DURAG

D-R 290

Dust and Opacity Monitor

Installation and operation

CE

TÜV CERT
DIN ISO 9001
Zertifikat
QA 07 100 052

Durag, Inc ▪ 1355 Mendota Heights Road ▪ Suite. 200 ▪ Mendota Heights, MN 55120
Phone: 651-451-1710 ▪ Fax 651-457-7684 ▪ Website: www.durag.com

Table of Contents

Figures **3**
1. Applications **4**
2. Basic Features **4**
3. Operating Overview **5**
3.1. Opacity Calculation at the Stack exit 7
3.2. Extinction Measurement Principle 8
3.4.1 Measurement 12
3.4.2 Internal Reference 12
3.4.3 Internal Zero Check 13
3.4.4 Upscale Calibration Check 13
3.5 System Components 14
3.5.1 Configuration options for stack and control room displays 16
4. Selection of the Measuring Location **17**
5. Installation **17**
5.1 Flange Installation 17
5.2 Blower Panel and Weather Hood Installation 18
5.2.1 Weather Hood and Blower Panel Electrical Installation 20
5.3 D-R 290 AZG Stack-Mounted Display Module 21
5.3.1 Electrical Installation, D-R 290 AZG Stack-Mounted Display Module 22
5.4 Transceiver and Reflector Installation 23
5.4.1 Transceiver and reflector alignment and focus 24
5.4.2 Transceiver and reflector electrical installation 25
5.5 D-R 290 AW Evaluation Unit Installation 25
5.5.1 D-R 290 AW Electrical Connection when used with D-R 290 AZ 27
5.5.2 D-R 290 AW Stand Alone Electrical Connection (No D-R 290 AZ) 29
6. Operation **30**
6.1 Operation of the D-R 290 AW evaluation unit 30
6.1.1 Parameters 30
6.1.2 Key functions 34
6.1.3 Saving / Data entry 34
6.1.3 Liquid Crystal Display (LCD) 36
6.1.4 Switch settings and Operation with or without the D-R 290 AZ 37
6.2 Operation of the D-R 290 AZ Stack Display Unit 37
6.3 Reflector Operation 38
6.4 Transceiver Operation 38
6.4.1 Maintenance 38
6.4.2 Transceiver circuit board 39
6.4.2.1 Transceiver Switch Functions 39
6.4.3 Clear Path Procedure 41
6.4.4 Manual internal zero point (Window Check) 44
6.4.5 External Zero Point Calibration 44
7. Error Messages **45**
8. Purge air system **46**
9. D-SK 290 Fail-safe Shutters **46**
9.1. Function 47
9.2. Installation 48
9.3. Electrical Connection D-SK AE 50
9.3.1 Automatic check of shutter operation 51
9.4 Shutter Operation 52
10. Technical Specifications **53**
10.1 Technical Specifications: D-R 290 53
10.2 Technical Specifications for the Purge Air Blower 53
10.3 Technical Specifications for the D-SK AE Electronics 54
10.4 Technical Specifications for the D-SK 290 MA Mechanics 54

Figures

(Fig. 3.1) Relationship between Extinction, Transmission and Opacity 6
(Fig. 3.2) Reference locations for determining opacity 7
(Fig. 3.3) Optics diagram D-R 290 11
(Fig.3. 4) System components 14
(Fig. 5.1) D-R 280-10E installation flange for D-R 290 Opacity Monitor 18
(Fig. 5.2) Weather hood dimensions 19
(Fig. 5.3) Transceiver side interconnect wiring, typical 20
(Fig. 5.4) Reflector side interconnect wiring, typical 20
(Fig. 5.5) D-R 290 AG wall mount housing dimensions 21
(Table 5.6) D-R 290 AZ stack display I/O 22
(**Fig. 5.7)** Mounting monitor on the installation flange 23
(Fig. 5.8) D-R 290 BT dimensional diagram 26
(Fig. 5.9) D-R 290 AW19 dimensional diagram 26
(Fig. 5.10) D-R 290 BT terminal connectors 27
(Table 5.11) D-R 290 AW mounted in D-R 290 BT housing, terminal connections 28
(Table 5.12) D-R 290 AW mounted in D-R 290 AG housing, terminal connections (No D-R 290 AZ) .. 29
(Table 6.1) How set-up mode changes I/O 31
(Fig. 6.2) D-R 290 AW Key Functions 34
(Fig. 6.3) D-R 290 AW operating sequence 35
(Table 6.4) D-R 290 AW and AZ processor board switch functions 37
(Fig. 6.5) Transceiver switch functions 39
(Table 7.1) Error messages 45
(Fig.9.1) Dimensions (in mm) of shutter (D-SK 280 MA) 47
(**Fig. 9.2)** Dimensions (in mm) of control electronics D-SK AE 48
(Fig. 9.3) Air Flow Sensor 49
(Fig. 9.4) D-SK 290 Mounting 49
(Fig. 9.5) Electrical Connection for the D-SK AE 50
(Fig. 9.6) Electrical connection between the D-R 290 AZ and the fail-safe shutter 51

Valid for PROM version 2.00 and higher

1. Applications

The **Durag D-R 290** opacity monitor can be used for continuous emissions monitoring in smokestacks, exhaust ducts, and other similar applications. This monitor has been designed to comply with the new Performance Specification 1 found in 40 CFR part 60, Appendix B and the ASTM D6216-98 standard.

This type of opacity monitor is necessary for the legal and economically sound operation of power plants, heating plants and other industrial large boiler facilities. These systems are also critical for use in the chemical and cement industries where careful monitoring of the industrial processes is a criterion for problem-free operation.

Durag opacity monitors have functioned successfully for years in applications where dust emissions could have potentially damaging environmental pollution effects. The data they collect is incorruptible, precisely reproducible, unaffected by seasonal changes or weather conditions, and functions easily in either automatic or manual operation. These systems have been used for applications in refineries and other facilities of the petrochemical industry, in waste-burning facilities and many others.

2. Basic Features

- Continuous, **in situ** measurement directly in the exhaust stream without disruption or dust sampling.
- The white light semi-conductor light source has a long life.
- The wide spectrum of the Super-Wide Band Diode (SWBD) optimizes system accuracy because the measurements are more stable than those made with conventional LEDs.
- Modern microprocessor technology and software allow digital information processing.
- LCD shows measurements as opacity or extinction.
- Automatic calibration cycle corrects values for window contamination.
- Purge air system protects the reflector and heated exit window reduce maintenance.
- Control panel with digital display makes installation and operation simple.
- Hermetically sealed optics and electronics prevent dust or smoke from damaging internal system components. Two analog outputs with selectable measuring ranges on each system.

Optional

- Fail-safe shutter system protects the transceiver and reflector.
- Protective weather hoods for transceivers, reflectors, and purge air systems.
- Stack mounted display for single person filter audits.

3. Operating Overview

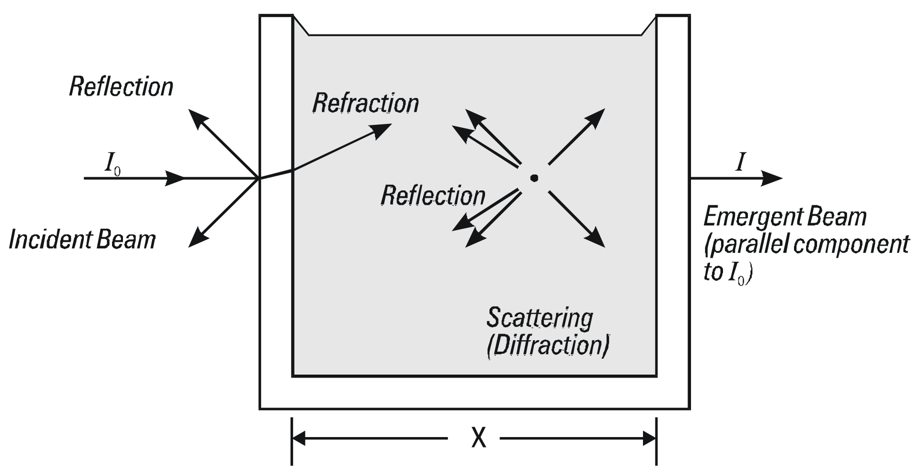
The transceiver emits a beam of light which passes through the stack or duct and strikes a reflector. The light beam is reflected back and the amount of light returned is measured by the transceiver. Dust particles in the stack will absorb and scatter the transmitted beam of light so the returned light will be less than the transmitted light. The ratio of the returned light to the transmitted light is call the transmission. One minus the transmission is referred to as opacity. For dust concentration measurements optical density (also called extinction) is historically used because the dust concentration is linear to the optical density value. The log of 1 divided by the transmission give the optical density.

The measured transmission value is sent via RS 422 to the stack display (**D-R 290 AZ**). From this local display the measured value can be read and maintenance actions can be initiated. Also purge air alarms are wired into this stack display. From here the measured value and any purge air failure is sent via RS422 to the evaluation unit (**D-R 290 AW**).

At the evaluation unit the measured value is displayed and system parameters can be viewed or changed. This remote display also contains the status inputs, relay outputs and the 2 independent current outputs. One current output could be set to read opacity and the other to read the dust concentration. If dust concentration is required, normally a stack test is needed to calibrate the extinction reading to a concentration (determine the extinction coefficient).

Purge air blowers are used to keep the optics clean. Weather hoods are used to protect the blowers and the opacity system. Fail-safe shutters can be installed to protect the optics if a purge air blower should fail or loose power and may also protect service personnel on over pressure stacks. These shutters are exercised during the daily calibration to insure they are in working order when needed and to prevent them from sticking in the open position.

The Durag D-R 290 opacity monitor is designed to utilize the principles of light transmission. The transceiver and reflector are mounted opposite one another. Using the auto collimation principle, the light beam traverses the distance to be measured twice. This significantly increases the sensitivity of the measurements made by the system.



The light beam loses intensity proportionally to the particle concentration of the air. The light beam has a significantly larger diameter than the reflector surface. This makes alignment easier and reduces measurement errors caused by possible heat-induced shifts in the transceiver or reflector mounting flanges.

3.1. Transmission Measuring Principle

If a light shines through a smoke stack or dust exhaust duct, this light beam will become weaker as the dust density increases.

Transmission is the ratio of the intensity of the light received *(I)* compared to the intensity of the light transmitted (I_0).

$$\frac{I}{I_0}$$

Eq.1

The relationship between the irradiated light and the received light is given as a percent value, as shown in equation 2.

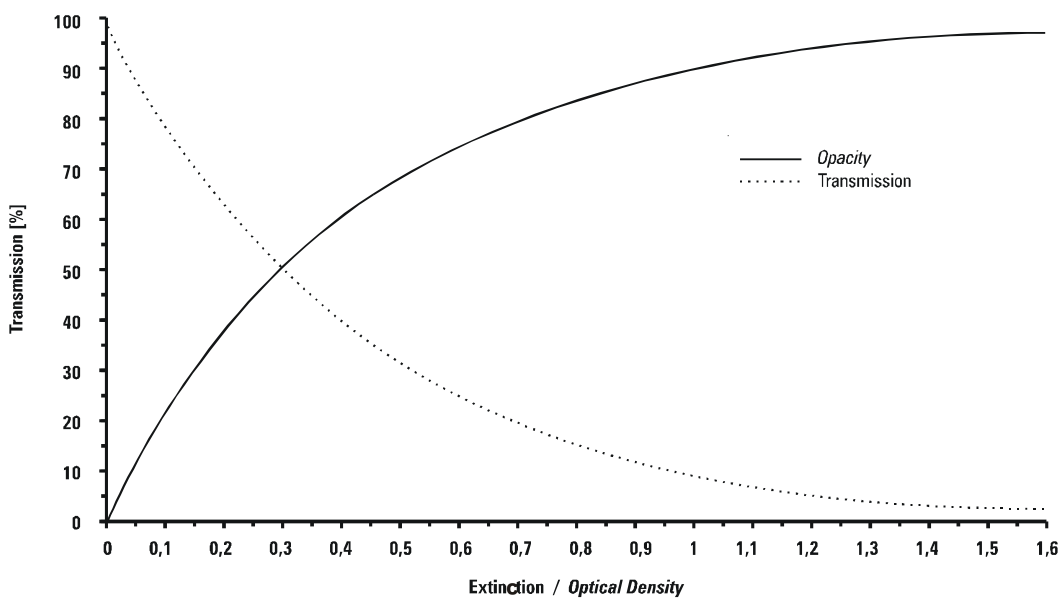
$$\frac{I}{I_0} \times 100\% = T$$

Eq.2

Subtracting the transmission measurement from one gives the opacity value. Opacity is the default measurement mode of the **D-R 290**, since this results in an increasingly strong signal at the detector as the dust density diminishes.

$$100\% - \frac{I}{I_0} \times 100\% = OP$$

Eq.3



(Fig. 3.1) Relationship between Extinction, Transmission and Opacity

Because the **D-R 290** operates on the auto collimation principle, the light beam being measured crosses the measurement region twice. This means that the measurement light beam will lose the same percentage of intensity on each pass through the dust particles in the exhaust air.

Since an observer looking at the stack exit is only looking through the plume once, the **D-R 290** will correct the double pass measurement and the opacity reading as a single pass measurement at the stack outlet.

3.2. Opacity Calculation at the Stack exit

Op = Single pass opacity at the measurement point.

Op1 = Double pass opacity at the measurement point measured using the auto collimation principle.

Op2 = Single pass opacity at the stack exit.

L1 = Diameter of the stack at the measurement point.

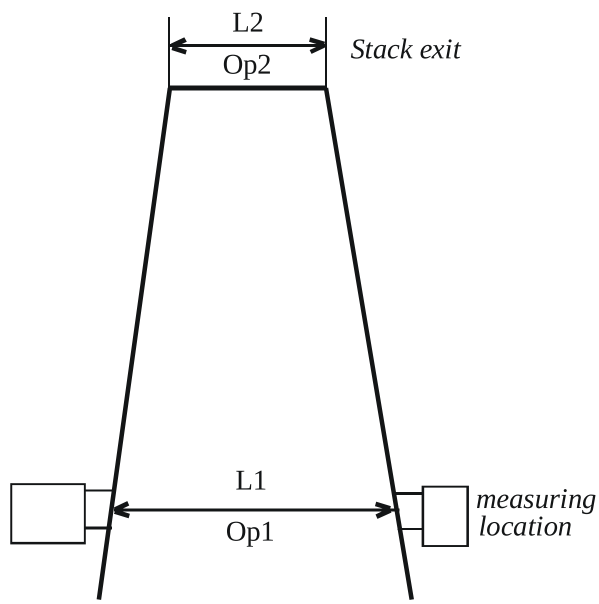
L2 = Diameter of the stack at the stack exit.

Eq.4

If both losses of light intensity from the measurement beam passes are taken into account, the following equation (**Eq. 5**) can be used to calculate the opacity at the stack exit:

$$Op2 = 1 - (1 - Op1)^{\frac{L2}{2\,L1}}$$

Eq.5



(Fig. 3.2) Reference locations for determining opacity

Since the data must be evaluated as if the measured light beam has crossed the stack opening a single time, the **D-R 290** system can make these corrections. This means that the stack correction factor L2/L1 must be entered into the control unit. This value can be set as shown in section 6.5. Once set, the stack correction factor is used in all opacity measurement ranges on both measurement channels.

For example:

Measurement location	= 6.00 ft	= L 1	
Stack exit	= 5.10 ft	= L 2	
Stack correction factor	☐	$= \frac{5.10\,ft}{6.00\,ft}$	= 0.850

The stack correction factor is set by DURAG using information supplied by the customer based upon the specific stack dimensions. If this needs to be changed, please contact DURAG for assistance.

3.3. Extinction Measurement Principle

If a beam of light shines through a flue gas channel or dust extraction line, the light intensity will attenuate as the dust concentration ***C*** increases. This loss of light intensity is caused by absorption and diffraction, collectively referred to as extinction. Generally, the light intensity ***I*** decreases exponentially as the path length ***L*** increases.

$$I = I_o \cdot e^{-KLC}$$

Eq.6

In calculating the measured dust intensity, I_o is the constant for the emitted light intensity and ***L*** is the constant value of the measured path length. The value of the extinction constant ***K*** can then be determined. In general, the dust concentration (in grain/ft^3 or mg/m^3) has a linear relationship to extinction. Many parameters, however, will vary at different installations including particulate size, composition of the particles, specific weight, index values, and the absorption constant for the light being used. In many installations, the load of the facility will affect the size of the dust particles. Wet (whether steam of condensation-based) and dry filtering systems will also influence the particulate exhaust. Thus, the exact relationship between the extinction value the monitor displays and the actual dust emissions should be determined through gravimetric measurement.

$$E = lg(\tfrac{1}{T}) = lg(\tfrac{I_o}{I})$$

Eq.7

Solving **equation 6** allows the derivation of the extinction constant ***K*** as shown below:

$$K = \frac{\ln\left({}^{I_o}\!/_{I} \right)}{C \cdot L}$$

Eq.8

To express the extinction constant ***K*** in a linear relationship to the dust concentration ***C***, the values of the measurement and comparison light beams are written as a part of log functions.

The dust concentration *C* is:

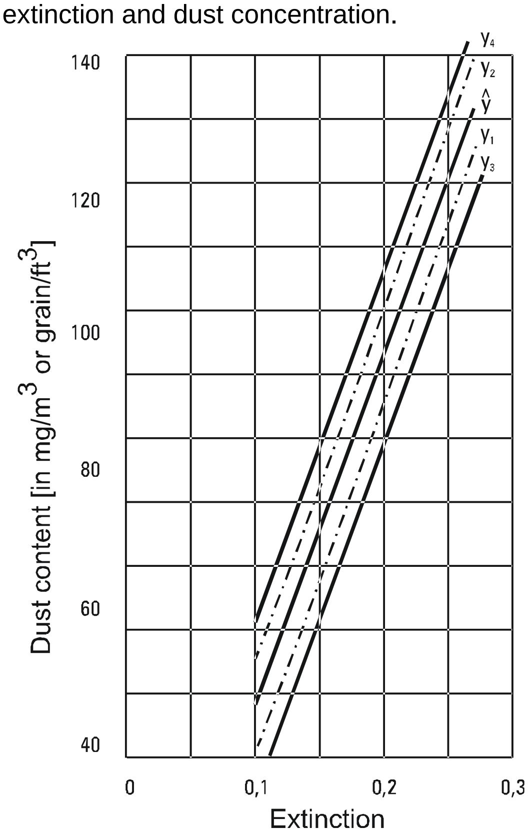
$$C = \frac{\ln\left(I_o / I \right)}{K \cdot L} \qquad \textbf{Eq.9}$$

Io = Emitted light	***K*** = Extinction coefficient
I = Received light	***E*** = Extinction
L = Measuring path length (for Auto collimation ∗ 2)	***c*** = Dust concentration

For the reasons above, dust concentration **c** must be determined by gravimetric measurement. The necessary measurement must be carried out at the expected plant loads and the expected filter settings of the respective plant. When changing fuel types, checking the measurements is necessary. Only when these comparison values are available can the extinction values in respect to the particulate emissions be correctly evaluated. As dust concentration readings are subject to fluctuations, most favorable are statistical methods for determining the calibration curve for the relationship between extinction and dust concentration.

See DIN 1319 p. 3 'Fundamentals of Measuring Techniques' and DIN 55302 p.1 and 2 'Statistic evaluation procedures, frequency distribution, mean value and scattering', as well as VDI 2066 'Dust measuring in streaming gases'.

The compensating straight-line, which is drawn through the measuring points, is established to the 'smallest quadratic error' method. It is also designated as regression straight-line (Ý). The (*Y*1, *Y*2) lines represent the reliability range, i.e., the mean value of extinction *x* obtained over a long period lies with a probability of 95% between *Y*1 and *Y*2. Two further lines (*Y*3, *Y*4) define the tolerance range. This means that as a result of many gravimetric dust measurements at the indicated extinction value *x*, at least 75% of the spot-checked dust contents will lie with 95% probability in the tolerance range between *Y*3 and *Y*4.



