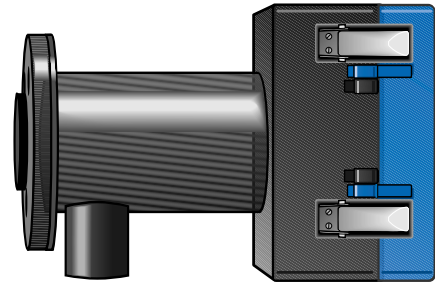
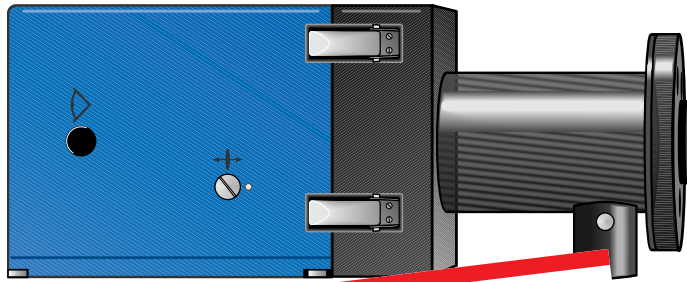




## The Visible Emission Monitor Opacity Meter and/or Dust Concentration Meter

# U.S.EPA Compliance



# TÜV approved



### D-R 281 AV Opacity/Dust Concentration Monitor with dual channel capability

The DURAG D-R 281 AV Visible Emission Monitoring System has been specifically designed to continuously detect both values, opacity and optical density levels of effluent particulate from industrial and commercial ducts or stacks.

#### ■ Features

- Digital operation with microprocessor
- Auto collimation principle
- Provides analog outputs for opacity and optical density and dual channel capability
- Automatic and manual zero and span calibration and correction for dirt accumulation on windows
- Meets all design requirements of U.S.EPA
- Double pass optical system for accuracy and sensitivity
- Modulated light beam to eliminate interference
- 5 selectable ranges for opacity
- 5 selectable ranges for optical density
- Automatic correction for stack exit diameter
- Lamp life greater than 20.000 hours
- Heated window to protect lenses and prevent condensation
- Remote electronics to help prevent component problems
- Large purge air blowers to overcome at least 15 inches H<sub>2</sub>O positive flue gas pressure, with large capacity automotive filter system
- Microprocessor-based remote digital display with multi-range capability

- Excess alarms with adjustable set points on remote control room lines
- Control room indicators for blower failure, filter blockage, excessive window dirt and alphanumeric readout of system faults
- Alarm/indication on remote panel of:
  - Blocked air purge filters
  - Blower motor overload
  - Excessive dirty windows, >3%
  - Alpha numeric code/alarm of internal and operational faults
- Viewing lens and focussing adjustment for precise alignment
- Rugged 'O' ring sealed housings for transmissometer and reflector
- Safety shutters available for high temperature and harmful effluents

### Particle Measurement Technology in Flue Gases

# D-R 281 AV

## Overview

The D-R 281 AV Visible Emission Monitor, based upon an 8 bit microprocessor (8039) provides the following main features:

### Ten selectable measuring ranges:

- **five in opacity % (O)**

range 1	0-20% O.
range 2	0-40% O.
range 3	0-80% O.
range 4	0-100% O.
range 5	0-100% O.
- Automatically corrected for stack exit conditions
- **five in optical density (O.D.)**

range 1	0-0.1 O.D.
range 2	0-0.2 O.D.
range 3	0-0.4 O.D.
range 4	0-0.8 O.D.
range 5	0-1.6 O.D.

### Large alphanumeric display area for:

- **the display of opacity % optical density mA**
  - 3 digits, or
  - 4 digits, or
  - 3 digits
- **the display of measuring range:** % O or O.D., five ranges each
- alarm set points:** LV1, LV2 direct, in %. LV1, LV2 integrated, in %
- integration time:** 1 to 10 minutes, in minutes
- calibration interval:** 1 to 24 hours, in hours
- **display of faults:**
  - 1) **system faults or faulty settings:** alphanumeric: E.01 to E.06
  - 2) **purge air faults:** LEDs and alarm indicator

### Models

- **D-R 281 AV-21/-31 Single Channel** unit, with two linear 0-20 mA current outputs
- **output 1:** direct (instantaneous), response time 1-10 sec, in 1 sec steps
- **output 2:** integrated, 1-10 minutes, in 1 min steps
- **D-R 281 AV-22/-32 two Channel** unit, with, in addition to the above outputs, a second set of two linear 0-20 mA current outputs as described above. The outputs for Channel 2 can be set on a range different to the one for Channel 1. It is therefore possible to monitor simultaneously in opacity % and optical density.

