decodes the discrete/digital output requested by the controller. The discrete drivers in U14 will go low, light the required LED, and assert a ground to activate a solid-state relay in the J-box. Note that the discrete outputs can also be manually activated by a switch. The switches are enabled only while Manual switch S5 is in the manual mode (to the left). The Manual switch becomes a discrete input to inform the controller to release control of all discrete outputs for use by the J-box operator.

The controller selection of discrete/digital inputs and analog inputs is available on U3-10 through U3-12. Analog inputs are selected by U11. If the selection is zero (pins U3-10 through U3-12 all low), then the analog input on P3-K will be connected to the analog-to-digital converter U1-35. If only U3-12 is high, then P3-H will be connected. The discrete inputs are similarly selected; however, the selected input is only loaded into the UART transmit buffer when the analog-to-digital converter is transmitting its most significant byte (asserting a low on U13-15).

The UART controls the serial transmission as requested by the controller. The analog-to-digital converter is placed in the run mode when U1-26 is asserted high by selecting the identification code and having the receiver data ready (high on U3-19). When the analog-to-digital conversion is complete, the converter places the most significant byte on the UART transmitter byte lines and, by placing a high on U13-15, asks the discrete input to place its requested status bit on bit 8 of the transmitter byte. The converter then sends the least significant byte to the UART for transmission.

When the most significant byte has been transferred to a holding register within the UART (by assertion of a low on U3-23 by the converter), the UART asserts transmitter empty high (U3-22). When the UART asserts transmitter empty a second time, the converter starts conversion for the next measurement requested by the controller. This conversion proceeds even though the J-box is not selected, giving the controller time to communicate with another J-box.

9.0 Engineering Drawings

The engineering drawings listed below are included in this section.

80390010-3	Installation, O_2 Calibration with UNICON Assembly
80390075	Plumbing and Wiring Diagram, O_2 Calibration
80610023-1	Wiring Diagram, LS710 System Interconnect
80610023-2	Wiring Diagram, LS710 to System J-Box (es) with Surge Protection
80610032-1	Wiring Diagram, Interconnection /8 Analog
81001201	Probe Assembly Drawing Less Than 20 cm (750 ppm and greater)
81001203	Probe Assembly Drawing 15 and 20 cm (500 and 375 ppm respectively)
81001205	Probe Assembly Drawing 36 cm (208 ppm)
81001239	Probe Assembly, 75 cm/5' Long
81750001-1	SM8175 Wiring Diagram, System Interconnect with Heat Exchanger
81750002-2	Site Installation
81750004	Mounting Plate Assembly, J-Box
81750006	J-Box Assembly
81750007-X	J-Box Schematic, 8175
81750011	Serial Data Acquisition (SDA) Schematic
81750012	Serial Data Acquisition (SDA) PCB Assembly
81750014	Utility/Power Supply Schematic
81750015	Utility/Power Supply PCB Assembly
81750027	Optic Plate Assembly
81750042-X	Access Door Assembly, SM8175/8100B

81750044-X	Transceiver Schematic, SM8175
81750045	Transceiver PCB Assembly, SM8175/8100B
81750048	Wiring Diagram, Transceiver, SM8175
81751207	37.5 & 75 Cm Probe Assembly
94200018	Typical Installation, LS420 with Calibration to SM and EX Instruments

SM8175 Glossary of Terms and Abbreviations

Absorption. The process by which the number of particles or photons entering a body of matter is reduced by interaction with that matter.

Absorption coefficient. The ratio of light energy absorbed by a medium to the total intensity of light leaving the original source.

Beam splitter. A device used to divide a light beam into two parts, one transmitted and the other reflected.

Collimated light. Parallel light rays as opposed to converging or diverging rays. In the SM8175, a collimating mirror is used in the monochromator to divert parallel rays to the diffusion grating.

Configuration Menu. The basic menu that includes all headings and subheadings programmed into the controller; used primarily during initial setup or reconfiguration of a system.

Demodulator. A device that operates on a previously modulated wave to give it substantially the same characteristics as the original modulating wave. The SM8175 demodulator is a half-wave demodulator.

Diffraction grating. A device that bends incident light at angles that are a function of the light wavelengths. Light is separated according to wavelength in a manner similar to a prism separating white light into a rainbow of colors.

DVM. Digital voltmeter.

Dynode. An auxiliary electrode that, when functioning within a PMT and bombarded by photoelectrons, gives rise to secondary emission and amplification.

Electromagnetic wave spectrum. The range of electromagnetic wavelengths including radio frequency waves, light waves, infrared waves, X-rays, and gamma rays.

E/O calibration. Electro-optical calibration; the basic calibration cycle used to verify instrument readings, using the same optics and electronics used in normal process measurement. E/O calibration places a zero gas and span filter into the measurement path, rather than using NBS-traceable gases injected into the measurement cavity.