3.4 Principle of Operation

The **D-R 290** operates according to the principle of auto collimation (double-pass). The light beam crosses the measuring path twice. The system measures and evaluates the attenuation of the light beam caused by the dust in the measuring path.

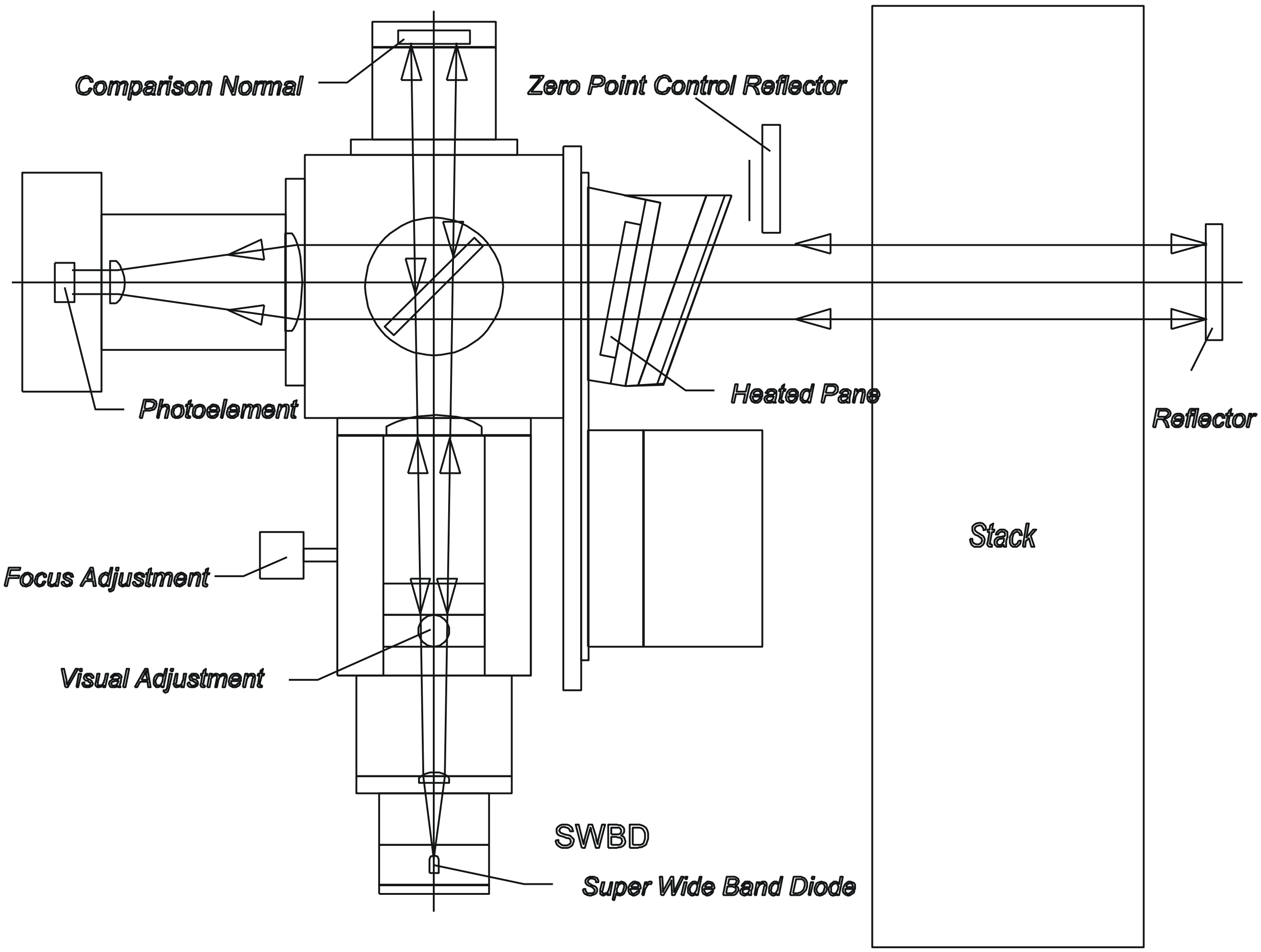
The two main features that separate the D-R 290 from the older designs of the competition are the Super Wide Band Diode and the single detector optical design.

The Super Wide Band Diode with a spectral response of 400 to 700 nm is modulated with no moving parts. This modulation prevents influences from other light sources such as sunlight. The broad band light source minimizes the effects of changing particle sizes when measuring dust concentration. The calibration audit filters typically used are measured over the 400 to 700nm range. The broad spectrum light source will give a more accurate measurement of these filters when compared to a narrow band LED system. Optical techniques are employed to ensure a homogeneous light beam without “hotspots”. This light is then split by a beam splitter to form a measurement light beam and a comparison light beam. The measurement light beam passes through the dust in the stack, enters the optic head, passes through the beam splitter and is measured by the detector.

Since the basis for all opacity monitors is the measurement of transmission (the amount of light received divided by the amount of the light transmitted), it is very important that not only the received light be measured accurately, but the transmitted light as well. Every 2 minutes the measurement light path is briefly blocked and only the comparison light path is evaluated. The comparison light beam is measured to determine the amount of the transmitted light. This comparison light path uses the same light source as the measured light path, passes through the beam splitter once, and is reflected once – just like the measured signal – and is measured by the same detector used to measure the light beam from the measuring reflector. Using this optical design, any change in the amount of light from the source, contamination of the beam splitter, or drift in the detector will effect both light paths (comparison and measurement) by the same amount and no error will be introduced to the opacity measurement.

A control cycle is initiated periodically to ensure proper operation of the system. During this cycle, the **D-R 290** automatically measures and displays the zero point, window contamination, upscale calibration value, and stack taper ratio. If necessary, the subsequent measured values will be corrected for window contamination. If the correction exceeds a predetermined value, a warning signal will be generated.

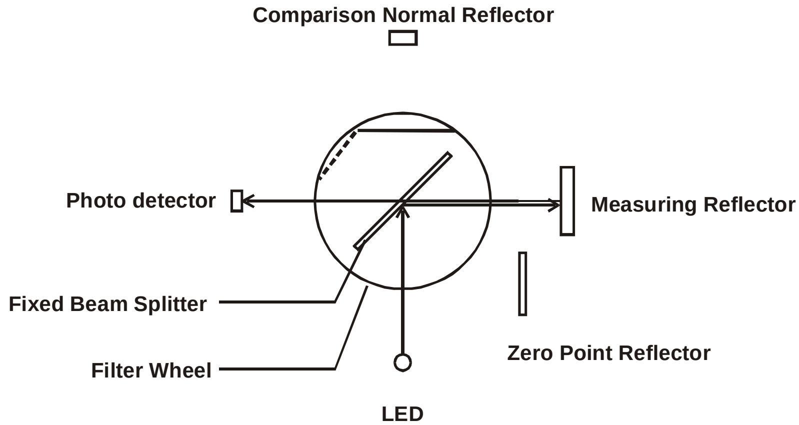
An integrated filter holder in the transceiver and a local display allow for quick and easy quarterly audits. The local display also allows service or maintenance by a single technician. Diagrams of the optics are given on the following pages.



(Fig. 3.3) Optics diagram D-R 290

3.4.1 Measurement

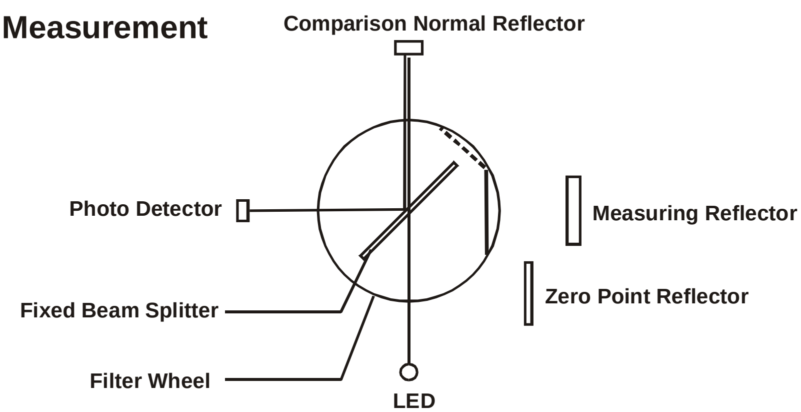
Measuring



The unavoidable drifts in light intensity that result from aging of the light source or temperature changes are automatically compensated by the monitor. The 2 kHz modulated light is split into both a measurement light beam and a comparison normal. An optical receiver (photo element) alternately reads these light beams. The selection of the light paths is driven by a stepper motor.

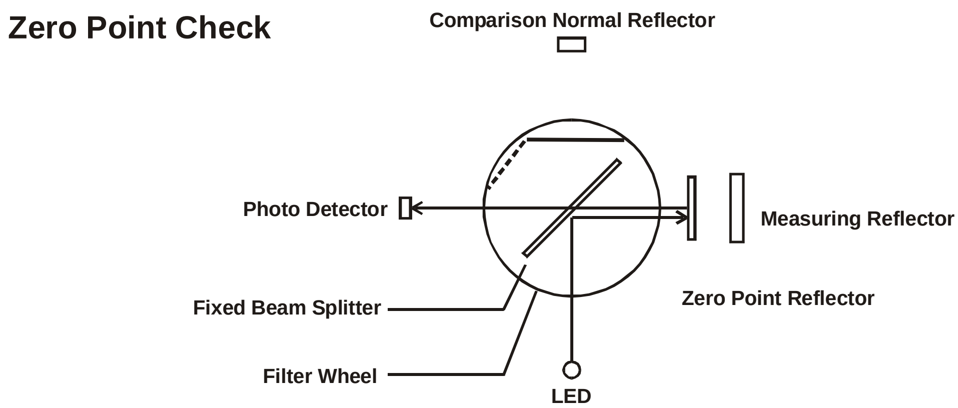
3.4.2 Internal Reference

Internal Reference Measurement



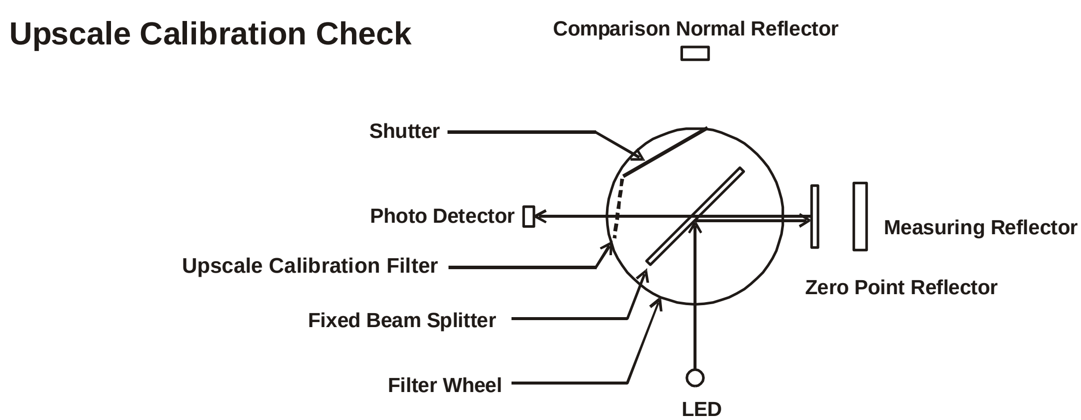
Every 2 minutes, for a period of 2 seconds, the opacity measurement is interrupted and an internal reference measurement (also called comparison normal) is performed. The filter wheel driven by a stepper motor moves the opaque filter from in front of the comparison normal reflector to a position in front of the measuring reflector. The light beam of interest leaves the LED and passes through the beam splitter. The light that was reflected from the beam splitter hits the opaque filter and is wasted. The light beam that passed through the beam splitter travels to the comparison normal reflector and is reflected. It travels to the beam splitter where the beam is reflected to the photo-detector. This value is digitized and stored in memory. This is how the system monitors the intensity of the LED. If the LED intensity is higher or lower than expected, the system can lower or raise the LED current by one step each 2 minute reference measurement cycle. In this way the light intensity of the system is held constant.

3.4.3 Internal Zero Check

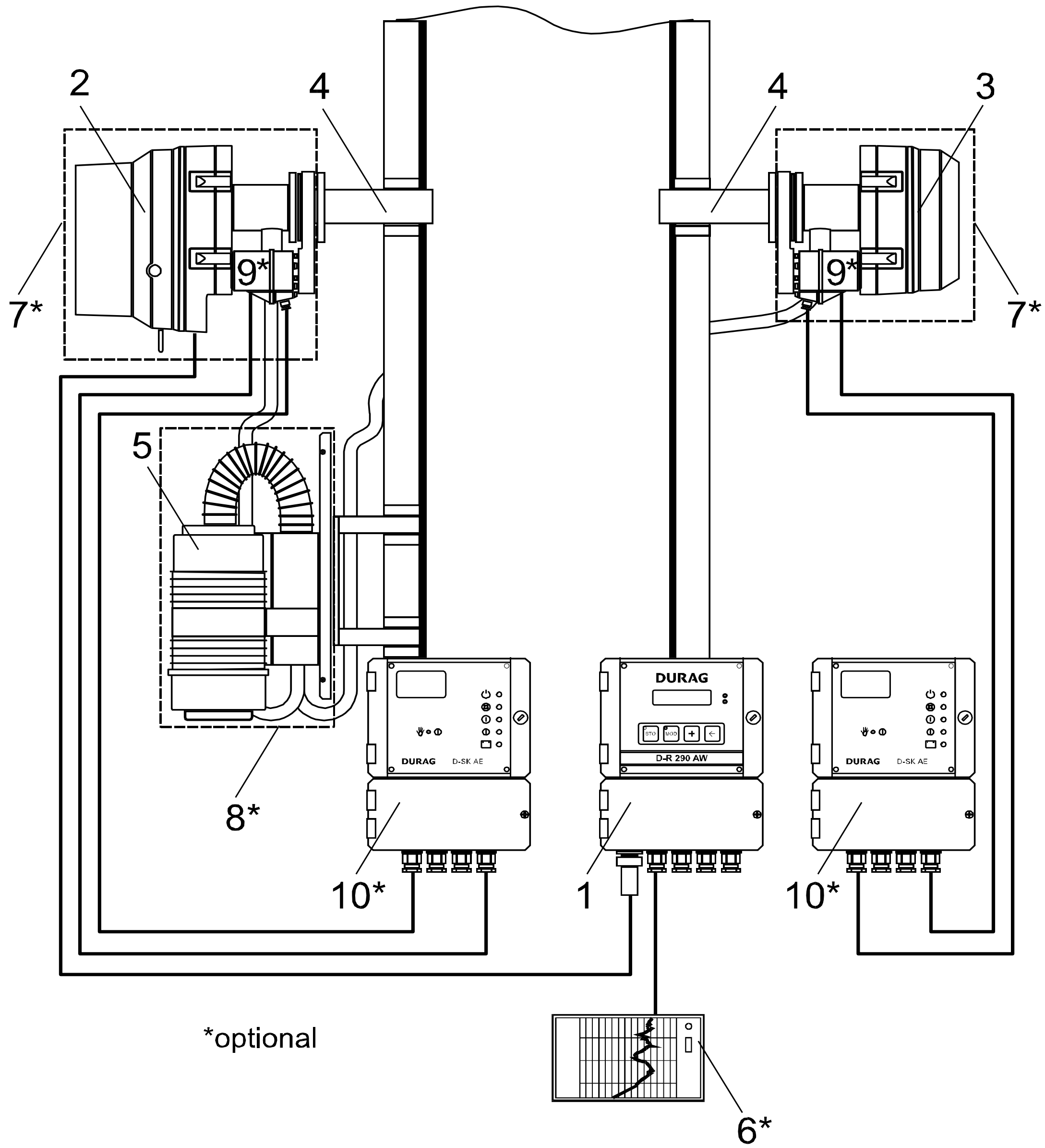


To make sure the **D-R 290** system is operating properly, a control cycle runs at regular intervals, which can be set to occur every 1-99 hours or can be initiated by the data logger. This cycle automatically measures and displays the zero point value, the level of window contamination on the optical surfaces, and a control value. All subsequent measurements are then adjusted to correct for the window contamination values. The acceptable value for this window contamination can be selected in %; if the value becomes higher, a warning message will be displayed (relay output). The control panel electronics then calculate the transmission intensity based on the light it receives and the intensity of the comparison normal beam. This data is then used in the calculation of the opacity or the extinction value. The extinction can be calibrated and is displayed in mg/m^3 ($grain/ft^3$). The result is then both displayed and given as an analog current output signal.

3.4.4 Upscale Calibration Check



3.5 System Components



(Fig.3. 4) System components

	Standard		* Optional
1	Control unit, D-R 290 AZ (stack display) Or D-R 290 AW (evaluation unit)	**6**	Customer supplied recorder or data logging system
2	Transceiver, D-R 290 MK	**7 & 8**	Weather Hood, US built systems use one
3	Reflector, D-R 290 R1 or R2		Large weather hood for blower and optics
4	Mounting flange, D-R 280 E	**9**	Fail-safe shutters
5	Purge air unit	**10**	Fail-safe shutter control electronics

Figure 4 shows standard and optional system components. Due to the many types of different applications, it is difficult to show all the different configurations of various components. DURAG, Inc. is committed to supplying the right system for the customer's particular application. There have been applications where weather hoods are not required, where only one shutter is used on the transceiver, or where one larger blower is used due to space constraints, 2 larger blowers have been used to overcome stack pressure, various adapter flanges have been used to mate with existing stack flanges, etc. Please consult with DURAG, Inc. for specific application recommendations.

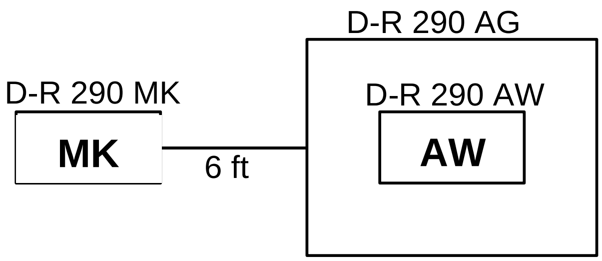
The system components are briefly described below. A more detailed description is given in the installation section of this manual.

1. **Stack Display Unit D-R 290 AZ**: This consists of an electronic insert (**D-R 290 AZ**) that is mounted in a housing with a terminal strip (**D-R 290 AG**). The insert in the housing will be called the **D-R 290 AZG**. This serves as the power supply for the transceiver, display unit of the measured values and system parameters, I/O termination point for shutters and pressure cells for blower alarms. This unit also relays the RS 422 information between the transceiver and the control room display unit. Calibration functions and the quarterly audit filters tests can be initiated from the **D-R 290 AZG**. This is part of the standard system although not required. It is possible to operate the system without the **D-R 290 AZG** and only with the Control Room Display Unit **D-R 290AW**.
   Evaluation Unit D-R 290 AW: This serves as the "brains" for the opacity system. This uses the same electrical hardware as the **D-R 290 AZ** but different software. This is typically mounted in a 19" rack using a **D-R 290 BT** rack mount housing. It can also be wall mounted in a **D-R 290 AG** housing. The **D-R 290 AW** serves a display unit, all the system parameters are entered with the keypad, and all the I/O for the data logging system is terminated here.