### Over limit alarms:

- Four alarm set points are available as follows:
 

L.V.1	direct values 0 - 100 %
L.V.2	(adjustable in 1 % steps)
L.V.1	integr. value 0 - 100 %
L.V.2	(adjustable in 1 % steps)

### Automatic zero and span check

- Automatic zero check and correction, span check and window contamination check settable at intervals of 1, 2, 3, 4, 5, 6, 7, 8, 12 and 24 hours

### Calibration

- Every calibration for the instrument to measure dust concentration in mg/m<sup>3</sup> should be done regarding VDI 2066 (Part 4, January 1989)

### Sensitivity and Maximum Value

- Sensitivity (System Detection Limit SDL) and Maximum Value (System Maximum Value SMV) of measurement system are depending on measuring distance (MD - flange to flange) and on mean particle diameter. Device Detection Limit (DDL) is approx. 10 mg/m<sup>3</sup> per meter measuring distance (flange to flange). Device Detection Limit corresponds to 3% of the measured range. Device Maximum Value (DMV) is approx. 5.000 mg/m<sup>3</sup> per meter Measuring Distance (MD - flange to flange). System Detection Limit (SDL) and System Maximum Value (SMV) can be calculated as follows:

$$\text{System Detection Limit } SDL = \frac{DDL}{MD}$$

$$\text{System Maximum Value } SMV = \frac{DMV}{MD}$$

### Wet Stacks and Humidity of Gases

- Beware of water vapour in the stack gas. Water vapour will be recognized as particles. Therefore, it is a minimum requirement to measure in gases with a minimum temperature over the dew point.

#### Remark

The setting of the measuring range, over limit values, response and integration times is performed internally in the Remote Panel/Signal Processor to prevent tampering or accidental off-setting.

## General Description

You can use the instrumentation to control combustion processes, monitor the performance of emission control equipment and indicate compliance with state emission standards.

All system components are mounted on the stack or duct in the field area except the remote control panel which can be conveniently located in a control room at ground level. The heart of the optical system is the measuring head. This instrumentation package includes the measuring head assemblies, a terminal box, and the remote control panel.

The measuring head assemblies consist of a measuring head unit mounted on one side of the stack and a light beam reflector on the other. The measuring head housing contains a light source and all optical, electronic and mechanical components to sense light attenuation and to produce outputs of both measured and reference signals.

The reflector housing contains the passive element of the system, a light beam reflector of either the Scotch Lite or glass comercube type depending upon the measurement distance involved.

To prevent solid particulate matter or condensate from depositing on the reflector and the interface window of the measuring head both units are purged with clean dry air. Each flange requires 1.1 m<sup>3</sup> / minute of clean air. Both housings are very rugged and sealed to withstand severe industrial environments.

The measuring head and the reflector are bolted to the stack mounting flange assemblies which are positioned on a common axis at opposite sides of the duct or stack. By unbuckling it to clasps on each side of the measuring head, you can swing it to the side on the hinge which connects the measuring head mounting flange assembly to the unit. This gives you access to the protective window for inspection and cleaning.

You can also swing the back door of the reflector to the side on a hinge by unbuckling two clasps on each side of the unit. This enables you to clean the reflecting surface which is mounted on the door.

An air purge system, consisting of an air blower with filter and precleaner, is installed on each mounting plate.

Interconnecting hoses provide clean purging air to stack openings on both the measuring head and reflector. Air flow sensors monitor the air purge system operation. The system indicates when there is an overload, but it does not turn off the blower motors.

## Remote Signal Processor

In addition to the stack-mounted components, the D-R 281 AV features the remote control panel. This microprocessor-based electronic instrument is designed to be located remotely from the stack or duct installation. It has operating controls, indicators and a three digit display meter for all operational functions of the emission system. From the front panel of the instrument you can select ten ranges, each corresponding to 4 - 20 mA indication on the digital display or recorder. The first 5 ranges provide readout in opacity % values as follows:

**Opacity (5 Ranges)**

Range 1 = 0 - 20 %	}	Automatically corrected for stack exit conditions
Range 2 = 0 - 40 %		
Range 3 = 0 - 80 %		
Range 4 = 0 - 100 %		
Range 5 = 0 - 100 %		Uncorrected - used only for testing