Ferrule. A metal ring near the end of the SM8175 thermocouple probe that secures the thermocouple connection.

Gain factors (XX G). Gain factors used to trim out variations from instrument to instrument that can be manipulated manually or calculated from NO G and SO_2 G during a manually-activated gas calibration.

Gas (dynamic) calibration. A sequence of zero and span checks used to verify instrument readings using NBS-traceable standard gases injected into the measurement cavity. Gas calibrations differ from E-O calibrations in that E-O calibrations use span filters placed in the measurement path instead of span gases.

HV. High voltage.

HV CONT. High voltage control or high voltage controller.

In situ. In situ analysis places the sensor in the process being measured.

J-box. Junction box; a separate component of the SM8175 that houses test points, circuit boards, manual switches, and interface points/terminal strips.

Low-pass filter. A filter that passes all frequencies below a specified cutoff point and attenuates (decreases the amplitude of) all frequencies above that point.

Modulation. The process of modifying some characteristics of a wave; controlled variation of frequency, phase, or amplitude.

Monochromator. An instrument used to isolate narrow portions of the spectrum by making use of the dispersion of light into its component wavelengths. In the SM8175, the monochromator is a self-contained unit that optically generates the second-derivative signals for NO and SO_2.

Nanometer. One billionth of a meter (10^{-9})

PCB. Printed circuit board.

PMT. Photomultiplier tube; a phototube (photoelectric tube) with one or more dynodes that acts as a simple photocell with a high-gain amplifier in a self-contained unit. In the SM8175, the PMT transforms UV light into an electrical current.

Retroreflector. A reflector that returns light along a straight path regardless of the angle of the light striking the reflector.

RTD. Resistance temperature detector.

SCR. Silicon controller rectifier.

Scroll. A repeating list or display of the controller headings and subheadings. The scroll steps through each heading in order and returns to the first heading when the sequence is finished. The subheadings within each heading are also arranged in a repeating list.

SDA. Serial data acquisition.

Second-derivative spectroscopy. The measurement of the amount of curvature in a narrow wavelength band. The SM8175 determines SO_2 and NO concentrations by measuring the amount of curvature around specific absorption wavelengths.

Spectroscopy. The measurement of radiation absorbed or emitted when molecules change from one energy level to another; the branch of science dealing with the theory and interpretation of spectra; a branch of optics dealing with radiations in the infrared, visible, and ultraviolet regions of the spectrum.

Transceiver. Transmitter/receiver. In the SM8175, the transceiver houses the UV lamp optics, detector, and signal processing electronics used to measure NO and SO_2.

UART. Universal asynchronous receiver transmitter; a component of the serial data acquisition circuit in the SM8175 J-box that controls communication with the controller.

UV. Ultraviolet.

XCVR. Transceiver.

Appendix A. O_2 Calibration Assembly

The O_2 calibration assembly works in conjunction with the SM8175 so that whenever the SM8175 is put in calibration, either manually or automatically, the O_2 assembly also actuates the appropriate solenoid to cause the oxygen monitor to calibrate simultaneously.

The assembly must be mounted by the customer (see *drawings 80390075* and *80390010-6*) no more than 20 feet from the O_2 detector. Instrument air and a low O_2 calibration gas bottle should be located near the calibration assembly. Connect like terminal numbers 26, 27, and 28 between the SM8175 J-box and the O_2 calibration assembly with 18 AWG wire.

When the SM8175 does a zero calibration, the O_2 calibration assembly actuates SOL 1, turning on low gas to the O_2 detector. When the SM8175 does a span calibration, the O_2 calibration assembly actuates SOL 2, turning on HI CAL (instrument air) to the O_2 detector. Swap TB1 terminals 27 and 28 to reverse this sequence and use instrument air (20.9% O_2) for auto zero calibration. (This reserves calibration gas for use during E/O calibrations.)

Appendix B. Second-Derivative Spectroscopy Mathematical Theory

Second-derivative spectroscopy is an optical process that extracts the second derivative $d^2I/d\lambda^2$ of light intensity (I) versus wavelength (λ) from a narrow wavelength region about a peak absorption wavelength (λ_O).

In the SM8175 gas measurement cavity, ultraviolet (UV) light traverses through a constant length absorption medium (*Figure B-1*). Whenever NO or SO_2 exists in the cavity, absorption of UV light occurs. The mathematical relationship between these physical quantities is expressed by this equation:

$$I = I_O e^{-aLc}$$

Equation 1

Where:

I_o = initial UV light intensity before traveling through the cavity

$I = I(\lambda)$ = UV light intensity exiting the cavity; I is a function of λ

$a = a(\lambda)$ = absorption coefficient; a is also a function of pressure and temperature

L = total light path length in the cavity

c = NO or SO_2 gas concentration.