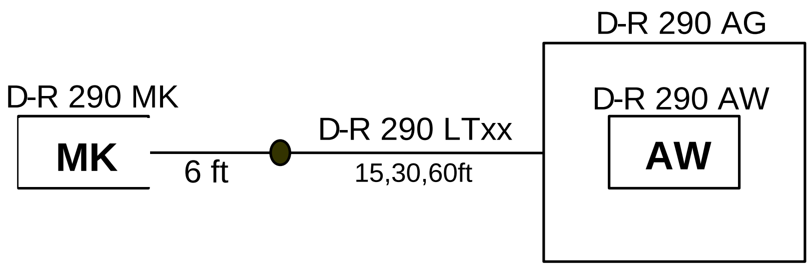
2. **Transceiver D-R 290 MK**: This transmits light to the reflector and receives the light from the reflector. The D-R 290 MK contains the modulated white LED light source, the detector, and the hardware for performing the daily calibration checks.
3. **Reflector D-R 290 R1** or **D-R 290 R2**: Both these types of reflectors auto-collimate the light. This means the light that hits the reflector is returned parallel to the incoming light (back to the transceiver). The R1 reflector is a "scotchlite" material and is for use with flange-to-flange distances up to 7.4 ft. (2.25m). The R2 reflector is a glass corner cube and can be used from distances of 5.7 ft. (1.75m) to 46 ft. (14m).
4. **Stack Flange D-R 280 E**: This is used to support the monitor on the stack. Different versions are available for brick stacks as well as to adapt to existing flanges.
5. **Purge Air Unit**: This is a centrifugal blower, typically ½ HP, with one used on the transceiver side of the stack and one on the reflector side. When larger than standard stack flanges are used (existing) or when the stack is positive pressure a larger blower may be used. Normally these blowers are mounted below the transceiver or the reflector inside the weather hood.
6. **Recording device**: Durag can supply a chart recorder but normally the customer has a recorder or data logging system to use to record the data.
7. **Weather Hoods for transceiver and reflector**: This is a large fiberglass box with a hinged cover to protect stack opacity components from the weather and birds. Normally the purge air system is mounted inside this box below the transceiver or reflector for US built systems. Typically there is one weather hood on each side of the stack.
8. **Weather Hood for purge air system**: For US built systems there is not a separate weather hood for the purge air system. See item 7.
9. **Fail Safe Shutters D-SK 280 MA**: The shutter will close during a loss of power or loss of purge air. This will prevent damage from the stack gas to the opacity system. The shutter may also be used for personnel protection on over pressure stacks.
10. **Fail Safe Shutter Control Electronics D-SK 290 AE**: This is the sensor electronics for the purge air flow sensor and has the battery pack to run the shutter motor, and has control functions to open and close the shutter when instructed.

3.5.1 Configuration options for stack and control room displays

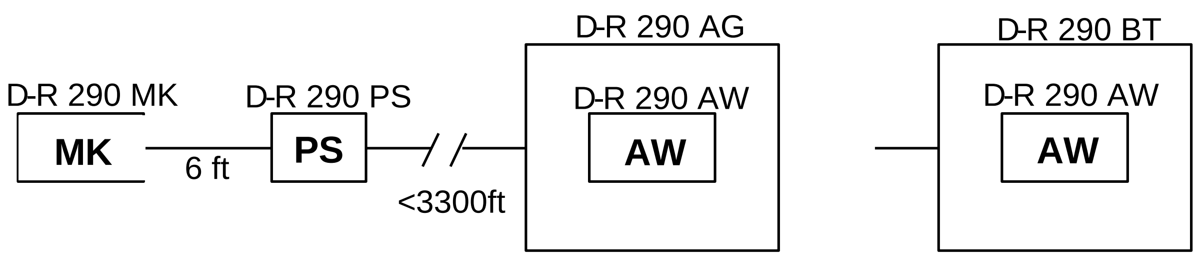
Since the **D-R 290** system can be used with or without a **D-R 290 AZ** and there can be different housings used (primarily for the **D-R 290 AW**) it can be somewhat confusing. The diagrams below illustrate the different configurations for the **D-R 290 AW** evaluation unit and the **D-R 290 AZ** stack display.



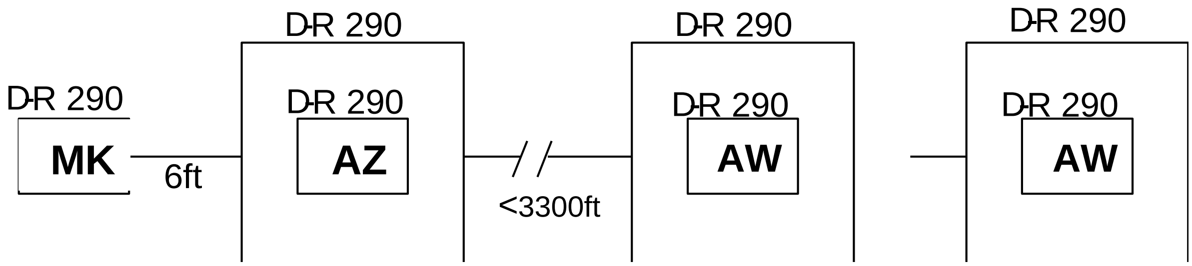
Transceiver connected directly to the D-R 290 AW located at transceiver location. The D-R 290 AW electronic insert is mounted in the D-R 290 AG wall mount housing.



Similar to above except an extension cable is placed between transceiver and D-R 290 AW.



The transceiver is now powered from the **D-R 290 PS** power supply located at the monitor location. Now the **D-R 290 AW** can be located up to 3300 feet (1000m) from the transceiver. A 2 pair cable is used to transmit the data over the RS 422 interface. Since the **D-R 290 AW** unit can be mounted indoors now, a panel mount housing, **D-R 290 BT**, can be used. More information is given on these different housings in the installation section of this manual.



The above diagram shows the recommended mounting arrangement. The **D-R 290 AZ** is used in the **D-R 290 AG** housing at the transceiver location. Calibration functions and filter audits can be ran from this location using the
D-R 290 AZ. The remotely mounted **D-R 290 AW** can be mounted in the wall mount or panel mount housing with panel mount in a 19" rack being the most common.

4. Selection of the Measuring Location

The measuring location should be positioned in a straight section of the duct, as far from upstream or downstream turns as possible. 40 CFR part 60, Appendix B, Performance Specification 1 gives guidelines for the mounting location. If necessary, check with local authorities to insure a proper installation location is selected. Try to install the equipment in a location that will allow for service and is free from vibration and with the best ambient conditions possible.

5. Installation

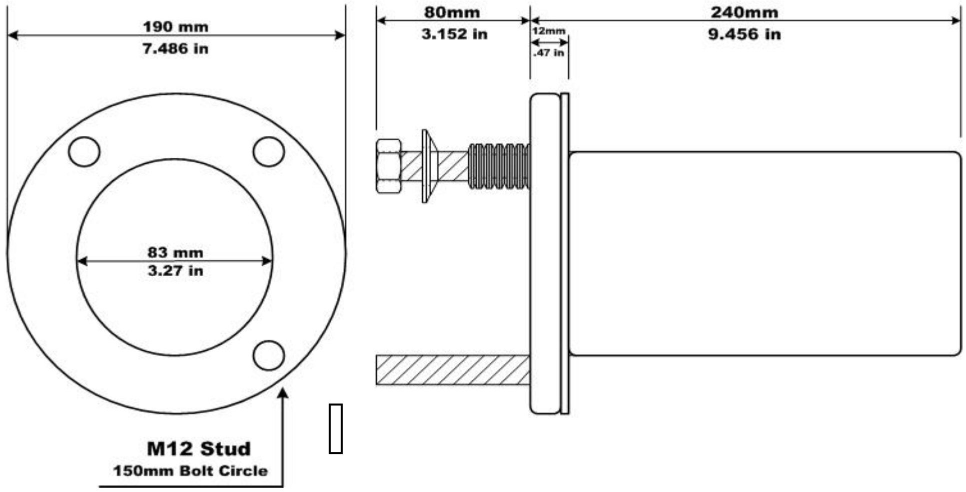
5.1 Flange Installation

For installation of the optic head and the reflector, installation flanges must be installed. For thickly insulated stacks and brick-lined chimneys, the tube must be lengthened accordingly. The flanges are available in carbon steel as a standard and stainless steel as an option. Normally these flanges are welded to the stack but for brick or concrete stacks a plate may be welded to the flange and then bolted to the stack. If existing flanges are available, Durag, Inc. can supply adapter flanges in most cases.

The pipes and installation flanges **must** be precisely aligned to allow the light beam to pass through the flanges. For short path lengths, a pipe may be inserted through the flanges to help align the flanges. For longer path lengths an alignment tool (**D-R 280-70**) is available from **DURAG, Inc**. The flange alignment must be within ± 1° of accuracy of centerline. The red dot on the installation flange must be on the top. Often it is recommended that the flange tube protrudes into the stack about 1 inch from the stack wall. This is done so that if rain or condensate runs down the stack wall it should run around the flange tube and not into the flange tube. There are many installations where this is not a concern and the flange tube is flush with the stack wall with no problems.

If the walls are thin, gusset plates must be installed for reinforcement. For stacks with flue gas temperatures of over 482°F (250°C), insulation should be installed. Use of fail-safe shutters is also recommended. If there is an existing set of flanges, **DURAG, Inc.**, can make adapter flanges to mate to these flanges.

If the flange tube length is modified, please note this distance because it will be required when setting up the operating parameters of the system. When the flanges have been installed, measure the flange-to-flange distance so the monitor can be set up to this same distance on a clear path to get an accurate zero reading.

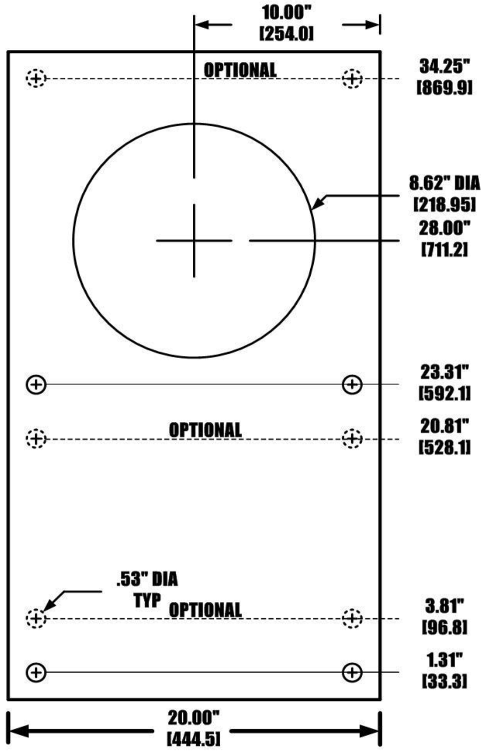


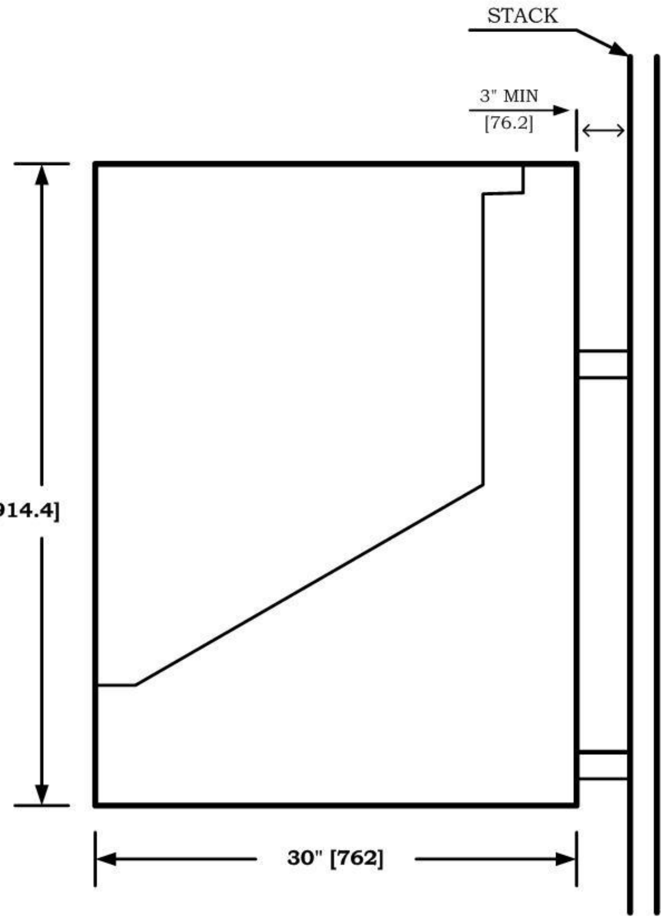
(Fig. 5.1) D-R 280-10E installation flange for D-R 290 Opacity Monitor

Important Note: The red dot on the installation flange must be on top.

5.2 Blower Panel and Weather Hood Installation

In outdoor applications the purge air blower, the stack display unit (**D-R 290 AZ**), the shutter control electronics (**D-SK AE**) if used, and a small junction box for power terminations are mounted to the weather hood. The weather hood is a fiberglass box with a cover that hinges. After the stack flanges are installed on the stack, the weather hood is then mounted to the stack. It is recommended to leave a 3 to 4 inch gap between the back of the weather hood and the stack. This will allow for airflow behind the weather hood and help minimize the amount of radiant heat from the stack to the box. If the stack is well insulated this should not be an issue. This box will also serve as a weather hood for the transceiver and reflector. Typically this box is mounted with stand-offs from the stack or by a framework that the box sits into and this framework is mounted to the stack. The weather hood with all components will weigh 100 to 150 pounds depending upon the size of the blower and optional equipment so care should be used when attaching this weather hood and associated mounting hardware. It is important to note that the transceiver side weather hood will be different from the reflector side weather hood. The **D-R 290 AZ** (stack display) will be mounted in the transceiver side weather hood and the J-Box will be different. There will normally be a sticker labeling this on the back of the weather hood but in the event this gets removed, look inside for the **D-R 290 AZ**.

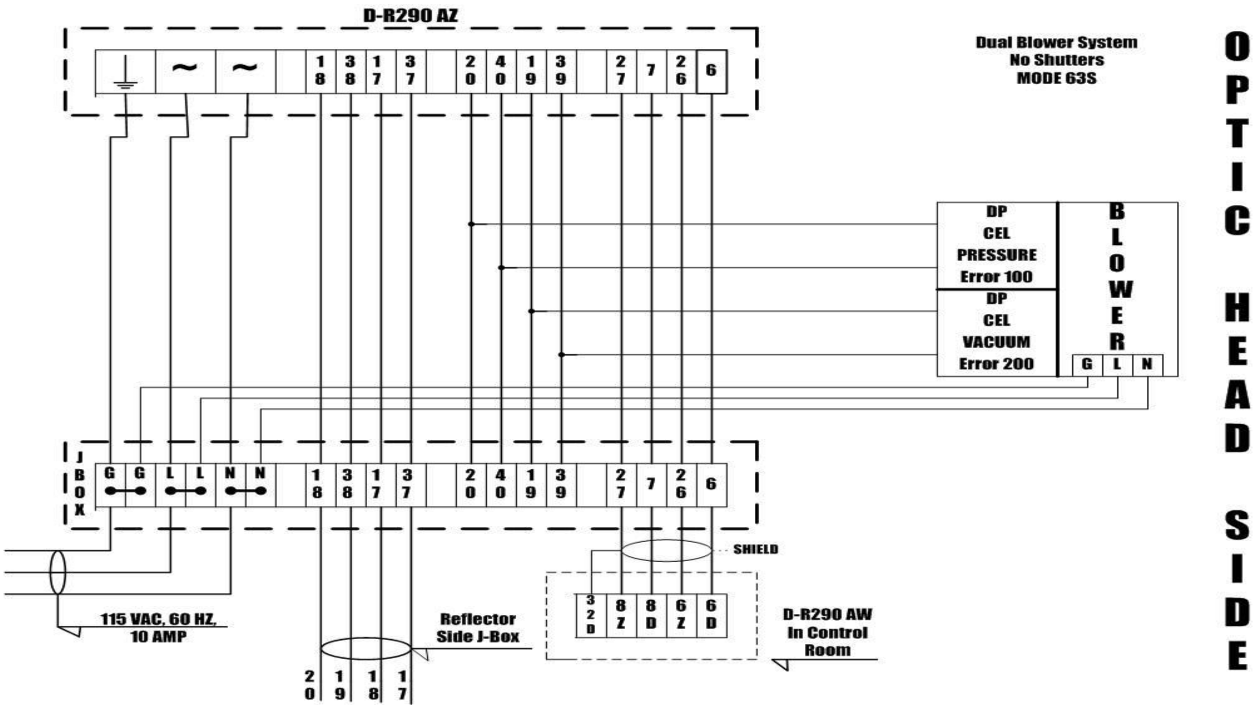




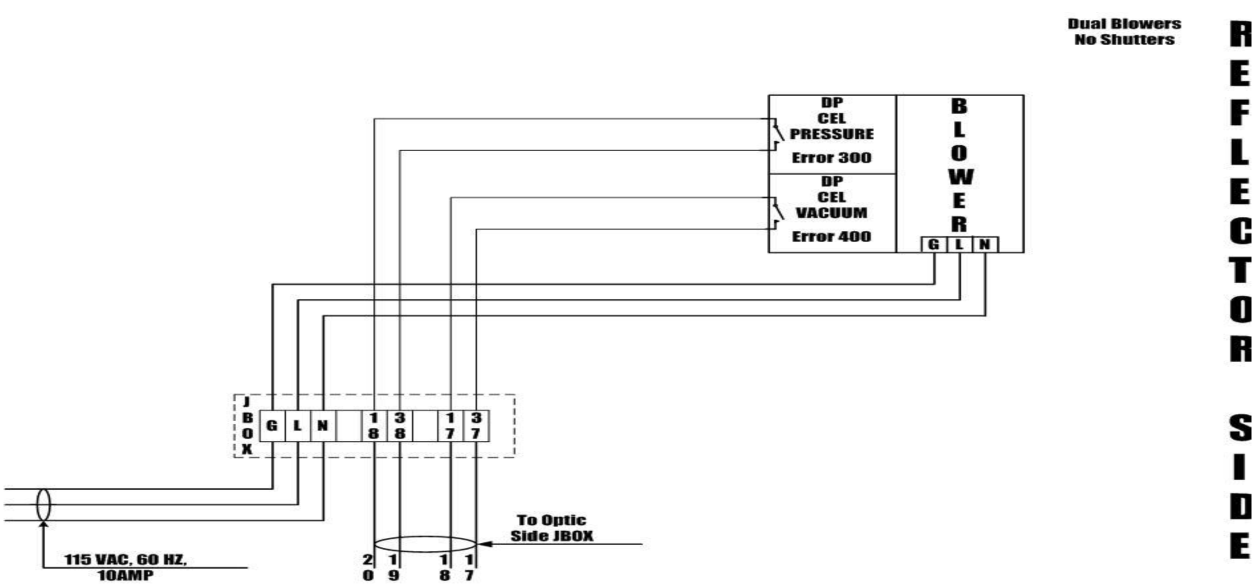
(Fig. 5.2) Weather hood dimensions

5.2.1 Weather Hood and Blower Panel Electrical Installation

Normally Durag, Inc. will pre-wire as much as possible to minimize the number of field terminations. Typically a J-Box will be installed in the weather hood or on the blower panel and the various components will be pre-wired to this J-Box and the customer will make their terminations to a terminal strip in the J-Box. Due to all the different configurations of the blower panel or weather hood (single blower, dual blower, one, two, or no shutters, with or without D-R 290 AZ) it is not practical to show all the wiring diagrams. The specific wiring diagrams will be included with the monitor and can be sent out prior to installation. An example of a typical wiring diagram for the transceiver side and reflector side weather hood is given below.