The second 5 ranges provide readout in optical density (extinction) values as follows:

**Optical Density (Dust Concentration, 5 Ranges)**

Range 1 = 0 - 0.1

Range 2 = 0 - 0.2

Range 3 = 0 - 0.4

Range 4 = 0 - 0.8

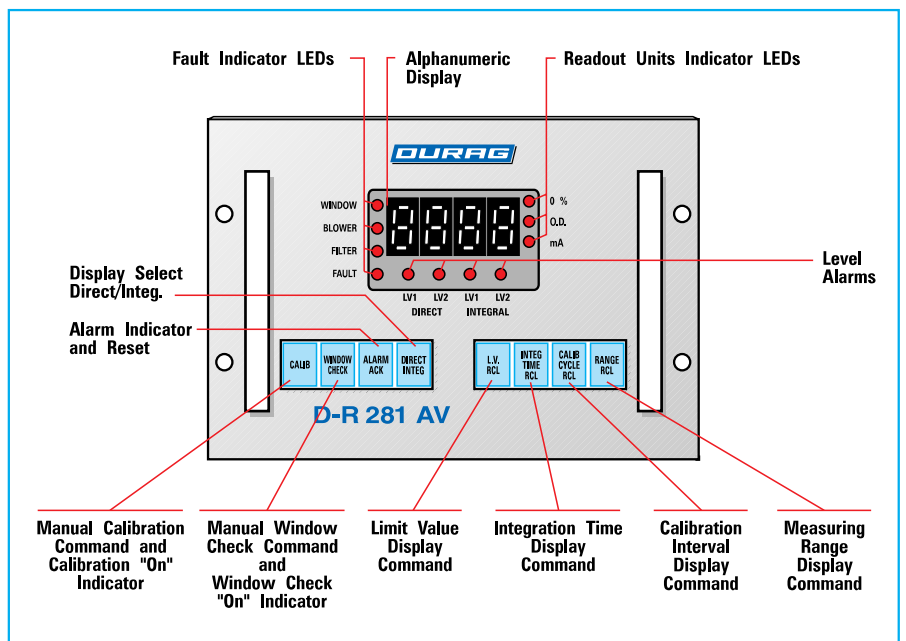
Range 5 = 0 - 1.6

You can also select an integrated readout for all of the ten ranges.

The remote control panel contains circuitry for automatic zero and span calibration and window soiling correction at selected hourly intervals. You can also manually initiate these functions from the instrument's front panel. The set point alarm adjustments for both direct and integrated opacity or optical density measurements are provided. In addition, the front panel includes alarm lamp indicators for over range signals, blower failure, filter blockage and excessive window contamination.

There is an output connector on the rear of the remote control panel for external wiring to recording equipment and alarm devices. The unit features plug-in PC cards, quick disconnects for all wiring, and front-panel handles for easy removal from rack or panel mounting.

Front view of the D-R 281 AV Remote Control Panel



## ■ The Measuring Head

The measuring head (transmitter and receiver) is the heart of the system. This rugged unit projects the light from a single source lamp (lamp life exceeds 20,000 hours). The light is modulated to 1.2 KHz, making it insensitive to sunlight or other outside light sources. The light is passed through a 50% mirror, developing a reference beam and a measurement beam. The measurement beam is projected through a heated window (treated to prevent condensation) to the reflector and returned to the optical head, where the single photo cell compares the reference beam to the measurement beam.

The head incorporates automatic zero and span compensation by periodically interrupting the measurement beam with an internal reflector to represent zero opacity, and also with a neutral density filter to reproduce a known upscale or span signal. During this period, the dirt accumulation on the window is measured. The zero and span signals are automatically adjusted to compensate for dirt accumulation.

All electronic components incorporate microprocessor design for long-term, trouble-free reliability.

## ■ Reflector

The reflector is a passive corner cube type reflector mirror. Reflector models are optimized for path lengths 450 - 15,000 mm flange-face to flange-face.

## ■ Remote Control Panel

The microprocessor display/control panel can be located in the plant control room or at any other remote location.

This unit provides a digital display for up to 10 selected ranges (5 for opacity and 5 for optical density), corrected for stack exit conditions and uncorrected for path light measurement. This readout may be integrated over a range of time periods.