The first derivative of intensity with respect to wavelength is:

$$\frac{dI}{d\lambda} = \left(\frac{dI_O}{d\lambda}\right)e^{-aLc} - \left(\frac{da}{d\lambda}\right)LcI_O e^{-aLc}$$

Equation 2

Dividing each side of Equation 2 by Equation 1:

$$\frac{dI}{d\lambda} \div I = (\frac{1}{I_O})(\frac{dI_O}{d\lambda}) - Lc(\frac{da}{d\lambda})$$

Equation 3

Where $da/d\lambda$ is the rate of change of absorption coefficient with wavelength.

The two right-side terms of Equation 3 are independent of intensity. The first is a constant indicating the amount of slope in the UV source spectrum. The second term varies linearly with gas concentration.

Taking the second derivative of intensity with respect to wavelength:

$$\frac{d^2I}{d\lambda^2} \div I = (\frac{1}{I_O})(\frac{d^2I_O}{d\lambda^2}) + (Lc[\frac{da}{d\lambda}])^2 - (\frac{2}{I_O})(\frac{dI_O}{d\lambda})(\frac{da}{d\lambda}) - Lc(\frac{d^2a}{d\lambda^2})$$

Equation 4

At the point of maximum curvature, which is at the peak absorption wavelength (I_o), the slope da/d I= 0; Equation 4 then reduces to:

$$(\frac{d^2I}{d\lambda^2}) \div I = \frac{1}{I_O}(\frac{d^2I_O}{d\lambda^2}) - Lc(\frac{d^2a}{d\lambda^2})$$

Equation 5

The first term on the right side of Equation 5 is a constant that measures curvature in the source spectrum. The second term is the curvature in the absorption coefficient.

See *Figure B-2* for a graphic representation of the absorption spectrum and its first and second derivatives.

Next examine the effect of modulating the measured wavelength, λ, over time. I(I) is first expanded into a Taylor series:

$$I(\lambda) = I(\lambda_O) + (\frac{dI}{d\lambda})[\lambda - \lambda_O] + (\frac{d^2I}{d\lambda^2})[\frac{(\lambda - \lambda_O)^2}{2!}] +$$

Equation 6

Now, the wavelength and time variables are introduced. Let:

$$\lambda = \lambda_O + A \sin \omega t$$

Equation 7

A is the amplitude of wavelength modulation and $\omega = 2\pi f$, where f is the modulating frequency. I_o is the peak absorption wavelength.

Note

The quartz window within the monochromator driven by the scanner motor performs this modulation (see *paragraph 7.1.1.1*).

Substituting Equation 7 into Equation 6:

$$I(\lambda_O, t) = I(\lambda_O) + (\frac{dI}{d\lambda}) A \sin \omega t + (\frac{d^2I}{d\lambda^2})(\frac{A^2 \sin^2(\omega t)}{2!} + K$$

Equation 8

Substituting the formula $\sin^2 \omega t = (1/2)(1 - \cos 2\omega t)$ for the sine-squared term in Equation 8 gives:

$$I(\lambda_O, t) = I(\lambda_O) + (\frac{dI}{d\lambda}) A \sin \omega t + (\frac{A^2}{4})(\frac{d^2I}{d\lambda^2}) - (\frac{A^2}{4})(\frac{d^2I}{d\lambda^2}) \cos(2\omega t) + K$$

Equation 9

In Equation 9, the amplitudes of sin (ωt) and cos ($2\omega t$) are respectively proportional to ($dI/d\lambda$) and ($d^2I/d\lambda^2$) evaluated at I_o.

Extracting the coefficient expressing the amplitude of the second-derivative signal cos ($2\omega t$) from Equation 9 and defining it as the signal S (2F, used for the second-derivative signal in the previous section, approximately equals S):

$$S = (\frac{A^2}{4})(\frac{d^2 I}{d\lambda^2})[\lambda - \lambda_O]$$

Equation 10

Rewriting Equation 5:

$$(\frac{d^2 I}{d\lambda^2}) = -ILc(\frac{d^2 a}{d\lambda^2})$$

Equation 11

where $(d^2 I_O / d\lambda^2)$ is assumed negligible (ie, a linear source spectrum).