(Fig. 5.3) Transceiver side interconnect wiring, typical



(Fig. 5.4) Reflector side interconnect wiring, typical

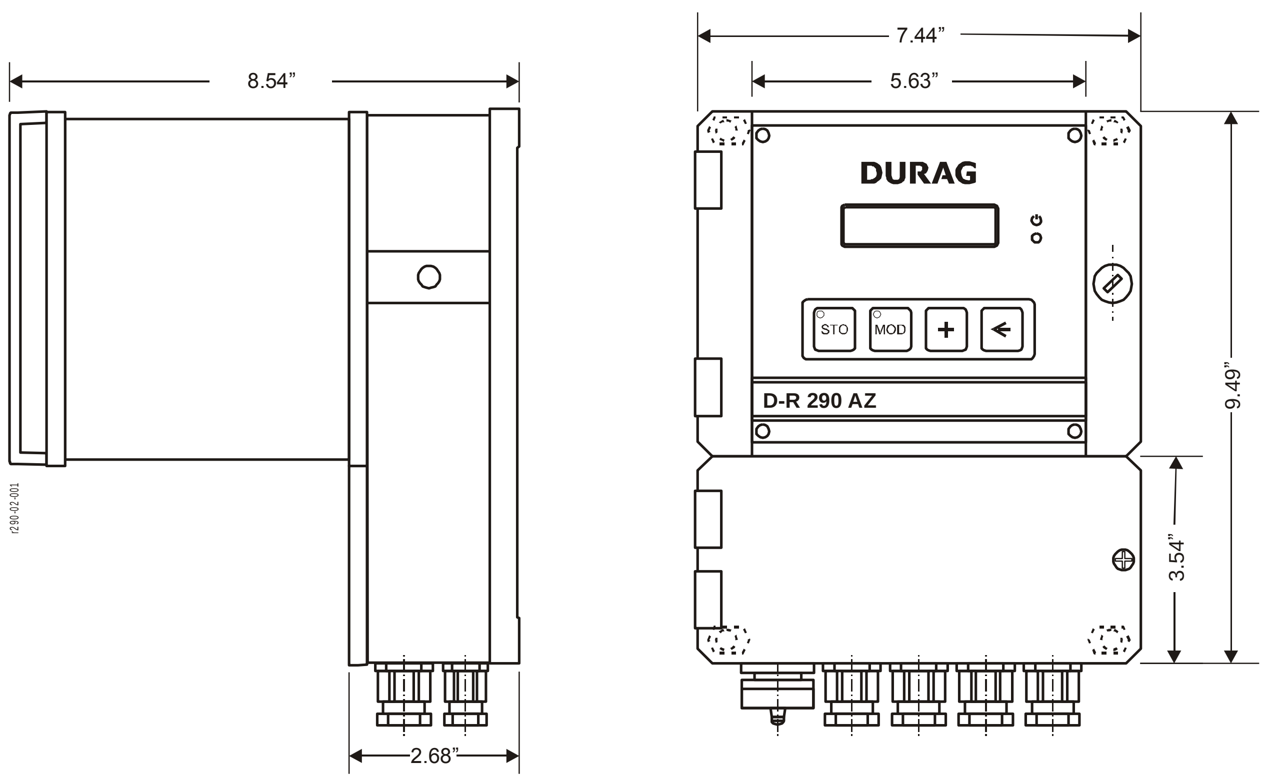
5.3 D-R 290 AZG Stack-Mounted Display Module

The **D-R 290 AZG** consists of two components. The electronic module is the **D-R 290 AZ** and the housing with electrical terminations is the **D-R 290 AG**. Since these components are almost always used together, the term **D-R 290 AZG** is used to refer to this housing with the display electronics.

The **D-R 290 AZG** is mounted on the stack at the measuring location and is usually mounted in the weather hood. The **D-R 290 AG** housing has an enclosure rating of IP 65 (corresponding to NEMA 4X) in a watertight aluminum housing. The cable from the transceiver that plugs into the **D-R 290 AZG** is 6 feet long so the **D-R 290 AZG** must be mounted near the transceiver.

The buttons and Liquid Crystal (LC) display on the front panel are visible through a transparent cover that swings opens to the left. The terminal connections are towards the bottom of the housing with a separate access cover from the LC display portion of the housing. Cord grip (Pg) fittings are provided for electrical connections and one connector for the connection to the transceiver. Normally only 4 wires for the RS 422 interface will need to be connected to this unit to communicate with the **D-R 290 AW**. The power, shutter control, and DP Cells will be pre-wired by DURAG. More information regarding the electrical interface is given in the electrical installation section.

The **D-R 290 AG** housing is normally pre-install in the weather hood but if it must be removed or installed, open the transparent cover, and then remove the electronics insert from the housing, use a screwdriver to release the latch on the right hand side and swing this portion open, and then remove the mounting bolts.



(Fig. 5.5) D-R 290 AG wall mount housing dimensions

Color: Housing body and enclosure are blue RAL 5017.
Ambient temperature: -40°F to +200°F (-40°C to +100°C).
Mounting hole diameter 6,5 mm, spacing 166 x 220 mm.

5.3.1 Electrical Installation, D-R 290 AZG Stack-Mounted Display Module

Normally the **D-R 290 AZ** is pre-wired and the customer only needs to connect the 4 wires for the RS 422 link to the **D-R 290 AW** in the shelter.

Stack Display D-R 290 AZ		**D-R 290 AZ must be used with D-R 290 AW (evaluation unit)**		
Terminal	**Name**	**Function**		
PE	Ground	Power supply 90 - 264 Volt		
N	Neutral			
L	Line			
40	Digital Input 1	Error 100 Blower fail transceiver side		
20				
39	Digital Input 2	Error 200 Purge filter plugged transceiver side		
19				
38	Digital Input 3	Error 300 Blower fail reflector side		
18				
37	Digital Input 4	Error 400 Purge filter plugged reflector side		
17				
36	Digital Input 5	Error 500 Shutter (Optional) fail transceiver side		
16				
35	Digital Input 6	Error 600 Shutter (Optional) fail reflector side		
15				
34	Relay 6	NO	Measuring relay, energized when measuring,	
14		Common	Fault, in cal, or power off	
33		NC	Relay is de-energized	
13	Relay 5	NO	Warning energizes relay	
32		Common		
12		NC		
31	Relay 1	Status signal when shutters are used For D-SK 1		
11				
30	Relay 2	Status signal when shutters are used For D-SK 2		
10				
29	Relay 3	Used to signal shutter controller	To D-SK AE 1 pin 16	
9		D-SK AE 1	To D-SK AE 1 pin 17	
28	Relay 4	Used to signal shutter controller	To D-SK AE 2 pin 16	
8		D-SK AE 2	To D-SK AE 2 pin 17	
27	RS 422 Link	To D-R 290 AW plug 1, terminal **8Z**		
7		To D-R 290 AW plug 1, terminal **8D**		
26		To D-R 290 AW plug 1, terminal **6Z**		
6		To D-R 290 AW plug 1, terminal **6D**		
4	Analog out 2	plus	4 – 20 ma, 2nd termination	Current signal on the D-R 290 AZ analog Outputs will be the same As on the D-R 290 AW Analog outputs Normally these are not connected Since the D-R 290 AZ is Located on the stack
5		minus		
24	Analog out 2	plus	4 – 20 ma, 1st termination	
25		minus		
2	Analog out 1	plus	4 – 20 ma, 2nd termination	
3		minus		
22	Analog out 1	plus	4 – 20 ma, 1st termination	
23		minus		
1		⊥ PE (Ground)		

(Table 5.6) D-R 290 AZ stack display I/O

5.4 Transceiver and Reflector Installation

The transceiver consists of the optical portion in the blue housing and the black purge air flange. The reflector consists of the reflector element in the blue housing and the black purge air flange. The purge air flange is identical for the transceiver and reflector. The purge air flange is connected to the transceiver or reflector by 2 hinge pin bolts. If there is stack gas coming from the stack flanges due to an overpressure stack, the optics of the transceiver and reflector should be protected. The best way to do this is to connect the air hose to the purge air fan and turn on the blower. Make sure the 12 spring washers are on each stud and the black rubber sealing collar is slipped over the flange. Then the purge air flange can be slipped onto the 3 studs on the flange. Next put the spherical washers on each stud and then the lock nut. Tighten the lock nuts until there is some compression of the spring washers. If this is not tightened enough, the system will not be help in position. If tightened too much, the spring will be collapsed and there will not be any vertical or horizontal adjustment to the transceiver or reflector.

Figure 5.7 shows a typical installation:

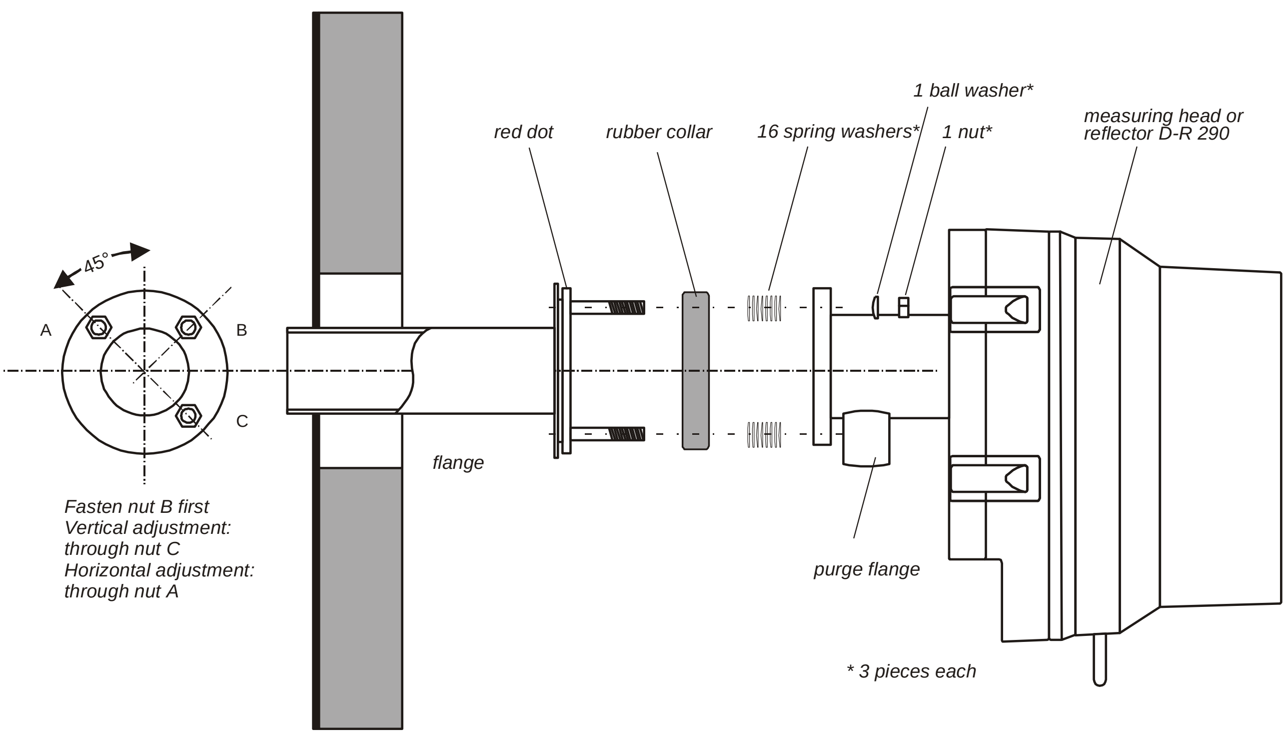
1. 12 spring washers (the 16 washers on drawing is from old flange design)

2. Rubber sealing collar

3. Purge air flange of instrument

4. Spherical washer

5. M12self-lockingnut



(Fig. 5.7) Mounting monitor on the installation flange

5.4.1 Transceiver and reflector alignment and focus

The transceiver and reflector are aligned to each other by adjusting the 3 nuts on each flange. However this can't be done until **all** the system components have been connected and the opacity system is running. This is because the alignment sight on the side of the transceiver uses the light from the LED to generate the image and the LED is not operating until the system is all powered. Once the system is powered and the initial daily calibration (that starts automatically upon power-up) is complete, the system can be aligned.

To align the transceiver, look through the alignment sight on the side of the transceiver housing. Make sure the reflector is closed on the reflector side. Then by adjusting the nuts on the stack flange of the transceiver side as shown in the previous figure, move the transceiver in the horizontal and vertical directions until the reflector image is centered in the "bulls eye" of the alignment sight. Please note that as the transceiver is moved horizontally, the image in the alignment site will move vertically. On longer-range systems the image in the alignment sight may not appear very bright. It may be helpful to cup your hands around the eye piece of the alignment site to block the ambient light when aligning the transceiver. The adjustment nuts should compress the spring washers to the point that the transceiver (or reflector) is stable. The spring washers should not be completely compressed, then there would be no room for further adjust the alignment.

The focus adjustment was set at the factory and should not need to be changed unless the system is being installed at a different path length. The focus only needs to be adjusted for flange-to-flange path lengths under 88 inches (Reflector 1 systems). For longer path lengths, the focus knob will need to be turned CCW as far as possible to achieve the proper focus. To adjust the focus, loosen the metal thumb screw and then move the objective lens by turning the thumb screw with the plastic knob. Adjust the focus until the image in the alignment sight is sharp. When finished, tighten the metal optics screw again to secure this setting.

To align the reflector, first release the latches and swing the reflector open from the purge air flange. Sight down the inner tube of the purge air flange and look at the light from the transceiver. Adjust the reflector purge air flange by with nuts on the stack flange until this tube is aligned and pointing at the transceiver. The reflector is auto collimating so the reflector alignment is usually not as critical as the transceiver alignment. This alignment procedure for the reflector requires a judgment call for when the inner tube is aligned. If the end user is not comfortable with this, a purge air flange alignment tool is available from DURAG, Inc. Once the purge air flange is aligned, the reflector will automatically be aligned when the reflector is closed and latched against the purge air flange. Then go back to the transceiver side and verify the transceiver alignment.

5.4.2 Transceiver and reflector electrical installation

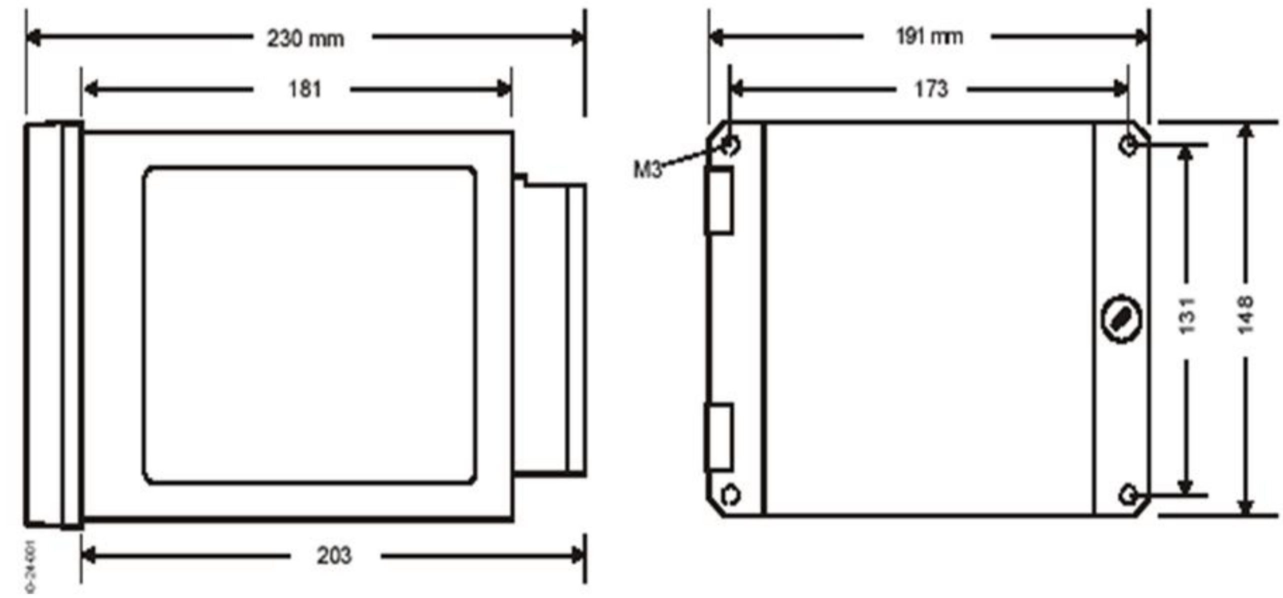
The reflector is a passive component and there are no electrical connections. The transceiver has a 6 foot cable with a 10 pin keyed bayonet style connector. This connector will be plugged into the **D-R 290 AZG** (Stack Display) or will be plugged into the **D-R 290 AW** on systems without the **D-R 290 AZ**. A diagram of the cable connections and function is shown below.

Connection to the Transceiver D-R 290 MK					
Evaluation Unit D-R 290 AW		Transceiver Cable Connection			
Plug	**Contact**	**Pin**	**Cable Nr**	**Pin X4**	**Function**
Plug 1	32 D Z	Housing	Ground		Ground
Plug 1	12 D Z	B	1	1	+ 15 Volt
Plug 1	32 D Z	D	2	2	GND
Plug 1	14 D Z	C	3	3	- 15 Volt
Plug 1	2 D Z	A	4	4	+ 5 Volt
Plug 1	32 D Z	E	green / yellow	5	PE
Plug 1	32 D Z	F	6	6	GND
Plug 1	8 D	J	7	7	RS 422 < --
Plug 1	8 Z	H	8	8	RS 422 < --
Plug 1	6 D	G	9	9	RS 422 -->
Plug 1	6 Z	M	10	10	RS 422 -->

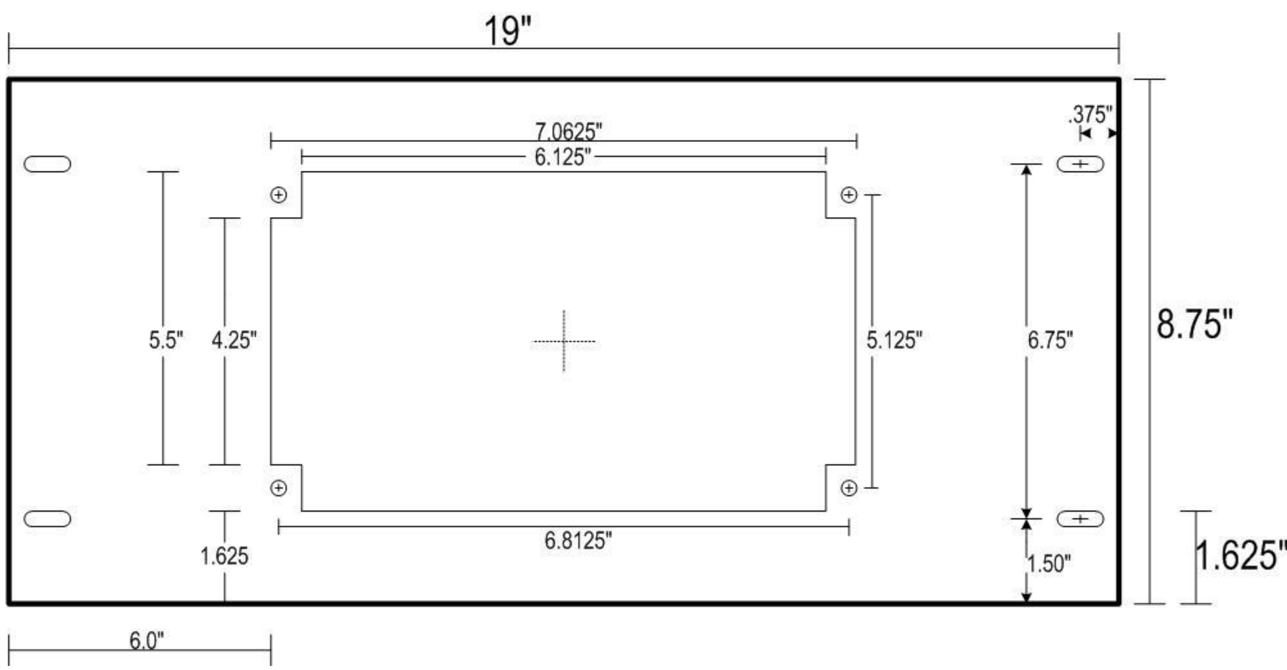
5.5 D-R 290 AW Evaluation Unit Installation

The **D-R 290 AW** is typically panel mounted or placed in a 19" rack. The **D-R 290 AW** electronic insert is the same as the **D-R 290 AZ** electronic insert except for the software. This electronic insert is then placed into a panel mount housing that has terminal strips on the back for electrical connections. This panel housing has the part number **D-R 290 BT**. This is usually mounted in a 19 inch rack but this could be mounted in any panel. A ¼ inch thick aluminum plate with a cut out for the **D-R 290 BT** is available for rack mounting. This plate has the part number **D-R 290 AW19 Plate**.