The processor contains circuitry for automatic zero and span calibration and window soiling correction at selected intervals. These functions can also be manually initiated from the instrument's front panel. Set point alarm adjustments for both direct and integrated opacity or optical density measurements are provided inside the instrument. The front panel also includes an alarm lamp and LED indicators for over range signals, blower failure, filter blockage and excessive window contamination, and alphanumeric readout of system faults.

One or two output connectors are

provided on the rear panel of the signal processor for external wiring to recording equipment and alarm devices. The unit features plug-in printed circuit cards, quick disconnects for all wiring, and front panel handles for easy removal from a rack or panel mounting.

The distance between the measuring head and the remote control panel can be greater than 1,000 m.

## ■ Terminal Box

The terminal box is located on the stack or duct adjacent to the optical head, and serves as a junction box for interconnection cables between the optical head and the remote control panel.

In addition, the terminal box provides a stack display of opacity, a manual calibration initiation switch, and a window "dirty display" switch.

## ■ Purge Air Blower System

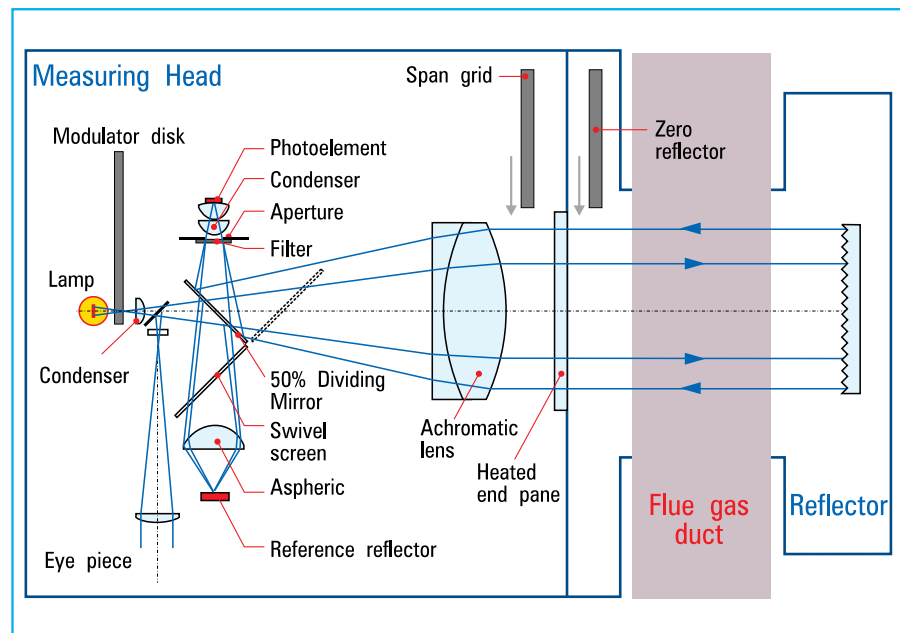
The windows of the optical head and reflector units are kept clean month after month through a purge air blower system (75 standard cubic feet per minute at 60 inches of water pressure, single or plural purge). This system blows clean outside air in front of the window to keep flue dust and heat away from the windows and out of the mounting pipes.

The incoming air is filtered by means of economic automotive filters. In most applications, the filter need only be changed once every three or more months.

## Optional Accessories

- 2 Weather protection hoods for measuring head and reflector
- 2 Weather protection hoods for the purge air fan. The weather protection hoods are not necessary when the instrument is mounted in a protected area.
- Fail safe shutters for measuring head and reflector for pressurized plants, with proximity-type limit switches, air flow sensors for purge air control, switching units for protection system control.
- Connection facility for emission evaluators, e.g. DURAG D-MS 285. The necessary status signals are available. Equipment delivered comes accompanied by extensive documentation on mounting and installation.
- For alignment of the welding pipes an optical sighting device is available
- On request, we delegate our technicians for instrument initiation and optical/electrical adjustment, who, at the same time, can instruct your personnel on the functioning and maintenance of the unit

Optical Schematic D-R 281 AV



## Principles of Visible Emission Measurements

The D-R 281 AV uses the photo-electric dual beam principle where attenuation of a reflected light beam is registered electronically as the beam passes through dust particles in a stack or duct. A single light source is separated into a measuring beam and a reference beam. The measuring beam is projected across a stack or duct to a reflector unit which returns the beam back through the same optical path to the detector.