Substituting Equation 11 into Equation 10:

$$S = (\frac{-A^2 ILc}{4})(\frac{d^2 a}{d\lambda^2})[\lambda - \lambda_O]$$

Equation 12

Assuming a Gaussian distribution for a:

$$a(\lambda) = a_O e - [\frac{(\lambda_O - \lambda)}{Z}]^2$$

Equation 13

where Z is the half-width of the band at $a = a_o/e$

Differentiating Equation 13 twice with respect to I:

$$(\frac{d^2 a}{d\lambda^2})\lambda = \lambda_O = (\frac{-a_O}{Z^2})$$

Equation 14

Substituting Equation 14 into Equation 12:

$$S = (A^2 ILca_O) \div (4Z^2)$$

Equation 15

If the modulation amplitude, A, is chosen as 2Z and substituted into Equation 13, then:

$$S = ILca_O$$

Equation 16

Thus S varies linearly with gas concentration. This result is important, because the electronics measurement system is better able to process a linearly-changing signal (S) than a nonlinear one.

The instrument measures the amplitude of the waveform at frequency 2ω coming from the detector. This amplitude is proportional to $d^2a/d\lambda^2$ if measured at a wavelength where “a” is a maximum and where the gas exhibits narrow band absorption.

Reducing this results to direct absorption spectroscopy by setting the product Lc, <<1, then Equation 1 can be expressed as:

$$I = I_O e - aLc \approx I_O (1 - aLc)$$

Equation 17

Solving for the difference between I_o and I:

$$I_O - I = I_O aLc$$

Equation 18

Let a = a_o, since a_o is the maximum value at I_o:

$$I_O - I = I_O a_O Lc$$

Equation 19

The right side of Equation 19 equals the right side of Equation 16. Therefore:

$$S = I_O - I$$

Equation 20

Equation 20 shows that the second-derivative maximum signal amplitude S is equal to the difference between the initial, UV light intensity (I_o) and the absorption wavelength light intensity (I) exiting from the cavity. This result is identical to direct absorption methods.

The signal levels from the two techniques are, then, approximately the same. However, there is one important difference. The derivative spectrometer is a signal which is proportional to concentration, where the direct absorption is the difference between light levels (a very small value). Note also that the derivative is a function of the signature of the gas making this method highly specific; hence, immune to interference. Figure B-3 shows that Equation 20 is approximately correct, because the (2F) amplitude nearly equals (S).