It is possible to operate the opacity system with only the **D-R 290 AW** without using the **D-R 290 AZ**. In this case the **D-R 290 AW** electronic insert will be mounted in the **D-R 290 AG** wall mount housing and this assembly will be called the **D-R 290 AWG**. The cable of the transceiver will be plugged directly into the **D-R 290 AG** wall mount housing. An extension cable is available to increase the distance between the transceiver and the **D-R 290 AWG**. The maximum distance of this extension cable is 65 feet (20 meters) and the part number is **D-R 290 LTx** where **x** is the length in meters. **DURAG, Inc**. recommends using the **D-R 290 AZ** in most applications and the additional features are well worth the small cost. However there are applications such as when the data logger is located near the opacity monitor where this type of installation would make sense.



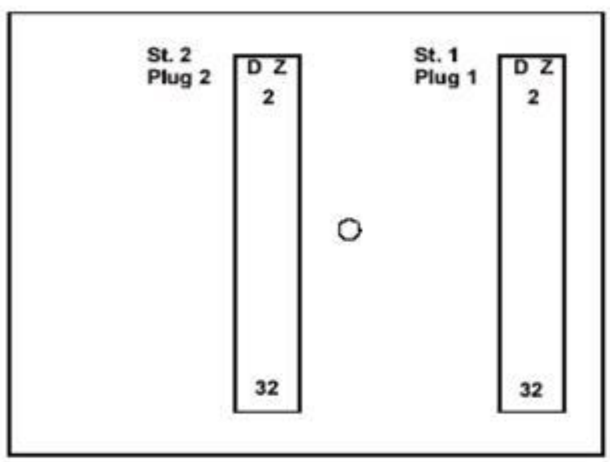
(Fig. 5.8) D-R 290 BT dimensional diagram



(Fig. 5.9) D-R 290 AW19 dimensional diagram

5.5.1 D-R 290 AW Electrical Connection when used with D-R 290 AZ

Since the in the majority of the installations the **D-R 290 AW** will be used with the **D-R 290 AZ** stack display The **D-R 290 AW** will also be mounted in the control room or shelter and placed in the **D-R 290 BT** housing. The electrical connections when the **D-R 290 AW** is used without the **D-R 290 AZ** will be described in the next section. Electrical connections for the D-R 290 AW control panel are made using the two terminal strips on the back of the **D-R 290 BT**. These 2 terminal strips are labeled Plug 1 and Plug 2. When you view the back of the **D-R 290 BT** Plug 1 will be on you right and Plug 2 on the left. The rows of terminals are numbered 2, 4, 6,…32 from top to bottom. The column of terminals on the left is D and the column on the right of the plug is Z. When you see a terminal listed as 32 DZ, the DZ together indicates that the D and Z terminals on row 30 are internally bridged together. **Warning:** These 2 plugs appear identical so one must be careful not to get these two plugs confused. Power is applied on Plug 2 (terminals 28 DZ, 30 DZ, and 32DZ). If you apply power to these terminals on Plug 1 you will probably blow up one of the analog outputs.



(Fig. 5.10) D-R 290 BT terminal connectors

Evaluation Unit D-R 290 AW		For use when D-R 290 AW is connected to D-R 290 AZ							
Plug	**Terminal**	**Name**	**Function**						
Plug 2	32 D Z	Ground	Power supply 90 - 264 Volt						
Plug 2	28 D Z	Neutral							
Plug 2	30 D Z	Line							
Plug 2	2 D	Digital Input 1	Programming Enable						
Plug 2	2 Z								
Plug 2	4 D	Digital Input 2	Start Cal Cycle						
Plug 2	4 Z								
Plug 2	6 D	Digital Input 3	Set up Mode 0x-5x	External Error 002					
Plug 2	6 Z		Set up Mode 6x	Zero Check					
Plug 2	8 D	Digital Input 4	Set up Mode 0x-5x	Range 2 for Analog Out 1					
Plug 2	8 Z		Set up Mode 6x	Window Check					
Plug 2	10 D	Digital Input 5	Set up Mode 0x-5x	Range 2 for Analog Out 2					
Plug 2	10 Z		Set up Mode 6x	Upscale Calibration Check					
Plug 2	12 D	Digital Input 6	Set up Mode 0x-5x	External Error 003					
Plug 2	12 Z		Set up Mode 6x	Display Stack Factor					
Relays 1-4 Function determined by set-up mode			**0x**	**1x**	**2x**	**3x**	**4x**	**5x**	**6x**
Plug 2	20 D	Relay 1	None	Limit 1 Analog1	Limit 1 Analog2	Limit 1 Analog1	Zero Check	Zero Check	Zero Check
Plug 2	20 Z								
Plug 2	22 D	Relay 2	None	Limit 2 Analog1	Limit 2 Analog2	Limit 2 Analog2	Window check	Window check	Window check
Plug 2	22 Z								
Plug 2	24 D	Relay 3	D-SK 1	D-SK 1	D-SK 1	D-SK 1	Upscale check	Upscale check	Upscale check
Plug 2	24 Z								
Plug 2	26 D	Relay 4	D-SK 2	D-SK 2	D-SK 2	D-SK 2	Stack Factor	D-SK 1	Stack Factor
Plug 2	26 Z								
Plug 2	16 Z	Relay 5	NO	Warning energizes relay					
Plug 2	18 D		Common						
Plug 2	18 Z		NC						
Plug 2	14 D	Relay 6	NO	Measuring relay, energized when measuring (If in Fault, in cal, or power off Relay is de-energized)					
Plug 2	14 Z		Common						
Plug 2	16 D		NC						
Plug 1	6D	RS 422 Communication	To D-R 290 AZG terminal 6						
Plug 1	6Z		To D-R 290 AZG terminal 26						
Plug 1	8D		To D-R 290 AZG terminal 7						
Plug 1	8Z		To D-R 290 AZG terminal 27						
Plug 1	24 D Z	Analog out 1	plus	4 – 20 ma, 2nd termination		Data on analog Outputs (opacity, optical density, calibration results) is also Function of the Set-up Mode See table 6.1			
Plug 1	26 D Z		minus	Normally not connected					
Plug 1	28 D Z	Analog out 1	plus	4 – 20 ma, 1st termination					
Plug 1	30 D Z		minus						
Plug 1	16 D Z	Analog out 2	plus	4 – 20 ma, 2nd termination					
Plug 1	18 D Z		minus	Normally not connected					
Plug 1	20 D Z	Analog out 2	plus	4 – 20 ma, 1st termination					
Plug 1	22 D Z		minus						
Plug 1	32 D Z		⊥ PE shielding for RS 422						

(Table 5.11) D-R 290 AW mounted in D-R 290 BT housing, terminal connections

5.5.2 D-R 290 AW Stand Alone Electrical Connection (No D-R 290 AZ)

Evaluation Unit D-R 290 AW		Only for Use with D-R 290 AW in Wall Mount Housing No D-R 290 AZ is Used	
Terminal	**Name**	**Function**	
PE	Ground	Power supply 90 - 264 Volt	
N	Neutral	Power supply 90 - 264 Volt	
L	Line	Power supply 90 - 264 Volt	
40	Digital Input 1	Programming Enable	
20	Digital Input 1	Programming Enable	
39	Digital Input 2	Start Cal Cycle	
19	Digital Input 2	Start Cal Cycle	
38	Digital Input 3	Set up Mode 0x-5x	External Error 002
18	Digital Input 3	Set up Mode 6x	Zero Check
37	Digital Input 4	Set up Mode 0x-5x	Range 2 for Analog Out 1
17	Digital Input 4	Set up Mode 6x	Window Check
36	Digital Input 5	Set up Mode 0x-5x	Range 2 for Analog Out 2
16	Digital Input 5	Set up Mode 6x	Upscale Calibration Check
35	Digital Input 6	Set up Mode 0x-5x	External Error 003
15	Digital Input 6	Set up Mode 6x	Display Stack Factor

Relays 1-4 Function Determined by set-up mode		0x	1x	2x	3x	4x	5x	6x
31 / 11	Relay 1	None	Limit 1 Analog1	Limit 1 Analog2	Limit 1 Analog1	Zero Check	Zero Check	Zero Check
30 / 10	Relay 2	None	Limit 2 Analog1	Limit 2 Analog2	Limit 2 Analog2	Window check	Window check	Window check
29 / 9	Relay 3	D-SK 1	D-SK 1	D-SK 1	D-SK 1	Upscale check	Upscale check	Upscale check
28 / 8	Relay 4	D-SK 2	D-SK 2	D-SK 2	D-SK 2	Stack Factor	D-SK 1	Stack Factor

Terminal	Name		Function	
13	Relay 5	NO	Warning energizes relay	
32	Relay 5	Common	Warning energizes relay	
12	Relay 5	NC	Warning energizes relay	
34	Relay 6	NO	Measuring relay, energized when measuring, Fault, in cal, or power off Relay is de-energized	
14	Relay 6	Common	Measuring relay, energized when measuring, Fault, in cal, or power off Relay is de-energized	
33	Relay 6	NC	Measuring relay, energized when measuring, Fault, in cal, or power off Relay is de-energized	
27 / 7 / 26 / 6	RS 422 Link		**Note:** When using D-R 290 AW without D-R 290 AZ Terminals 6 and7 must be connected with a jumper and Terminals 26 and27 must be connected with a jumper to Complete the RS 422 communication to the transceiver	
2	Analog out 1	plus	4 – 20 ma, 2nd termination Normally not connected	Data on analog Outputs (opacity, optical density, calibration results) is also Function of the Set-up Mode See table 6.1
3	Analog out 1	minus	4 – 20 ma, 2nd termination Normally not connected	Data on analog Outputs (opacity, optical density, calibration results) is also Function of the Set-up Mode See table 6.1
22	Analog out 1	plus	4 – 20 ma, 1st termination	Data on analog Outputs (opacity, optical density, calibration results) is also Function of the Set-up Mode See table 6.1
23	Analog out 1	minus	4 – 20 ma, 1st termination	Data on analog Outputs (opacity, optical density, calibration results) is also Function of the Set-up Mode See table 6.1
4	Analog out 2	plus	4 – 20 ma, 2nd termination Normally not connected	Data on analog Outputs (opacity, optical density, calibration results) is also Function of the Set-up Mode See table 6.1
5	Analog out 2	minus	4 – 20 ma, 2nd termination Normally not connected	Data on analog Outputs (opacity, optical density, calibration results) is also Function of the Set-up Mode See table 6.1
24	Analog out 2	plus	4 – 20 ma, 1st termination	Data on analog Outputs (opacity, optical density, calibration results) is also Function of the Set-up Mode See table 6.1
25	Analog out 2	minus	4 – 20 ma, 1st termination	Data on analog Outputs (opacity, optical density, calibration results) is also Function of the Set-up Mode See table 6.1
1			⊥ PE (Ground)	

(Table 5.12) D-R 290 AW mounted in D-R 290 AG housing, terminal connections (No D-R 290 AZ)

6. Operation

Before the **D-R 290** opacity system will function, the electrical connections need to be made at the transceiver location (blowers, transceiver, stack display) and the **D-R 290 AW** will need to at a minimum have power and the RS 422 communication lines terminated. In a typical installation with the **D-R 290 AZ** stack display, the **D-R 290 AW** evaluation unit talks to the **D-R 290 AZ**, the **D-R 290 AZ** talks to the **D-R 290 MK** (transceiver) and the **D-R 290 MK** talks to the **D-R 290 AW**. In a system without a **D-R 290 AZ**, the **D-R 290 AW** and the D-R 290 MK talk back and forth to each other but the **D-R 290 AW** is the “brains”. This is the flow of data in the communication loop. If any piece of the equipment is not powered or there is a wiring error in the 4 wires for the RS 422 there will be a communication error. This will show up on the display panel(s) as an “Error 000”. Without communication, the transceiver does not know what to do and will idle and not function. Since in this error condition the transceiver is not functioning, it is not possible to align the transceiver or really do much of anything. The first step is to make sure communication is established, then the transceiver can be aligned or system parameters viewed or changed.

6.1 Operation of the D-R 290 AW evaluation unit

The D-R 290 is controlled using the four buttons and the LCD on the front panel of the evaluation unit. These buttons are membrane switches that are polled about every second. You may have to hold the button in for about a second and then release to activate the desired function. A description of the buttons is given below.

6.1.1 Parameters

There are a number of parameters that the user can set in the **D-R 290** evaluation unit such as measuring range, alarm points, integration time, etc. Below is a list of these parameters in the same order as they appear when you scroll through the display as well as a description. These parameters are set by **DURAG** before the system is shipped and normally should not need to be changed.

There are many different data logging systems and many desired features from an opacity system. **DURAG** has tried to incorporate as much flexibility as possible with a fixed amount of I/O. Many of the features and options will not be used in most cases. The description of the parameters may seem over complicated at first but when you look at just the features you are using, the system should appear much easier to use.

When the parameters are viewed from the **D-R 290 AW** or the **D-R 290 AZ**, the system is still measuring and the data on the analog output is still valid until the Filter Audit parameter is reached. The parameters can be scrolled through up to Limit Value 2. At this point the MOD Key can be pressed again and you can step out of the display parameters mode without affecting the measured opacity data on the analog outputs. The last 5 parameters, Filter Audit and the 4 calibration phases, will cause these tests to be performed and the data on the analog outputs and relays will respond accordingly.

6.1.1.1 SET-UP MODE

The set-up mode determines how the systems inputs and outputs (I/O) functions. The data on the analog outputs (opacity or optical density), the function of the digital inputs and the relay outputs is determined by the 2 digit number for the set-up mode.

Opacity: = [OP%], Extinction: = [OD] calibrated in mg/m³.

Set-up Mode I/O Function

Display 1s digit	Output – 1 Measuring in	Output – 2 Measuring in	Control cycle on
X 0 S	OD	OD	Output-1
X 1 S	OP%	OD	Output-1
X 2 S	OD	OP%	Output-1
X 3 S	OP%	OP%	Output-1
X 4 S	OD	OD	Output-1 + Output-2
X 5 S	OP%	OD	Output-1 + Output-2
X 6 S	OD	OP%	Output-1 + Output-2
X 7 S	OP%	OP%	Output-1 + Output-2

Display 10s digit	Relay 1 Function	Relay 2 Function	Relay 3 Function	Relay 4 Function
0 X S	X	X	D-SK 1	D-SK 2
1 X S	Limit 1, output 1	Limit 2, output 1	D-SK 1	D-SK 2
2 X S	Limit 1, output 2	Limit 2, output 2	D-SK 1	D-SK 2
3 X S	Limit 1, output 1	Limit 2, output 2	D-SK 1	D-SK 2
4 X S	Zero Check	Window check	Upscale check	Stack Factor
5 X S	Zero Check	Window check	Upscale check	D-SK
6 X S	Zero Check	Window check	Upscale check	Stack Factor

<table>
<tr><th>Display 10s digit</th><th>Digital Input 1</th><th>Digital Input 2</th><th>Digital Input 3</th><th>Digital Input 4</th><th>Digital Input 5</th><th>Digital Input 6</th></tr>
<tr><td>0 X S</td><td rowspan="7">Enable Programming (close to change parameters)</td><td rowspan="7">Start Cal Closed=no cal Open=cal by timer Upon opening =start cal</td><td rowspan="6">External Error 002 (Shutter, DP Cell)</td><td rowspan="6">Range 2 Output 1 Close to change analog output 1 to range 2</td><td rowspan="6">Range 2 Output 2 Close to change analog output 2 to range 2</td><td rowspan="6">External Error 003 (Shutter, DP Cell)</td></tr>
<tr><td>1 X S</td></tr>
<tr><td>2 X S</td></tr>
<tr><td>3 X S</td></tr>
<tr><td>4 X S</td></tr>
<tr><td>5 X S</td></tr>
<tr><td>6 X S</td><td>Zero check</td><td>Window</td><td>Upscale</td><td>Stack factor</td></tr>
</table>

(Table 6.1) How set-up mode changes I/O

The ones digit will control the data on the analog outputs. Normally this will be a 3 or a 7 for opacity on both analog outputs. The difference between 3 and 7 is if the calibration data should appear on both analog outputs or just analog output 1. If a 3 is selected for the ones digit, no calibration data will appear on analog output 2 and this output will hold lost value during the calibration cycle.

The tens digit for the set-up mode controls the function of both the digital inputs (3-6) and the relay outputs (1-4). Digital input 1 has a fixed function to enable programming and input 2 is fixed to start a calibration. Digital inputs 3-6 have the same function for set-up mode 0X through 5X. When the tens digit is a 6 the digital inputs 3 through 6 will be to start individual phases of the calibration cycle. In addition to changing the function of the digital inputs, the tens digit of the set-up mode will control the function of relays 1 through 4 as shown above.

6.1.1.2 RANGE 1 OUT.-1

Each analog output has 2 measuring ranges. The analog output is normally in range 1 but it is possible to close a digital input and change to a new measuring range. The value displayed here is for range 1 of analog output 1. The value displayed hear will equate to the 20 ma point of the analog output (4.00 ma will be zero percent opacity). The minimum range is 0 to 20% and the maximum range is 0 to 100% opacity and can be set in 1% steps. This is normally set to 100%.

6.1.1.3 RANGE 2 OUT.-1

This is range 2 of analog output 1. If digital input 4 was closed and the system was in set-up mode 0X through 5X, analog output 2 would change to Range 2. It is very rare that this would ever be done. This value is normally set to 100% (same as range 1).

6.1.1.4 INT. TIME OUT.-1

This is the integration time for analog output 1. This can be set from 5 seconds to 1800 seconds. This is essentially the T95 time or the amount of time to reach 95% of the final value when a step change is applied. This value is normally set to 5 seconds from **DURAG** to meet the ASTM/EPA 10 second response time specification.

6.1.1.5 RANGE 1 OUT.-2 These are basically the

6.1.1.6 RANGE 2 OUT.-2 same functions as above

6.1.1.7 INT. TIME OUT.-2 but for analog output 2.

6.1.1.8 CHECK CYCLE => HRS

If digital input 2 is left open, the system will go through a calibration cycle periodically by its own timer. The value set here is the time in hours between calibration cycles. This can be set from 1 to 99 hours. If you want the **D-R 290** to initiate the calibration every day, this is set to 24 hours. If you want the data logging system to start the calibration, have the data logger close digital input 2 and disable the timer function. When you want the calibration to start, have the data logger open digital input 2 and the calibration will start. The amount of time to open digital input 2 should be at least 1 second (5 is typical) but digital input 2 must close before the internal timer forces another calibration. Some data logging systems can't hold a contact closed for 23 hours and 55 seconds. In this case the time between calibrations could be set this to 25 hours (some value larger than 24). 24 hours from the last calibration the data logger could close digital input 2 for 5 seconds and when this contact opened, the calibration would start. In this case you do not want this time set to 24 hours because you may end up in a race condition to see if the **D-R 290** AW timer or the data logger timer reaches 24 hours first. This is why when the data logger initiates the daily calibration this value is normally set to 25 hours.