The reference beam passes through a preset optical path within the measuring head. Every two minutes, for a period of two seconds, the reference beam is directed to the photo diode and its intensity ( $I_0$ ) is stored in the microprocessor. The measured signal ( $I$ ) is then compared to the reference signal and the quotient  $I/I_0$  is calculated. This value is the measuring head's output to the remote control panel.

### ■ Basis of Measurement

Suspended particles in a gas will scatter (diffract), reflect, and absorb radiation, with the relative effects depending on the size, shape and nature of the particles and the wavelength of the incident radiation. Their relative effects on the ability of light to traverse such an aerosol is a very complex problem. Due to the irregular shape and variation in the composition of particles, an analytical approach in the sense of calculation or experimentation does not lend itself to an exact description of the phenomenon.

However, it is possible to generalize and establish specific empirical relationships that allow the measurement of dust loading from ducts or stack plumes.

For very small particles (much smaller than the wavelength of the light employed, there is little scattering of light and attenuations primarily in the form of absorption. For particles the same or larger than the light wavelength, scattering of light is the predominant form of attenuation of light energy. Most industrial suspensions consist of particles in a range of 0.1 micron to as much as 50 microns.

The optical system of the D-R 281 AV responds to wavelengths in the visible range or between 400 and 700 nanometers, with a maximum between 500 and 600 nanometers. This short wavelength minimizes the dependency of light attenuation on particular size, although it is not possible to completely eliminate the effect.

### ■ Opacity Measurement

In passing through a finite thickness of matter, the light beam suffers a general attenuation which is termed "body absorption".

This phenomenon is graphically portrayed in the figure below. In traversing the chamber portions of the light energy are reflected, refracted, scattered, and absorbed. Similar effects for the optical windows between the atmosphere and the gas are not included in this consideration because they are constant. The attenuated light beam ( $I$ ) emerges at the second interface.

The light attenuation is expressed as transmission ( $T$ ) in the following formula:

$$(1) T = \frac{I}{I_0} \cdot 100\%$$

Transmission is related to opacity ( $O$ ) as follows:

$$(2) O = 100\% - T$$

The D-R 281 AV measuring head uses the above relationship to monitor the opacity of stack gases by the direct measurement of the attenuation of visible light caused by particulates in the effluent.

Some regulations are based on the opacity of the plume at the point of emission; therefore, an in-stack measurement must be corrected to the opacity for a path length equal to the stack exit diameter.

The correction made is in accordance with the following equation:

$$(3) I_g (1 - O_1) = \frac{I_1}{I_2} I_g (1 - O_2)$$

where

$O_2$  = opacity at stack exit\*

$O_1$  = opacity at measuring location

$I_1$  = diameter of stack exit

$I_2$  = optical path length at measuring location.

The light beam of the D-R 281 AV passes through the stack twice, and  $I_2$  is equal to twice the stack inside diameter at the measuring location.

### ■ Optical Density Measurement

The attenuation of the light beam through stack gases is also expressed in extinction or optical density ( $OD$ ) as defined by Lamberts law:

$$(4) I = I_0 \cdot e^{-k \cdot c \cdot l}$$

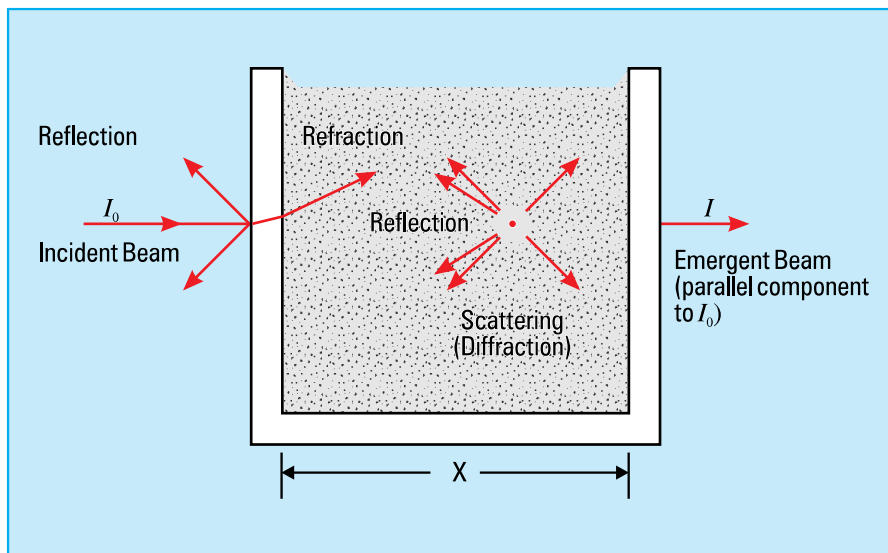
where

$l$  = measuring run length

$k$  = extinction constant

$c$  = particle concentration/  
dust concentration

\*Note: the instruments are normally delivered with a factor = 1 (S44, PC card no. 40) and therefore give straight opacity values at the measuring location for all the five opacity settings.