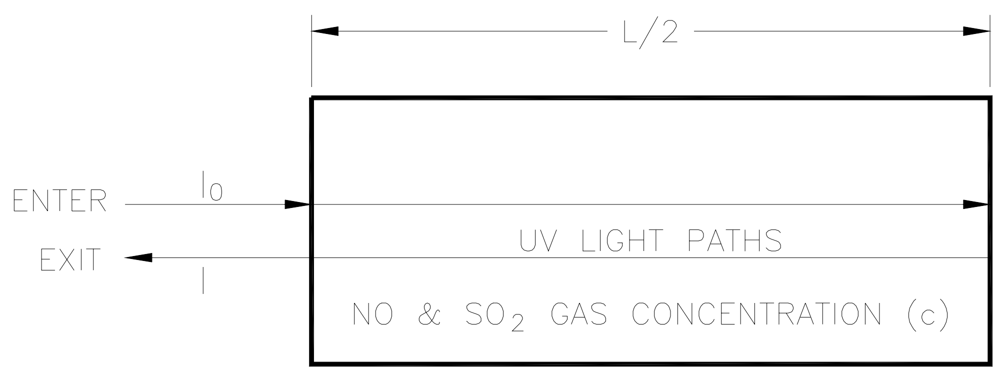


Figure B-1. Gas Measurement Cavity

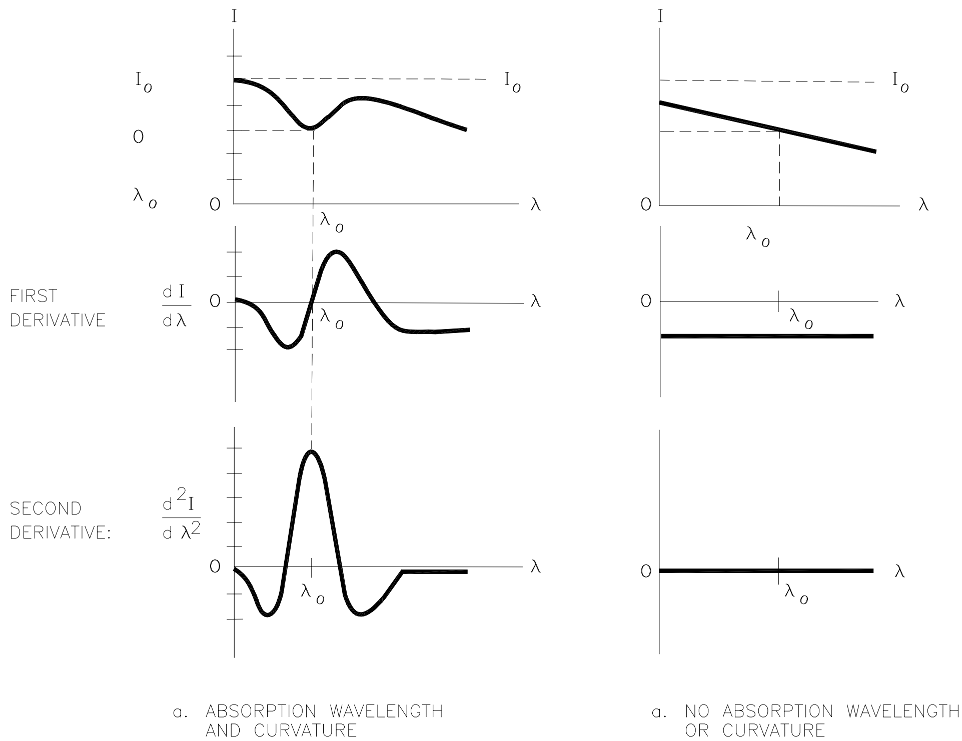


Figure B-2. Absorption Curves and Their Derivatives

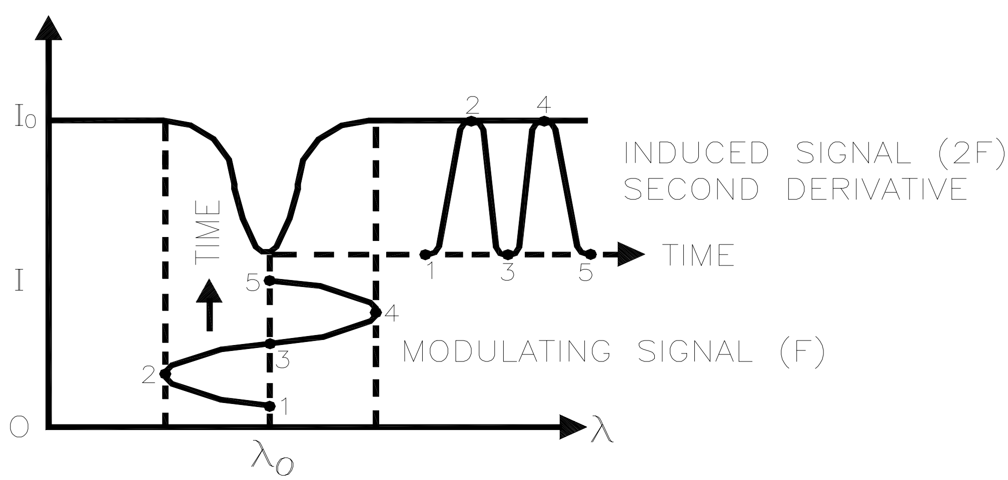


Figure B-3. Absorption Curve Modulated with Curvature

Appendix C. Temperature vs Resistance Table

For European Curve, Alpha = .00385 1^{o} Celsius Increments

*C	Ohm	Diff	*C	Ohm	Diff	*C	Ohm	Diff	*C	Ohm	Diff	*C	Ohm	Diff	*C	Ohm	Diff
-200	18.49		-140	43.87	.42	-80	68.33	.41	-20	92.16	.39	± 0	100.00	.39	+60	123.24	.38
199	18.93	.44	139	44.28	.41	79	68.73	.40	19	92.55	.39	+1	100.39	.39	61	123.62	.38
198	19.36	.43	138	44.70	.42	78	69.13	.40	18	92.95	.40	2	100.78	.39	62	124.01	.39
197	19.79	.43	137	45.11	.41	77	69.53	.40	17	93.34	.39	3	101.17	.39	63	124.39	.38
196	20.22	.43	136	45.52	.41	76	69.93	.40	16	93.73	.39	4	101.56	.39	64	124.77	.38
195	20.65	.43	135	45.94	.42	75	70.33	.40	15	94.12	.39	5	101.95	.39	65	125.16	.39
194	21.08	.43	134	46.35	.41	74	70.73	.40	14	94.52	.40	6	102.34	.39	66	125.54	.38
193	21.51	.43	133	46.76	.41	73	71.13	.40	13	94.91	.39	7	102.73	.39	67	125.92	.38
192	21.94	.43	132	47.18	.42	72	71.53	.40	12	95.30	.39	8	103.12	.39	68	126.31	.39
191	22.37	.43	131	47.59	.41	71	71.93	.40	11	95.69	.39	9	103.51	.39	69	126.69	.38
190	22.80	.43	130	48.00	.41	70	72.33	.40	10	96.09	.40	10	103.90	.39	70	127.07	.38
189	23.23	.43	129	48.41	.41	69	72.73	.40	9	96.48	.39	11	104.29	.39	71	127.45	.38
188	23.66	.43	128	48.82	.41	68	73.13	.40	8	96.87	.39	12	104.68	.39	72	127.84	.39
187	24.09	.43	127	49.23	.41	67	73.53	.40	7	97.26	.39	13	105.07	.39	73	128.22	.38
186	24.52	.43	126	49.64	.41	66	73.93	.40	6	97.65	.39	14	105.46	.39	74	128.60	.38
185	24.94	.42	125	50.06	.42	65	74.33	.40	5	98.04	.39	15	105.85	.39	75	128.98	.38
184	25.37	.43	124	50.47	.41	64	74.73	.40	4	98.44	.40	16	106.24	.39	76	129.37	.39
183	25.80	.43	123	50.88	.41	63	75.13	.40	3	98.83	.39	17	106.63	.39	77	129.75	.38
182	26.23	.43	122	51.29	.41	62	75.53	.40	2	99.22	.39	18	107.02	.39	78	130.13	.38
181	26.65	.42	121	51.70	.41	61	75.93	.40	1	99.61	.39	19	107.40	.38	79	130.51	.38
180	27.08	.43	120	52.11	.41	60	76.33	.40				20	107.79	.39	80	130.89	.38
179	27.50	.42	119	52.52	.41	59	76.73	.40				21	108.18	.39	81	131.27	.38
178	27.93	.43	118	52.92	.40	58	77.13	.40				22	108.57	.39	82	131.66	.39
177	28.35	.42	117	53.33	.41	57	77.52	.39				23	108.96	.39	83	132.04	.38
176	28.78	.43	116	53.74	.41	56	77.92	.40				24	109.35	.39	84	132.42	.38
175	29.20	.42	115	54.15	.41	55	78.32	.40				25	109.73	.38	85	132.80	.38