It is also possible to start a calibration cycle by pressing both the + key and the left arrow (←) key and hold for at least 5 seconds.

6.1.1.9 WINDOW ALARM

During the daily calibration (or whenever a Window Check is activated), the system will measure the amount of contamination on the exposed optical surfaces (window and zero point reflector). This window check value is then used to compensate the measured opacity to get a more accurate reading of true stack opacity. The EPA allows for a maximum of 4% opacity compensation so this value is normally set to 3.5%. If you want more warning before the maximum allowable compensation is reached, this value can be set to 3.0%. When the value set here is reached, a Error 001 (window contamination exceed) will be generated that will cause a forced message in the display of the **D-R 290** and the Warning Relay (R6) will energize.

6.1.1.10 LIMIT VALUE 1

Limit value 1 can be set on either analog output 1 or analog output 2 depending on the set-up mode. The value set here is in milli-amp (not %) and can be set in 0.1 ma steps. When this level is exceeded, the appropriate relay as determined by the set-up mode will close.

6.1.1.11 LIMIT VALUE 2

A second limit value can be set if in the appropriate set-up mode. This functions similar to limit value 1.

6.1.1.12 FILTER AUDIT

This mode is designed so the neutral density filters can be placed into the light path. In this mode the zero point reflector of the transceiver swings into the light path and the system is no longer measuring stack opacity. Before the filter audit test is performed, the optics should be clean and calibration cycle should have been ran so any changes in the window contamination reading from the cleaning will be updated. Undo the 4 clasps and swing the optic head open. The filter holder is located between the exit window and the zero point reflector. The filter holder is designed to accept the standard 2-Inch square filters mounted in a 2.5 inch wide frame.

Once you step to this parameter, the zero reflector will swing into the light path and the display will read FILTER AUDIT. The display should read 0.0 +/- 0.2 % opacity and then the filters can be placed in the filter holder. If the display does not show this value, it is possible to adjust this to zero. Press the STO key and the red LED will light. Wait 10 seconds and press the STO key again and the LED will turn off. The value should now have automatically adjusted to 0.0 +/- 0.2 % opacity.

6.1.1.13 ZERO POINT CHECK

The system will now read and display the zero point check value.

6.1.1.14 WINDOW CHECK

The system will now read and display the contamination on the exit window and the zero point reflector. When this test is performed a compensation value is calculated from the contamination on the optics. Subsequent opacity measurements are corrected by this compensation value to give the correct stack opacity reading. When you view the window check, remain at this step for at least 10 seconds to allow for a stable reading. If you step through this value too quick, the window check value that is stored may be wrong and then generate the wrong correction value and could give a window check error (error 001).

6.1.1.15 SPAN CHECK

During this test (also called upscale calibration check), the zero point reflector is still in the light beam and internally, a metal grid filter is moved in the light beam. This attenuation of the light beam will cause an increase in opacity which will be displayed.

6.1.1.16 STACK CORRECTION FACTOR

The stack correction factor is defined at the stack exit ID divided by the measuring path distance. This is shown in section 3.2 as L2/L1. A straight stack will normally give a stack correction value of 1.000. Sometimes a straight stack will have a stack correction factor slightly over 1 because the flange tubes protrude through the stack wall and into the stack. The range of allowable values for the stack correction factor is 0.5 to 2.9. The 4 to 20 ma will also equate to this 0.5 to 2.9. A stack correction factor of 1.000 will give a signal of 7.33 ma on the analog output.

For **D-R 290 AW** software version 5.20 the range of the allowable stack correction factor has been increased to allow from 0.1 to 3.3. For this version, a stack correction factor of 1.000 will give a signal of 8.5 ma on the analog output.

6.1.2 Key functions

Key [● MOD] Puts the system into the “*display parameters*” mode. The MOD key LED should be lit in this mode and then you can use the “+” key to scroll through and view the parameters. In this mode the parameters can only be viewed, they cannot be changed.

Key [● STO] Puts the system into the “*data entry*” (save) mode. Digital input 1 must be bridged to allow a parameter to be changed. If digital input 1 is open you will see an “Input disabled” message when you try to activate this button. To change a parameter, first use the MOD and “+” key to view the parameter you wish to change. Then press the STO key (the LED will light) and you will see a blinking cursor. Use the arrow key to move the cursor to the digit you wish to change and then use the “+” key to change the digit to the desired value. Then press the STO key again and the LED will go out and the new value is saved. The LED on this button will blink during a fault.

Key [+] Pressing this key in the *"Display measured value"* (the normal measuring mode) switches the display between viewing the data on analog output 1 or analog output 2. The MOD key LED should not be lit.
In the “*Display parameters*” mode, this key will cause the display to step to the next parameter. The MOD key LED will be lit.
In the ”*data entry*” mode, this will change the value of the blinking digit. LEDs on both the MOD and STO keys will be lit.

Key [←] This key moves the blinking cursor to the next digit in the display. It is active only in the “*data entry*” mode.
The LEDs on both the MOD and STO keys will be lit.

(Fig. 6.2) D-R 290 AW Key Functions

6.1.3 Saving / Data entry

The **D-R290 AW** control panel requires digital input 1 to be bridged to enable changing and saving data. If digital input 1 is open. You will not be able to change the parameter. In the **D-R 290 BT** panel mount housing, digital input 1 is on Plug 2, contact 2D and 2Z. When the **D-R 290 AW** is in the **D-R 290 AG** wall mount housing, digital input 1 in on the terminal strip, terminals 20 and 40.

Open: Save function disabled, closed: Save function enabled.

1. Pressing the "MOD" key takes the system out of “*Measuring*” mode and puts it into “*display parameters*” mode. The LED on the MOD button should light.
2. Press the "+" key until the desired value appears in the display field.
3. Press the "STO" key to switch into “*data entry*” mode. The LED on the STO key should light up.
4. One of the digits should be blinking. Pressing the "+" key will increase this number (zero will appear after reaching the number 9). Pressing the " 🡐 " key will move the blinking cursor to the next digit to the left. Again, press the "+" key until the desired number appears. When all digits have been adjusted, the cursor will automatically return to the right-most digit.
5. Pressing the STO key will save the newly entered value and return the system to the “*display parameters*” mode. The LED on the STO key should go out.
6. Pressing the MOD key while in the “*display parameters*” mode will return the system to the “*measurement*” mode. The MOD key LED will go out and the display will show the current measured value.

   If the MOD key is pressed during the “*data entry*” mode before saving, the system will revert to the “*measurement*” mode without saving changes.
7. After changes have been made and saved, digital input 1 can be opened to disable further changes.

	Operating mode	Key sequence	Explanation	Display
	Display measured value			Measured value
		+	Switch the display between the measured value output signal channels	Output 1 Output 2
1	Display parameters	● MOD	MOD - LED lights	Measured value
2	Select	+	Select the value you wish to view	Saved value
		Enable data entry. Close the status relay contact input.		
3	Data entry	● STO	STO - LED lights	
4	Change value	+	Increase the digit value	Previously saved value
		←	Change digit/move blinking cursor	
5		● STO	Save the adjusted value	Changed value
	Display parameters		STO - LED goes out	
6		● MOD	If the STO key has not been pressed, the changes will not be saved	
7	Display measured value		MOD - LED goes out	Current measured value
		Disable data changes by opening the status relay input		

(Fig. 6.3) D-R 290 AW operating sequence

6.1.3 Liquid Crystal Display (LCD)

The display has two 16-character lines and these two lines are divided into 4 sections as shown below. All error and warning messages appear in the first line (sections 1 and 2). In the event of an error, the display will alternate between the error message (see page 45 for error messages) and the currently selected display mode.

The display is divided into four sections.

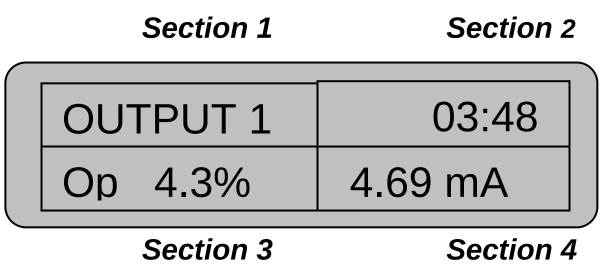
Display during normal measuring

Section 1: Currently selected output

Section 2: If the system is set to automatically run the control cycle at regular intervals, this will display the time remaining until the next control cycle.

Section 3: Calculated value of the current measurement.

Section 4: Current analog-output signal in mA, from output 1 or 2.



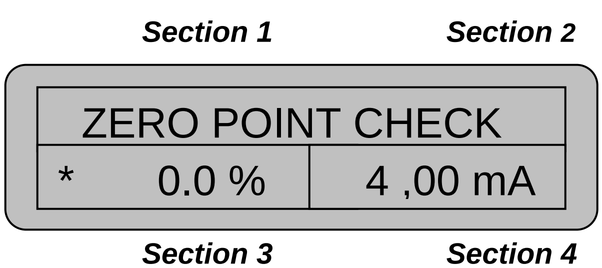
Calibration Cycle Display

Section 1+2: Current phase of calibration cycle

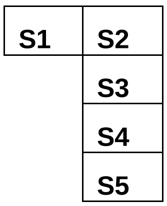
ZERO POINT CHECK, WINDOW CHECK, SPAN CHECK, STACK COR.CHECK

Section 3: Calculated value in % opacity

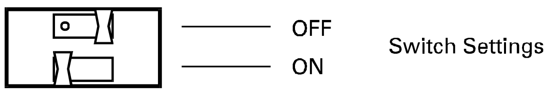
Section 4: Analog-output signal in mA for the current phase



6.1.4 Switch settings and Operation with or without the D-R 290 AZ



On the processor board (No. 30) inside the D-R 290 AW (and AZ) there are 5 switches located in the upper left corner of the circuit board. Switch 1 is in the upper left of this group and switch 2 through switch 5 are stacked to the right of switch 1. There are also 2 switches on the No. 40 board but these are for the fail safe shutters and will be discussed in the shutter section.



Most of the switches should be in the on position. In the on position the switch will be slid towards the rear of the circuit board (away from the display)

Switch	D-R 290 AW Function	D-R 290 AZ Function
S1	ON means Watchdog Timer on. The default is ON.	Same as AW
S2	ON to work without AZ, OFF when AZ is used	NA, Leave in ON position
S3	Setting of OFF will force analog outputs 1 and 2 to 20 ma which can be adjusted with P1 and P2	Same as AW
S4	Display amplification and LED-current when set to OFF.	Same as AW
S5	IF switch is OFF and digital input 1 closed before power is applied, turning on power will cause default data to be written from EPROM to RAM. Display will show “System Status”. After 10 seconds turn off power and switch 5 ON. Only used when changing software versions in AW.	NA, Leave in ON position

(Table 6.4) D-R 290 AW and AZ processor board switch functions

Since the hardware of the **D-R 290 AW** and the **D-R 290 AZ** is identical, it is possible to change the software and make one unit function as the other. This may be useful during trouble shooting or it may be convenient to turn a **D-R 290 AZ** in a wall mount housing (possibly a spare) into a **D-R 290 AW** (operation without AZ) to perform a clear path of the opacity monitor. When using the electronic insert as an AW or AZ, it is important to remember to get the switches in the correct position, connect the RS 422 wires or jumpers (see electrical installation), and if you are changing software versions in an AW or changing an AZ to an AW, load the software constants from the EPROM as described above.

6.2 Operation of the D-R 290 AZ Stack Display Unit

The operation of the **D-R 290 AZ** is nearly the same as the **D-R 290 AW**. The most important difference is that no parameters can be modified from the **D-R 290 AZ**, it is display only. However the phases of the calibration (zero check, window check, span check, and stack correction factor) can still be initiated. The relay outputs and digital inputs are also different and this can be seen in section 5.3.1.

6.3 Reflector Operation

The following reflectors can be used with the **D-R 290** opacity monitor:

Type	Flange to flange stack distance	Model
Reflector 2	Between 5.75 and 45 feet (1.75–14.00 m)	Glass corner cube with optics
Reflector 1	Between 1 and 7.5 feet (0.5–2.25 m)	Scotchlite

The reflector should be selected according to the opacity flange-to-flange distance. If the stack diameter is 3 feet, then have 2 foot long, 4" ANSI flanges on each side of the stack, then have 6" long adapter flanges to adapt from the ANSI to the opacity monitor, the flange to flange distance will be 8 feet even though the stack diameter is only 3 feet. This example would then require a type 2 reflector.

Since the reflector is passive the only action required is an occasional cleaning. When the window check indicates the transceiver optics require cleaning, the measuring reflector should be cleaned as well. Keeping a good purge air is also important in keeping the reflector and transceiver optics clean. The type 1 reflector is a Scotchlite material that can be damaged by high temperatures that could be encountered when the purge air fails.

6.4 Transceiver Operation

6.4.1 Maintenance

The D-R 290 MK opacity monitor transceiver requires little attention during normal operation. Periodically, when indicated by the window check results during the daily calibration, it may be necessary to clean the window and the zero point reflector with a soft cloth. Sometimes it may be helpful to use water, alcohol, or glass cleaner to clean the optics. Be careful if a cleaning solution of some type is used that it does not leave a film (this could adsorb light) and it does not have any abrasives that could scratch the optics. In most cases a clean, dry, soft cotton cloth will work fine.

The time between maintenance will vary based on the conditions at the installation. The stack conditions as well as the ambient conditions will determine the maintenance frequency. In general, a check of the equipment should be made every month. This includes a check of the fail-safe shutter system, if applicable.

A maintenance routine should include the following steps:

1. Clean the external parts of the unit.

2. Check the condition of the fail-safe shutters.

3. Check all seals and mounting hardware.

4. Check the purge air system and the air hose.

5. Check the filters: Although it may be possible to clean the air filter, it is usually better just to replace. The replacement elements are inexpensive and with cleaning there is always the risk of tearing the filter. The maintenance interval will depend on the dust loading in the ambient air. **NOTE: Keeping a good flow of purge air is the single most important step for the longevity of the opacity system.**

6. Cleaning the external optics: After opening the clasps on the housing, the transceiver and reflector can be swung open. Use a clean optics cloth to clean the transceiver window, zero point reflector, and the measuring reflector.

7. Any deposits or build-up in the mounting flanges should be removed. Dirt on the fail-safe shutter can be removed with a brush or cloth and a cleaning solution that dries without leaving a residue. Never use a solution that damages aluminum.

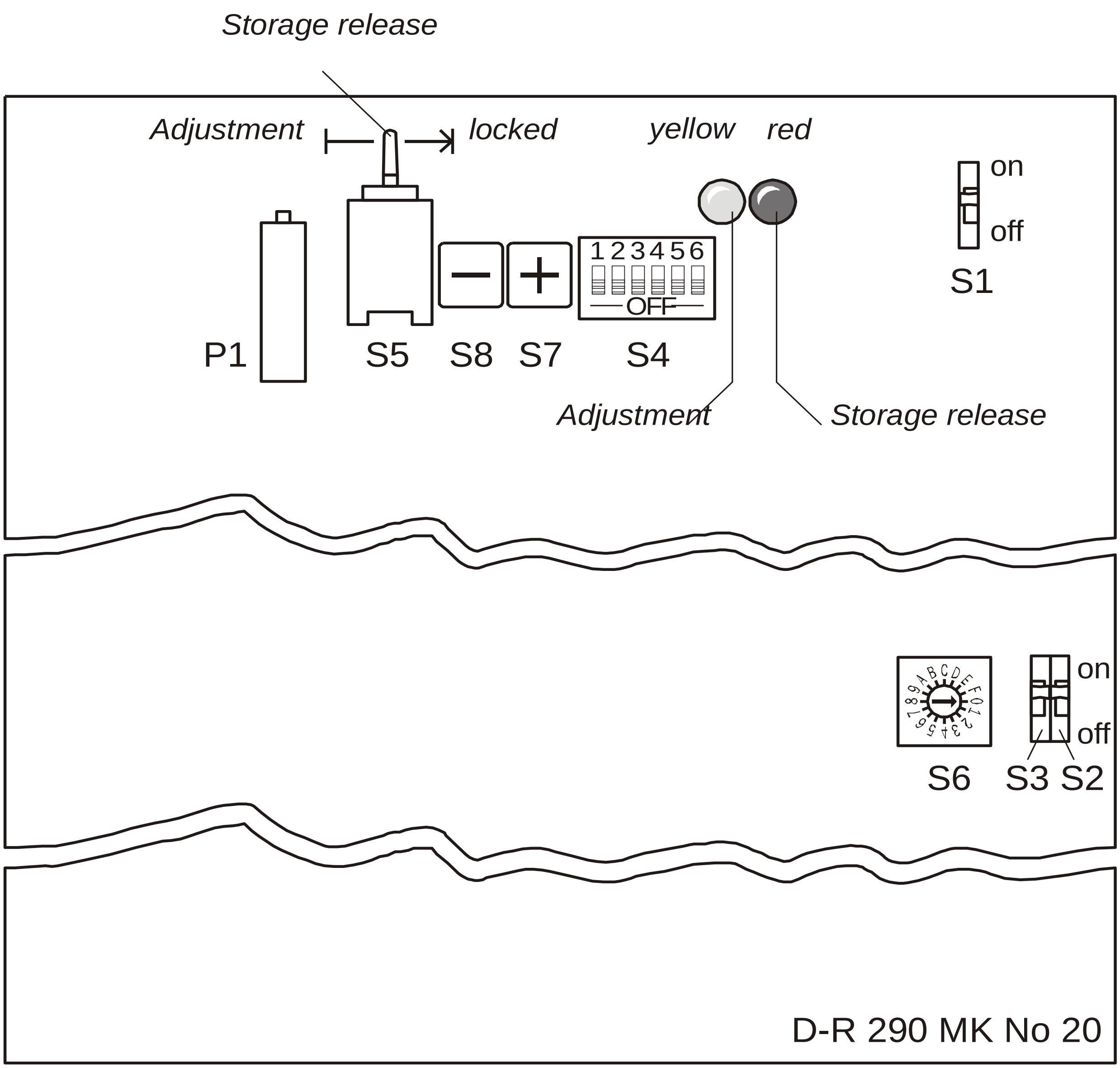
Warning!

Do not insert fingers into the fail-safe shutter system.
Serious injury may result!

6.4.2 Transceiver Circuit Board

There is only one circuit board, the **D-R 290 MKLP20**, in the transceiver. Values that affect the measurement of transmission and in turn opacity are stored on this circuit board. The **D-R 290 AZ** stack display or the **D-R 290 AW** evaluation unit can be replaced without changing the opacity measurement (as long as the stack correction factor in the **D-R 290 AW** remains the same).

The opacity system is normally adjusted at the factory for a specific installation. It should not be necessary to adjust the system. However, it may occur that the stack dimensions given to Durag, inc. came from stack drawings or were not correct for some other reason. Another reason the system may need to be adjusted is if the monitor is relocated. To adjust the opacity transceiver the switches on this main circuit board to be changed. The location of these switches is shown in the diagram below. **NOTE:** Make sure there is a valid reason before performing any adjustment. For example if a clear path procedure is run on the stack with opacity in the stack, the system has been “re-zeroed” and the opacity reading from the system will be wrong.



(Fig. 6.5) Transceiver switch functions

6.4.2.1 Transceiver Switch Functions

When using these switches, pay special attention to the switch position. Due to the microprocessor logic, sometimes the switch function is activated by turning the switch off. Some of the switches have a default position of on and some off. This manual will try to use up and down arrows (↑ or ↓) whenever possible to show the position of the switch.

Switch S1

This is for the watchdog timer function for the processor. The default position of this switch of this switch is off ↓ (in the down position) which will turn the watchdog timer on. This switch should be in the down position and not be moved.

Switch S2

This switch allows (in combination with S3 and S5) for special adjustment procedures such a clear path adjustment and LED current setting. This switch can also be used with S6 to access special test routines. How to use these switches is described in the appropriate section (clear path adjustment, window check adjustment, etc.). The normal position of this switch is ↓ (off).

Switch S3

This switch allows (in combination with S2 and S5) for special adjustment procedures such a clear path adjustment and LED current setting. This switch can also be used with S4 to adjust individual measurements such as the window contamination reading or the stack opacity zero. The normal position of this switch is ↓ (off).

DIL- Switch S4

S4 is actually 6 individual switches that are numbered 1 through 6. In an adjustment procedure you may see one of these switches referred to as S4/1. This means switch 1 of the S4 block of switches. This switch is enabled by S3. The default position for all 6 of these switches is the ↑ up or on position. To activate the feature associated with the individual switch, the switch will be slid down ↓ to the off position. Only 1 of these switches will be in the down ↓ position at any time. Use these switches with caution since the accuracy of the monitor may be changed.

S4/	Function
1	Slope in measurement mode
2	Slope in filter audit mode
3	Slope in span check
4	Offset in internal zero point (window check)
5	Offset in external zero point (measurement)
6	Basic calibration (reference light path gain setting and in turn LED current is set. **Warning: This will destroy all stored transceiver parameters.**

Switch S5

This is the blue toggle switch near the top of the circuit board. This is a 3-position switch back and center positions being fixed and the forward position is momentary. In the back position the system can't write any parameters to memory. This is the default position. The red LED will be off. In the center position data can be written to memory and saved. The red LED will be on. Moving the switch forward to the momentary position will start an automatic adjustment procedure that is determined by the position of switches S1 through S4. The yellow LED will blink.

Switch S6

This is a 16 position rotary switch that is only used for special test functions. The function of this switch is described in the service manual and will not be discussed further.

Switch S7 and S8

These are momentary push button switches used in conjunction with S4. S7 when depressed has the + (plus) function and is located next to S4. S8 has the – (minus) function and is located next to S5. In certain adjustment procedures, the **D-R 290 AZ** or **AW** display will show the plus and minus symbols. S7 or S8 will then be pressed to raise or lower the selected value.

6.4.3 Clear Path Procedure

In this procedure the measuring zero is set. The transceiver and reflector are mounted to the exact distance as on the stack or duct in a clean room with minimum dust in the air such as an air-conditioned office. This procedure then adjusts the monitor so that a zero percent opacity reading is obtained.

This procedure was done in the factory and normally will not be done in the field. Some examples of when this procedure would need to done in the field are: The flange to flange distance on the stack is not the same as was supplied to **DURAG**, the system is being relocated to a new measuring location with a different flange to flange distance, the measuring reflector was damaged by improper cleaning so the system needs to be re-zeroed, the **D-R 290MKLP20** circuit board was replaced.

The values determined during the clear path procedure are stored in the transceiver. It may be convenient to leave the **D-R 290 AW** (and **D-R 290 AZ** if used) in their respective housings and use a spare **D-R 290 AW** (or **D-R 290 AZ with AW** software installed) mounted in a **D-R 290 AG** housing. This way all the existing wiring can stay in place.

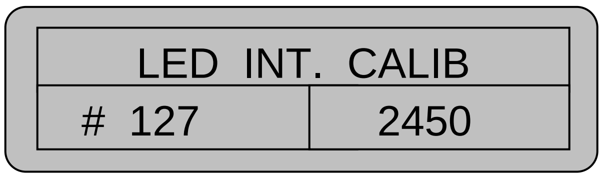
The display during adjustment

Segments 1 + 2: Current calibration function

Segment 3: Amplification factor

Segment 4: LED - Current

<u>**Line 1**</u> ***Segment 1*** ***Segment 2***



<u>**Line 2**</u> ***Segment 3*** ***Segment 4***

The clear path procedure should be run in the following order:

1. Set up the transceiver and reflector in a dust-free room to the exact optical path length as on the stack or duct. Make sure the test stands or flanges put the transceiver and the reflector in proper alignment. Make sure to include the appropriate allowances for the spring washers and fail-safe shutters if applicable. Clean the optical surfaces (transceiver window, zero reflector, and measuring reflector) with a soft, optics-safe cloth.
2. Open the four hasps on the transceiver and swing the housing open. With a 4 mm allen wrench, remove the six screws that secure the cover and remove it from the transceiver. Be careful not to drop the cover on the circuitry when removing the last screw. Swing the transceiver shut and latch the hasps. Supply power (connect plug “St1”) to the transceiver and the D-R 290 AW controller (and D-R 290 AZ if applicable). Once turned on, the D-R 290 will run a self-check cycle and check the value of the comparison light beam. The LCD display will read: **REF. LIGHT CHECK** on line 1. Once the automatic self-check has been completed and LED intensity has been set, the system can be calibrated (the yellow LED will go out).
3. Put switches **S2** and **S3** in the up, “**ON** ↑ “ position, Display line 1: **ZERO EXT. CALIB** .
4. Optically align the transceiver and reflector. (see section 5.4.1) It may be necessary to focus the transceiver if this system uses a reflector 1 and the path length was changed.
5. Return switches **S2** and **S3** to the lower, “OFF ↓” position, the push toggle switch **S5** towards the front of the monitor for 2 seconds. Switch **S5** can then be allowed to return to the center position. At this point the yellow LED should continue blinking and the red LED should be continuously lit. The lower line of the display (on the AW controller) should be working.
6. Display line 1: **LED INT. CALIB** the comparison light beam is calibrated. The LED current is fixed and the gain setting is determined to give a pre-determined output (8 volt at TP3).
7. Display line 1: **ZERO POINT CALIB** the internal zero point value is calibrated to determine the gain for the zero point reflector.
8. Display line 1: **SPAN CALIB** The reference light path is calibrated.
9. Display line 1: **ZERO EXT. CALIB** the external zero point value is calibrated.
10. After the clear path calibration procedure, the system automatically perform a calibration cycle. To allow these new clear path values to be saved, switch **S5** must be pushed back (the red LED will go out).
11. Loosen the 4 hasps on the transceiver head, swing open the transceiver, and replace the lid to the housing, making sure to secure all six screws. The transceiver head can then be closed and the hasps fastened again.

6.4.4 Manual internal zero point (Window Check)

Normally the window check reading should not need to be electrically adjusted. If the window check reading increases it indicates there is dust or contamination on the window or zero point reflector. Cleaning these surfaces should return the window check reading to near zero percent opacity (4.0 ma). At some time it may be necessary to adjust the window check reading back to zero. It is possible that over time the window or zero point reflector may have been scratched or damaged from improper cleaning or contamination on internal optics that is not possible to clean.

1. Clean the optical surfaces of the transceiver, the window and the zero point reflector, with a cloth designed for optics that does not leave any residue. Using the "MOD" and "+" keys on the control panel, select the "window check" measurement.
2. Remove the cover of the D-R 290 MK transceiver housing. On the circuit board, push switch **S4/4** on the 6-terminal switch **S4** to the OFF↓ position. Put switch **S3** (calibration function) to the ON↑ position. Toggle switch **S5** must be set to "free memory access" (the center position), so that the red LED lights. The first line of the display should alternate between "OFFSET - +" and "WINDOW CHECK".
3. Press push button **S8** [-] for a lower value and button **S7** [+] to increase the value to adjust the internal zero to 4.0 mA. Keep in mind that this new value will not take effect until after the 5-second integration time. Therefore, use the buttons briefly, and then wait at least 5 seconds before pressing a button again. The yellow LED should light when the buttons are being used.
4. At the end of the calibration, the switches should be returned to their normal positions. Switch **S5** should be set to OFF, which will turn off the red "data entry" LED. On the switch, **S4/4**, push **S4** to the ON↑ position. Switch **S3** should be put in the OFF↓ position. Place the housing lid back on the unit and tighten the screws.

6.4.5 External Zero Point Calibration

The external zero reading was also set at the factory to zero percent opacity and normally should not be adjusted. This procedure is basically one portion of the clear path procedure that was described above and can also be used to set the opacity reading to zero on a clear path. This procedure however will only affect the measured opacity reading and will not change the internal reference value or the window check reading. This procedure may need to be performed if the window or the measuring reflector is damaged.

1. Set-up the transceiver and the reflector in a dust free room (such as a clean office area) at the exact stack flange- to-flange distance and do the optical alignment. Clean the optics surfaces (window, zero reflector, and measuring reflector) carefully with a cloth designed for optical equipment. Check that the integration time is set to a short value (such as 5 seconds) or change if necessary on the D-R 290 AW control panel and return the system to normal measuring mode. The integration time is set to a small value to minimize the amount of time spent waiting for the adjustments to reach the final value.
2. Remove the cover for the electronics on the D-R 290 MK transceiver. On the circuit board, locate the 6-terminal switch **S4** and push the **S4/5** switch to the OFF↓ position and the calibration switch **S3** to the ON↑ position. Switch **S5** must be set to the "allow memory access" position (center position with the toggle lever straight up and down) so that the red LED lights. The first line of the display should alternate between "OFFSET - +" and "OUTPUT X".
3. Press button **S8** [-] for a lower value and button **S7** [+] to increase the value to adjust the external zero to 4.0 mA. Keep in mind that this new value will not take effect until after the 5-second integration time. Therefore, use the buttons briefly, and then wait at least 5 seconds before pressing a button again. The yellow LED should light when the buttons are being used.
4. At the end of the calibration, the switches should be returned to their normal positions. Switch **S5** should be set to OFF (back), which will turn off the red "enter value" LED. On the switch, **S4**, push **S4/5** to the ON↑ position. Switch **S3** should be put in the OFF↓ position. Place the housing lid back on the unit and tighten the screws. Reenter and save the old integration time on the D-R 290 AW control panel.

7. Error Messages

In the event of an error, the upper line of the LCD (segments 1 and 2) will alternately display an error message (as shown in the table) as well as the currently selected display. The LED on the STO key will also blink. After ten seconds, the associated relay contact will activate.

LCD-Display	ERROR	Probable Cause	R6	R5
ERROR 000	Communication error	1.Communication wires not connected correctly 2. RS 422 driver chip damaged (lightning) see schematics in service manual	**X**	**X**
ERROR 001	Window contamination exceeded	1. Window or zero reflector dirty – clean 2. Physical damage to window or zero reflector 3. Zero reflector loose or out of position		**X**
ERROR 002	External AW error 1	Input 1 has closed from external source- check connected device (DP Cell, switch)		**X**
ERROR 003	External AW error 2	Input 2 has closed from external source- check connected device (DP Cell, switch)		**X**
ERROR 004	EEPROM fault	Call DURAG for assistance		**X**
ERROR 005	RAM fault	Call DURAG for assistance	**X**	**X**
ERROR 006	PROM fault	Call DURAG for assistance	**X**	**X**
ERROR 007	AW system fault	Call DURAG for assistance	**X**	**X**
ERROR 010	Comparison normal error	Comparison signal out of specification-check Comparison normal reflector in transceiver		**X**
ERROR 020	External zero fault	System not able to determine valid gain setting for External zero during clear path-call DURAG		**X**
ERROR 030	Internal zero fault	System not able to determine valid gain setting for internal zero during clear path-call DURAG		**X**
ERROR 040	Stepper motor failure	Check zero reflector and filter wheel stepper motors And photo switch in transceiver for proper operation	**X**	**X**
ERROR 050	LED fault	1. Replace LED assembly 2. Check for dirty/damaged internal optics 3. Faulty photo-detector	**X**	**X**
ERROR 060	Heated exit window fault	Exit window heat trace or wires damaged		**X**
ERROR 070	MK system fault	Call DURAG for assistance	**X**	**X**
ERROR 100	AZ input 1 fault (Blower transceiver side)	1. Blower failure or loss of power 2. Faulty DP cell		**X**
ERROR 200	AZ input 2 fault (Filter transceiver side)	1. Air filter restricted-replace element 2. Faulty DP cell		**X**
ERROR 300	AZ input 3 fault (Blower reflector side)	1. Blower failure or loss of power 2. Faulty DP cell		**X**
ERROR 400	AZ input 4 fault (Filter reflector side)	1. Air filter restricted-replace element 2. Faulty DP cell		**X**
ERROR 500	AZ input 5 fault	1. Blower failure transceiver side when shutters used 2. Shutter failure transceiver side		**X**
ERROR 600	AZ input 6 fault	1. Blower failure reflector side when shutters used 2. Shutter failure reflector side		**X**
ERROR 700	AZ system fault	Call DURAG for assistance	**X**	**X**

(Table 7.1) Error messages

8. Purge air system

The purge air system protects the monitor from contamination on the external optical surfaces and keeps the unit from overheating. Typically a ½ HP centrifugal purge air blower is used on each side of the stack when the stack pressure is neutral or negative. When the stack pressure is 10 inches water column positive or more, a 1 HP blower is usually recommended.

When selecting the mounting location, the following conditions must be met:

- The air used should be as dry and dust-free as possible. In extremely dirty environments, it may be advisable to relocate the air intake or filter to a cleaner area.
- The air temperature should not exceed 104 F (40°C).
- There must be enough room to allow for changing the air filters.
- If the purge air unit will be mounted outdoors, a protective weather hood is available.

WARNING

The purge air system must be turned on at all times when the D-R 290 is mounted at the measuring location. This applies even when the D-R 290 itself has been turned off. Make sure the purge air unit electrical systems are secured separately from those of the D-R 290 itself.

9. D-SK 290 Fail-safe Shutters

If the **D-R 290** monitor is intended for use on an exhaust duct or smokestack, in which a high stack-pressure is present, a failure of the purge air system can lead to serious damage or destruction of the monitor. To protect the system in such an event, **D-SK 290** fail-safe shutters can be installed. The shutter system consists primarily of a motor-driven quick close shutter **D-SK 280** and the **D-SK AE** control electronics with the air current sensor F2.

Installation of fail-safe shutters offers effective protection against this type of damage. The **D-R 290** installation flange has long enough studs to allow the **D-SK 290** fail-safe shutter between the flange and the transceiver or reflector. These fail-safe shutters mechanically block the opening between the monitor and the exhaust gas in the event of a blower fail or loss of power. **Due to possible overheating, however, the D-R 290 should never be left on the stack without purge air for extended time periods.**

The control electronics, **D-SK AE**, is the same for all **DURAG** products. The shutter will vary depending upon the **DURAG** product it is used with and type of mounting flange. Since the **D-R 290** uses the same installation flange as the **D-R 280** and **D-R 281**, the shutter used will be the same as used with the **D-R 2**80. This is why the shutter for the **D-R 290** will have the number **D-SK 280 MA**.

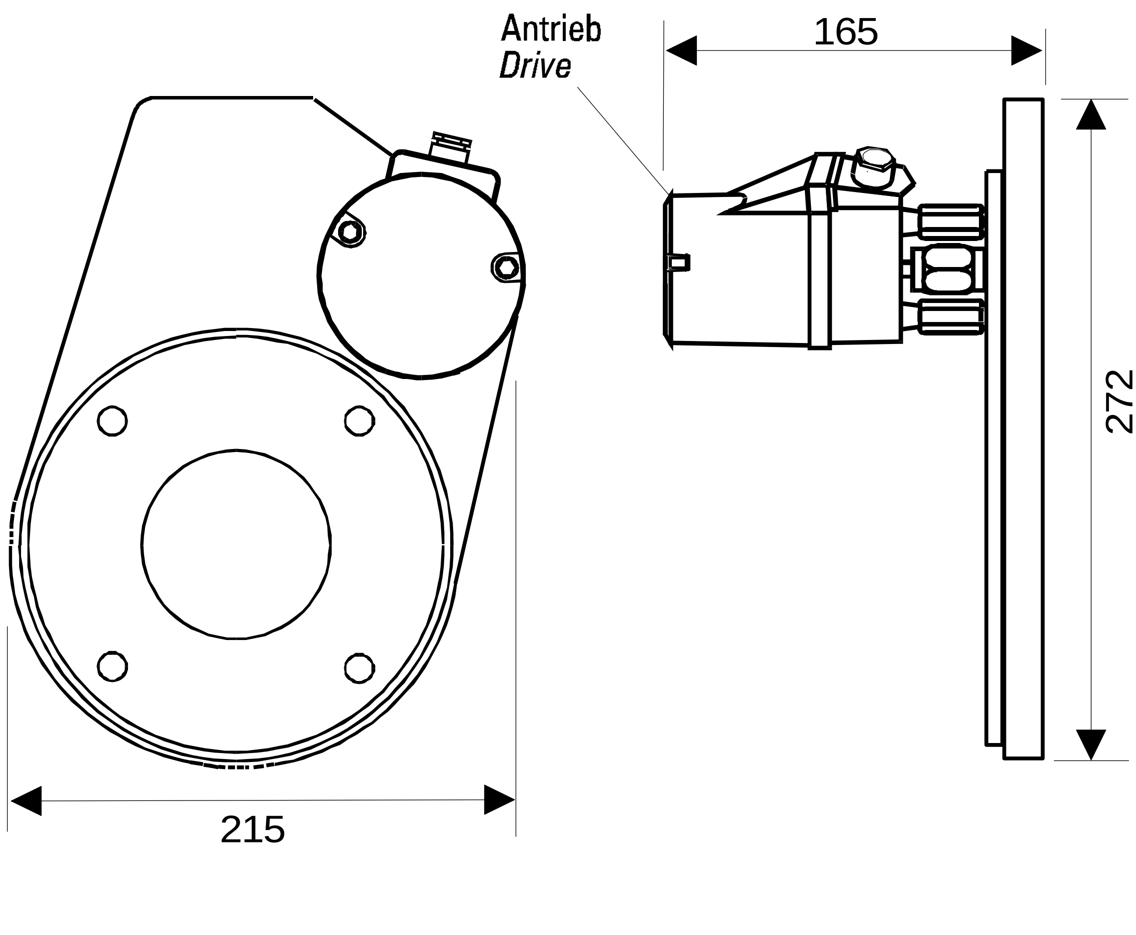
9.1. Function

After turning on the power supply and detecting purge air, the fail-safe shutter will automatically move to the "OPEN" position. If the power or the purge air blower fails, the shutter will close. For such an event, the **D-SK AE** electronics has a Ni-Cad battery pack to supply power to the shutter motor. After the problem has been corrected, the shutter will automatically open again. There are cams off the motor shaft that drive switches to give "shutter open" and "shutter closed" status signal. Terminals 7 and 8 in the **D-SK AE** will close when the shutter is open. Terminals 7 and 9 will be closed when the shutter is closed.