174	29.63	.43	114	54.56	.41	54	78.72	.40				26	110.12	.39	86	133.18	.38
173	30.05	.42	113	54.97	.41	53	79.11	.39				27	110.51	.39	87	133.58	.38
172	30.47	.42	112	55.38	.41	52	79.51	.40				28	110.90	.39	88	133.94	.38
171	30.90	.43	111	55.78	.40	51	79.91	.40				29	111.28	.38	89	134.32	.38
170	31.32	42	110	56.19	.41	50	80.31	.40				30	111.67	.39	90	134.70	.38
169	31.74	.42	109	56.60	.41	49	80.70	.39				31	112.06	.39	91	135.08	.38
168	32.16	.42	108	57.00	.40	48	81010	.40				32	112.45	.39	92	135.46	.38
167	32.59	.43	107	57.41	.41	47	81.50	.40				33	112.83	.38	93	135.84	.38
166	33.01	.42	106	57.82	.41	46	81.89	.39				34	113.22	.39	94	136.22	.38
165	33.43	.42	105	58.22	.40	45	82.29	.40				35	113.61	.39	95	136.60	.38
164	33.85	.42	104	58.63	.41	44	82.69	.40				36	113.99	.38	96	136.98	.38
163	34.27	.42	103	59.04	.41	43	83.08	.39				37	114.38	.39	97	137.36	.38
162	34.69	.42	102	59.44	.40	42	83.48	.40				38	114.77	.39	98	137.74	.38
161	35.11	.42	101	59.85	.41	41	83.88	.40				39	115.15	.38	99	138.12	.38
160	35.53	.42	100	60.25	.40	40	84.27	.39				40	115.54	.39	100	138.50	.38
159	35.95	.42	99	60.66	.41	39	84.67	.40				41	115.93	.39	101	138.88	.38
158	36.37	.42	98	61.06	.40	38	85.06	.39				42	116.31	.38	102	139.26	.38
157	36.79	.42	97	61.47	.41	37	85.46	.40				43	116.70	.39	103	139.64	.38
156	37.21	.42	96	61.87	.40	36	85.85	.39				44	117.08	.38	104	140.02	.38
155	37.63	.42	95	62.28	.41	35	86.25	.40				45	117.47	.39	105	140.39	.37
154	38.04	.41	94	62.66	.40	34	86.64	.39				46	117.85	.38	106	140.77	.38
153	38.46	.42	93	63.09	.41	33	87.04	.40				47	118.24	.39	107	141.15	.38
152	38.88	.42	92	63.49	.40	32	87.43	.39				48	118.62	.38	108	141.53	.38
151	39.30	.42	91	63.90	.41	31	87.83	.40				49	119.01	.39	109	141.91	.38
150	39.71	.41	90	64.30	.40	30	88.22	.39				50	119.40	.39	110	142.29	.38
149	40.13	.42	89	64.70	.40	29	88.62	.40				51	119.78	.38	111	142.66	.37
148	40.55	.42	88	65.11	.41	28	89.01	.39				52	120.16	.38	112	143.04	.38
147	40.96	.41	87	65.51	.40	27	89.40	.39				53	120.55	.39	113	143.42	.38
146	41.38	.42	86	65.91	.40	26	89.80	.40				54	120.93	.38	114	143.80	.38
145	41.79	.41	85	66.31	.40	25	90.19	.39				55	121.32	.39	115	144.17	.37
144	42.21	.42	84	66.72	.41	24	90.59	.40				56	121.70	.38	116	144.55	.38
143	42.63	.42	83	67.12	.40	23	90.98	.39				57	122.09	.39	117	144.93	.38
142	43.04	.41	82	67.52	.40	22	91.37	.39				58	122.47	.38	118	145.31	.38
141	43.45	.41	81	67.92	.40	21	91.77	.40				59	122.86	.39	119	145.68	.37