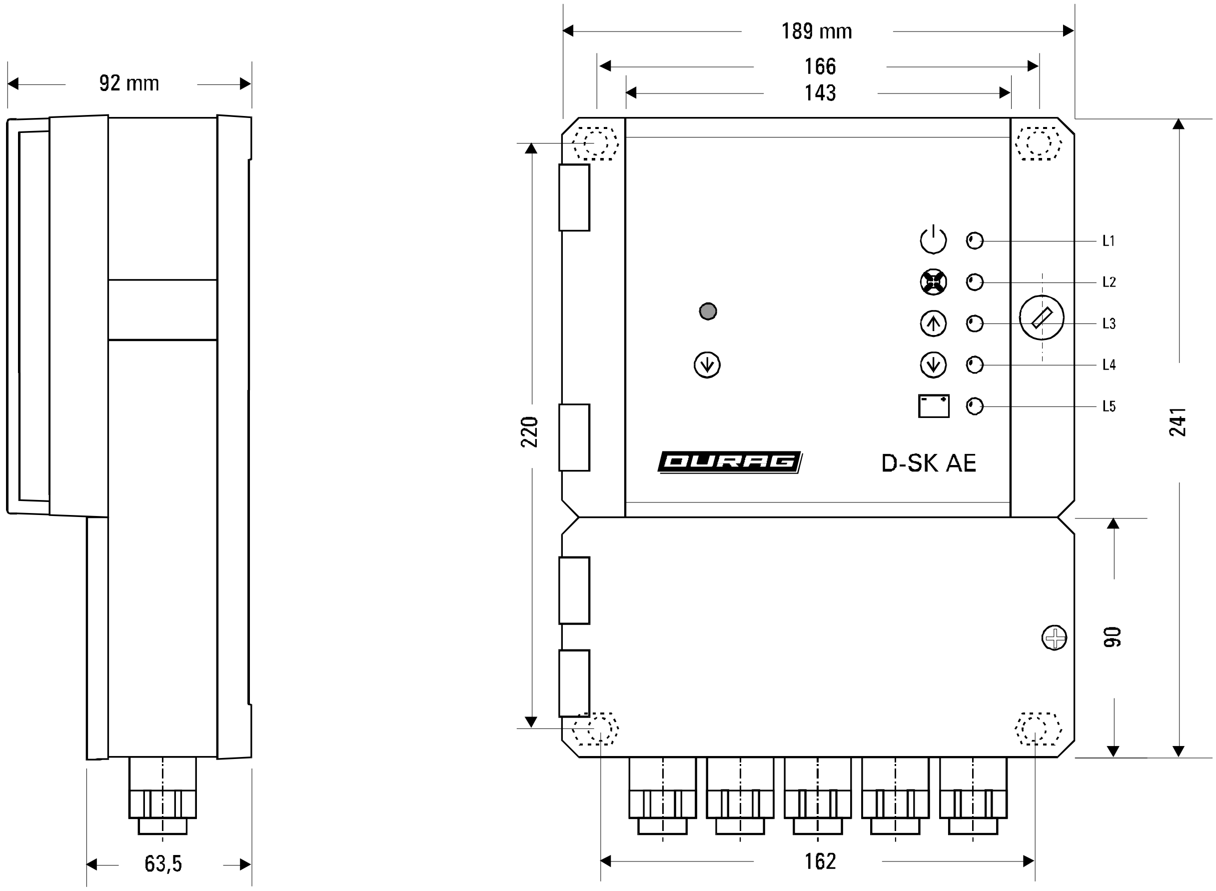
The battery charge is indicated by the **"battery charging LED"** on the front panel. The LED remains lit during rapid charging and blinks during a normal "float" charging. The fail-safe shutter can be manually closed by pressing the manual push-button (or flipping the toggle switch) on the front panel of the control electronics.

The **D-SK 290** fail-safe shutter can be tested using the input relays (terminals 16 and 17) for "close shutter". When the connection between terminals 16 and 17 is opened, the shutter will automatically close. The shutter closed message is transmitted over terminals 7 and 8 (closed contacts).

Schnellschlußklappe D-SK 280 MA
Fail Safe Shutter D-SK 280 MA



(Fig.9.1) Dimensions (in mm) of shutter (D-SK 280 MA)

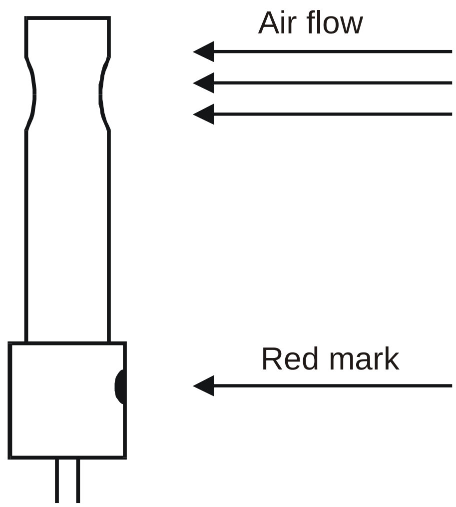


(Fig. 9.2) Dimensions (in mm) of control electronics D-SK AE

9.2. Installation

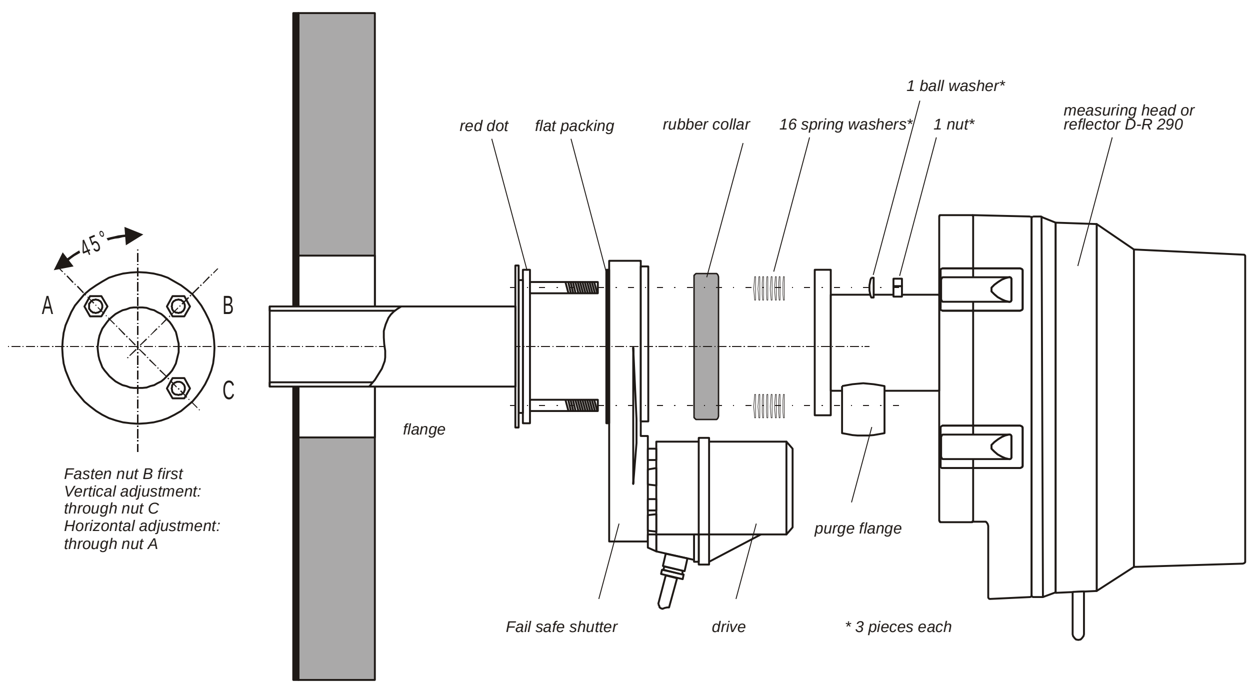
A D-SK 290 fail-safe shutter system is mounted on the transceiver and/or the reflector flanges, each with its own **D-SK AE** control electronics. The shutter can be mounted in any orientation so long as there is no interference with the weather hood or any obstructions near the installation flange. **The D-SK AE** control electronics are connected to the fail-safe shutter with a six-conductor cable. This connection should be made after the monitor has been mounted to make sure the shutter can't open or close while it is being installed.

The air current sensor (F2) should also be connected to the purge air flange and then to the **D-SK AE** controller. The F2 sensor is threaded into the purge air duct with the red dot pointing towards the airflow and secured with a lock nut. This sensor will detect a failure of the purge air system. The cable (six feet are provided at no charge, additional cable is available) that runs to the fail-safe shutter can be as long as 150 feet (the air flow sensor cable has 3 wires including the shielding).



The air current sensor should be mounted on the system after removing the cover (PG7). The sensor should be positioned at the monitor opening such that the air current flows directly through the hole in the sensor. The red mark is meant to aid in mounting and should face away from the monitor in the direction of the air current.

(Fig. 9.3) Air Flow Sensor

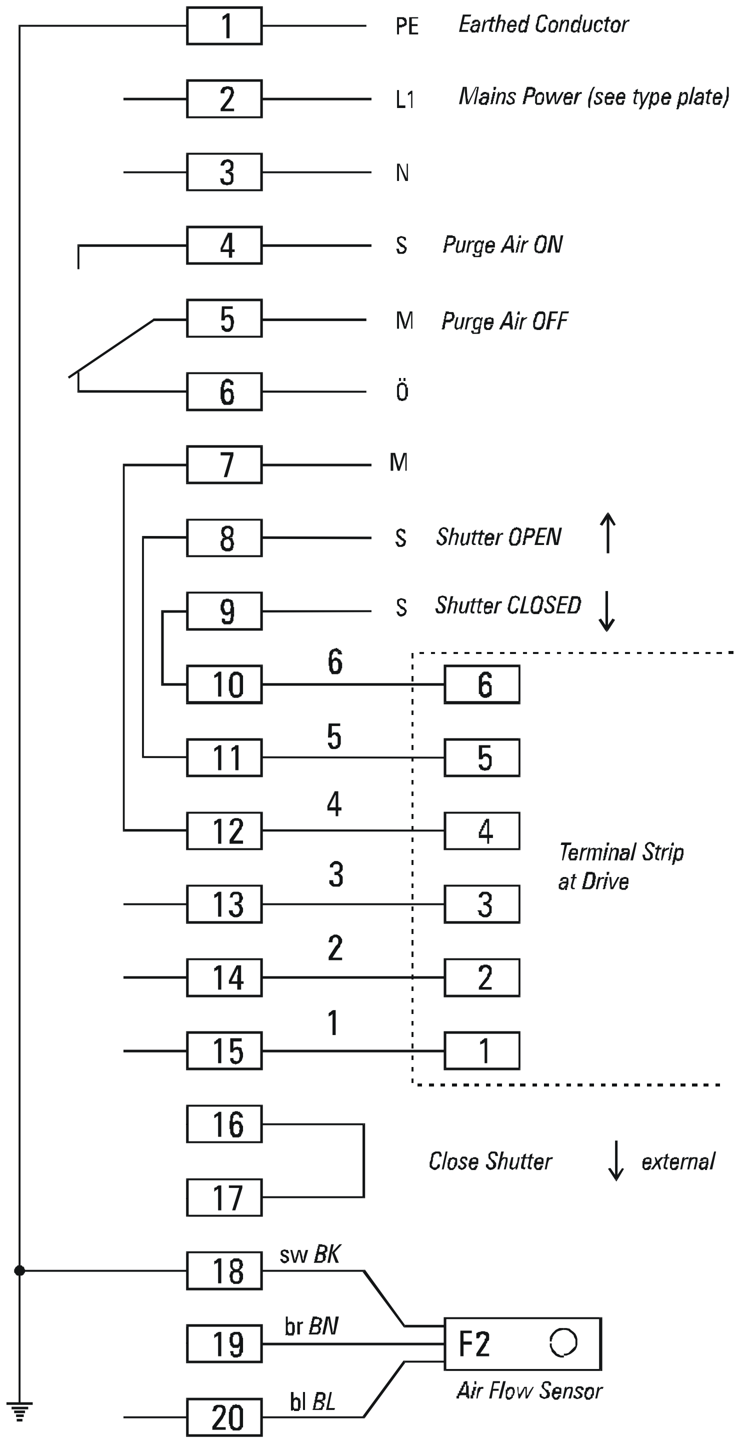


(Fig. 9.4) D-SK 290 Mounting

Warning!
Do not insert fingers into the fail-safe shutter system. Serious injury may result! Disconnect the unit by opening the connection at terminals 16 and 17 before conducting maintenance work on the D-SK AE.

9.3. Electrical Connection D-SK AE

The electrical connection to the fail-safe shutter uses a 20-pin terminal strip in the connection box of the **D-SK AE** as shown in the diagram below:



(Fig. 9.5) Electrical Connection for the D-SK AE

9.3.1 Automatic check of shutter operation

The purge air system is very reliable so the shutter should not have to close very often. This however can create another problem. If the shutter has been open for several years, the shutter could be dirty or corroded and may not close when required. To prevent this from occurring the **D-R 290** has been designed to allow for the check of the operation of shutter every day. To activate this feature, the display unit (either the **D-R 290 AZ** or **D-R 290** AW, whichever is connected to the transceiver) will need to have S1 and/or S2 as appropriate on the No. 40 board in the “ON” position. During the upscale calibration point check portion of the calibration cycle, relay output 3 (and 4 if there are 2 shutters installed) will close for approximately one minute. For the display unit to receive confirmation that the shutter(s) actually closed, the shutter electronics (**D-SK AE**) will provide a contact closure from terminals 7 and 9. This contact will be connected to digital input 5 for the first shutter and digital input 6 for the second shutter on the display unit.

Switch S1 In the “ON” position in the No. 40 board in the **D-R 290 AZ** (or **AW**), this switch activates relay output 3, and for the confirmation signal will be read by digital input 5 and will give the associated fault signal (ERROR 500).

Switch S2 In the “ON” position in the No. 40 board in the **D-R 290 AZ** (or **AW**), this switch activates relay output 4, and for the confirmation signal will be read by digital input 6 and will give the associated fault signal (ERROR 600).

During the reference point check, the **D-SK 290** fail-safe shutter is closed by the relay output (contact opens). If the confirmation signal (shutter CLOSED), is not sent within approximately 2.5 seconds, the first line of the LC display will alternate between the current SPAN CHECK display and the error message (ERROR 500 or 600), and the LED on the “STO” key will begin blinking. After a 10 second delay, the fault relay output will signal the error.

D-SK AE 1			**D-R 290 AZ display unit Connection block housing**	
Function	**Terminal**		**Terminal**	**Function**
Shutter status	**7**	**------->**	**36**	Input 5 ← Error 500 (1 D-SK)
(open or closed**)**	**9**	**------->**	**16**	⊥
Close or open	**16**	**<-------**	**29**	Relay 3 output switch
The shutter	**17**	**<-------**	**9**	For the fail-safe shutter #1 D-SK 290
D-SK AE 2				
Function	**Terminal**		**Terminal**	**Function**
Shutter status	**7**	**------->**	**35**	Input 6 ← Error 600 (2 D-SK)
(open or closed**)**	**9**	**------->**	**15**	⊥
Close or open	**16**	**<-------**	**28**	Relay 4 output switch
The shutter	**17**	**<-------**	**8**	For the fail-safe shutter #2 D-SK 290

(Fig. 9.6) Electrical connection between the D-R 290 AZ and the fail-safe shutter

9.4 Shutter Operation

When starting the system, the battery charge level should be checked. The battery charge will be indicated on the red "**battery charging LED**" (L5) on the front panel. The LED will remain lit by rapid charging and will blink during normal charging (indicating that the batteries are charged). When the batteries are strongly depleted, a slow normal charging will occur first (with the LED blinking). When the batteries have reached a minimal charge level, the rapid charging procedure will begin.

If necessary the batteries can be charged before the first system start-up. To do so, connect the D-SK AE controller to the power supply before connecting it to the fail-safe shutters. The shutter motor is driven from the NI-Cad battery pack. The shutter motor draws more power than the Ni-Cad charging circuit supplies. If the shutter controller has sat for a long time without power the batteries may be too low to power the shutter motor. If this occurs, remove the 6 wires going to the shutter motor from the D-SK AE terminal strip. Let the batteries charge for at leas 2 hours and then re-connect the 6 wires for the shutter motor.

Normally the shutters will function fine as delivered. However in cases where the stack pressure is negative (more air drawn through the purge air system) or when the stack pressure is high (less air through the purge air system), it may be required to adjust the point at where the shutter opens and closes. To set the potentiometers, open the latch on the right side of the housing with a screwdriver. The housing can then be opened and the 2 potentiometers should be visible.

The "airflow" potentiometers (P1) and the "hysteresis" potentiometer (P2) are set to a minimum (turn potentiometers clockwise).

Once power is supplied, the unit is ready for operation. The yellow "stand-by" LED (L1) and red "close shutter" LED (L4) light up.

If the purge air unit is running, the "air flow" potentiometer (P1) should slowly be turned counter-clockwise until the green "air flow" LED (L2) lights up. The adjustment is completed by turning the potentiometer half a turn counter-clockwise beyond this switching point. The green "open shutter" LED (L3) lights up and the shutter is automatically moved to the "OPEN" position.

The switch hysteresis is set using the "hysteresis" potentiometer (P2) such that erratic switching is avoided, but without making the switch hysteresis too great.

After settings have been made the housing is closed and latched. The proper function of the fail-safe shutters may be checked by briefly shutting off the purge air supply or detaching the purge air hose. A delay period for the closing of the shutter is necessary, since the air flow sensor will only detect an absence of purge air after a short time period.

10. Technical Specifications

10.1 Technical Specifications: D-R 290

Measuring range for a three foot (one meter) long measuring path: .... From 0-0.08 to 0-1.75 grains/ft^3 (0-200 mg/m³ to 0-4000mg/m³)

Light Source: .... Super Wide Band Diode (SWBD)

Measuring range
- **Extinction:** .... 0,1 - 1,6 Ext.
- **Opacity:** .... 0-20 to 0-100%
  Measuring ranges can be switched
- **Accuracy:** ………………………………………………... ± 2% Full Scale

Measurement Path Length: .... 3-46 ft (1 - 14m)
Output Signal: .... 2 x 0 - 20mA, Low scale value 4mA
Maximal Load: .... 500 Ohm
Relay Outputs: .... 6 x Status, potential free (limit value, error, control cycle, etc.)
Maximal Switch Capacity: 250V, 100VA
Inputs: .... 6x Status (Data entry enable, purge air error, 2x switch measurement range, control cycle)
Output Signal Integration Time: .... 5 - 1800s, each output independently set in 1 s - increments
Ambient Temperature: .... -40° to 122°F (-40°C to +50°C)
Stack Gas Temperature: Above the dew point
Enclosure Rating: .... NEMA 4x (IP65)
Weight
- **Transceiver:** .... Approx. 22 lbs (10 kg)
- Reflector: .... Approx. 15 lbs (7 kg)

Electrical Specifications:
Power Supply: .... 90 - 264V, 48 - 62Hz
Power: .... Approx. 30W

10.2 Technical Specifications for the Purge Air Blower

Supply Voltage:	115/230V, 50/60Hz,	Other voltages and frequencies available upon request
Power Consumption:	5.0/2.5 amps for ½ HP	
	8.6/4.3 amps for 1 HP	
Air Flow at 0 Backpressure:	56 cfm (1/2 HP), 98 cfm (1 HP)	
Weight:	27 lb (1/2 HP), 51 lb (1 HP)	

10.3 Technical Specifications for the D-SK AE Electronics

Power Supply: ....115 / 230 Volt ± 10% 48 / 62 Hz
Fuse: .... 0.1 A, slow blow
Power: .... Approx. 10 VA
Motor Driver:..24 Volt DC
Enclosure Rating:.. IP 65 DIN 40050 (NEMA 4X)
Weight: .... Approx. 7.75 lbs (3.5 kg)

Contacts:
1 contact shutter “closed“,
1 contact shutter “open“,
1 contact switch “ purge air “ present / failure

All contacts are potential-free, max. 250 Volt 100 VA switch capacity with resistive load.

Display messages:
5 Display-LEDs for the messages:
“ Stand by “,
“ Purge air present “,
“ Shutter open “,
“ Shutter closed “
“ Battery charge status “ –this LED is lit constantly when the batteries are charging rapidly and blinks during a normal slow charge.

Sensitivity:

Adjustable, minimum approximately 16.5 ft/s (5 m/s) air flow velocity

10.4 Technical Specifications for the D-SK 290 MA Mechanics

Driver:.. 24 Volt DC driver with built-in motor overload switch.
Torque:... 8 Nm
Run Time:.. Approx. 2 seconds from open to closed
Shutter:.. Stainless steel 1.4571
Housing: .... Aluminum
Enclosure Rating:.. NEMA 4x (IP 65) DIN 40050
Weight: .... Approx. 10 lbs (4.5 kg)