NOTE: At 100^{o} C resistance is 138.50 Ohms. Din 43 760

For European Curve, Alpha = .00385

1^{o} Celcius Increments

*C	Ohm	Diff	*C	Ohm	Diff	*C	Ohm	Diff	*C	Ohm	Diff	*C	Ohm	Diff	*C	Ohm	Diff
+120	146.06	.38	+180	168.46	.37	+240	190.45	.36	+300	212.02	.36	+360	233.17	.35	+420	253.90	.34
121	146.44	.38	181	168.83	.37	241	190.81	.36	301	212.37	.35	361	233.52	.35	421	254.24	.34
122	146.81	.37	182	169.20	.37	242	191.18	.37	302	212.73	.36	362	233.87	.35	422	254.59	.35
123	147.19	.38	183	169.57	.37	243	191.54	.36	303	213.09	.36	363	234.22	.35	423	254.93	.34
124	147.57	.38	184	169.94	.37	244	191.90	.36	304	213.44	.35	364	234.56	.34	424	255.27	.34
125	147.94	.37	185	170.31	.37	245	192.26	.36	305	213.80	.36	365	234.91	.35	425	255.61	.34
126	148.32	.38	186	170.68	.37	246	192.63	.37	306	214.15	.35	366	235.26	.35	426	255.95	.34
127	148.70	.38	187	171.05	.37	247	192.99	.36	307	214.51	.36	367	235.61	.35	427	256.29	.34
128	149.07	.37	188	171.42	.37	248	193.35	.36	308	214.86	.35	368	235.96	.35	428	256.64	.35
129	149.45	.38	189	171.79	.37	249	193.71	.36	309	215.22	.36	369	236.31	.35	429	256.98	.34
130	149.82	.37	190	172.16	.37	250	194.07	.36	310	215.57	.35	370	236.65	.34	430	257.32	.34
131	150.20	.38	191	172.53	.37	251	194.44	.37	311	215.93	.36	371	237.00	.35	431	257.66	.34
132	150.57	.37	192	172.90	.37	252	194.80	.36	312	216.28	.35	372	237.35	.35	432	258.00	.34
133	150.95	.38	193	173.26	.36	253	195.16	.36	313	216.64	.36	373	237.70	.35	433	258.34	.34
134	151.33	.38	194	173.63	.37	254	195.52	.36	314	216.99	.35	374	238.04	.34	434	258.68	.34
135	151.70	.37	195	174.00	.37	255	195.88	.36	315	217.35	.36	375	238.39	.35	435	259.02	.34
136	152.08	.38	196	174.37	.37	256	196.24	.36	316	217.70	.35	376	238.74	.35	436	259.36	.34
137	152.45	.37	197	174.74	.37	257	196.60	.36	317	218.05	.35	377	239.09	.35	437	259.70	.34
138	152.83	.38	198	175.10	.36	258	196.96	.36	318	218.41	.36	378	239.43	.34	438	260.04	.34
139	153.20	.37	199	175.47	.37	259	197.33	.37	319	218.76	.35	379	239.78	.35	439	260.38	.34
140	153.58	.38	200	175.84	.37	260	197.69	.36	320	219.12	.36	380	240.13	.35	440	260.72	.34
141	153.95	.37	201	176.21	.37	261	198.05	.36	321	219.47	.35	381	240.47	.34	441	261.06	.34
142	154.32	.37	202	176.57	.36	262	198.41	.36	322	219.82	.35	382	240.82	.35	442	261.40	.34
143	154.70	.38	203	176.94	.37	263	198.77	.36	323	220.18	.36	383	214.17	.35	443	261.74	.34
144	155.07	.37	204	177.31	.37	264	199.13	.36	324	220.53	.35	384	241.51	.34	444	262.08	.34
145	155.45	.38	205	177.68	.37	265	199.49	.36	325	220.88	.35	385	241.86	.35	445	262.42	.34
146	155.82	.37	206	178.04	.36	266	199.85	.36	326	221.24	.36	386	242.20	.34	446	262.76	.34
147	156.19	.37	207	178.41	.37	267	200.21	.36	327	211.59	.35	387	242.55	.35	447	263.10	.34
148	156.57	.38	208	178.78	.37	266	200.57	.36	328	221.94	.35	388	242.90	.35	448	236.43	.33
149	156.94	.37	209	179.14	.36	269	200.93	.36	329	222.29	.35	389	243.24	.34	449	263.77	.34
150	157.31	.37	210	179.51	.37	270	201.29	.36	330	222.65	.36	390	243.59	.35	450	264.11	.34
151	157.69	.38	211	179.88	.37	271	201.65	.36	331	223.00	.35	391	243.93	.34	451	264.45	.34
152	158.06	.37	212	180.24	.36	272	202.01	.36	332	223.35	.35	392	244.28	.35	452	264.79	.34
153	158.43	.37	213	180.61	.37	273	202.36	.35	333	223.70	.35	393	244.62	.34	453	265.13	.34
154	158.81	.38	214	180.97	.36	274	202.72	.36	334	224.06	.36	394	244.97	.35	454	265.47	.34
155	159.18	.37	215	181.34	.37	275	203.08	.36	335	224.41	.35	395	245.31	.34	455	265.80	.33
156	159.55	.37	216	181.71	.37	276	203.44	.36	336	224.76	.35	396	245.66	.35	456	266.14	.34
157	159.93	.38	217	182.07	.36	277	203.80	.36	337	225.11	.35	397	246.00	.34	457	266.48	.34
158	160.30	.37	218	182.44	.37	278	204.16	.36	338	225.46	.35	398	246.35	.35	458	266.82	.34
159	160.67	.37	219	182.80	.36	279	204.52	.36	339	225.81	.35	399	246.69	.34	459	267.15	.33
160	161.04	.37	220	183.17	.37	280	204.88	.36	340	226.17	.36	400	247.04	.35	460	267.49	.34
161	161.42	.38	221	183.53	.36	281	205.23	.35	341	226.52	.35	401	247.38	.34	461	267.83	.34
162	161.79	.37	222	183.90	.37	282	205.59	.36	342	226.87	.35	402	247.73	.35	462	268.17	.34
163	162.16	.37	223	184.26	.36	283	205.95	.36	343	227.22	.35	403	248.07	.34	463	268.50	.33
164	162.53	.37	224	184.63	.37	284	206.31	.36	344	227.57	.35	404	248.41	.34	464	268.84	.34
165	162.90	.37	225	184.99	.36	285	206.67	.36	345	227.92	.35	405	248.76	.35	465	269.18	.34
166	163.27	.37	226	185.38	.37	286	207.02	.35	346	228.27	.35	406	249.10	.34	466	269.51	.33
167	163.65	.38	227	185.72	.36	287	207.38	.36	347	228.62	.35	407	249.45	.35	467	269.85	.34
168	164.02	.37	228	186.09	.37	288	207.74	.36	348	228.97	.35	408	249.79	.34	468	270.19	.34
169	164.39	.37	229	186.45	.36	289	208.10	.36	349	229.32	.35	409	250.13	.34	469	270.52	.33
170	164.76	.37	230	186.82	.37	290	208.45	.35	350	229.67	.35	410	250.48	.35	470	270.86	.34
171	165.13	.37	231	187.18	.36	291	208.81	.36	351	230.02	.35	411	250.82	.34	471	271.20	.34
172	165.50	.37	232	187.54	.36	292	209.17	.36	352	230.37	.35	412	251.16	.34	472	271.53	.33
173	165.87	.37	233	187.91	.37	293	209.52	.35	353	230.72	.35	413	251.50	.34	473	271.87	.34
174	166.24	.37	234	188.27	.36	294	209.88	.36	354	231.07	.35	414	251.85	.35	474	272.20	.33
175	166.61	.37	235	188.63	.36	295	210.24	.36	355	231.42	.35	415	252.19	.34	475	272.54	.34
176	166.98	.37	236	189.00	.37	296	210.59	.35	358	231.77	.35	416	252.53	.34	476	272.88	.34
177	167.35	.37	237	189.36	.36	297	210.95	.36	357	232.12	.35	417	252.88	.35	477	273.21	.33
178	167.72	.37	238	189.72	.36	298	211.31	.36	358	232.47	.35	418	253.22	.34	478	273.55	.34
179	168.09	.37	239	190.09	.37	299	211.66	.35	359	232.82	.35	419	253.56	.34	479	273.88	.33

NOTE: At 100^{o} C resistance is 138.50 Ohms.

Din 43 760