Smoke density or dust concentration measurements are carried out using a constant light intensity  $I$  and a fixed beam length  $l$ . The only variable left in the above equation (4) is the extinction constant  $k$ .

It has been shown that under certain conditions a linear relationship exists between the extinction constant  $k$  and the dust burden in  $\text{mg}/\text{m}^3$ . A host of parameters such as particle size, shape and nature and the wavelength of the incident light (all of which can be different for each installation) define the value of the extinction constant  $k$ .

Moreover, on boilers or dust generating operations, such as cement plants, the load (output) level of the system influences the size of the dust particles. Finally for "wet" stack conditions, the steam or condensation particles as well as the filter system's efficiency are an important influence. This is the reason why up to date dust concentration monitors are only calibrated in optical density ( $OD$ ).

By rearranging equation (4) the extinction constant  $k$  can be determined:

$$(5) \quad k = -\frac{I}{c \cdot l} \cdot \ln\left(\frac{I}{I_0}\right)$$

To obtain a linear reading for  $k$  and therefore for the optical density, the signal processor plots the value optical density  $OD$  or extinction

$$(6) \quad OD = \lg\left(\frac{I_0}{I}\right)$$

The dust concentration  $c$  can be written as

$$(7) \quad c = \frac{\ln(I_0)}{k \cdot l} \cdot OD$$

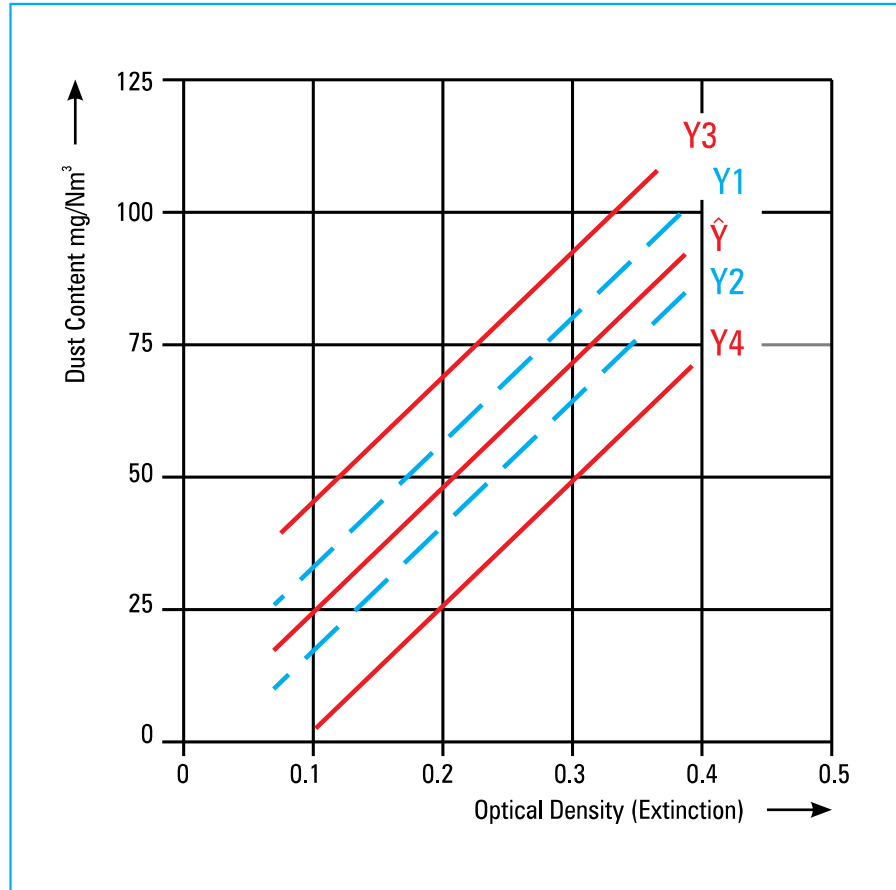
where

$\lg\left(\frac{I_0}{I}\right)$  is the optical density  $OD$  (or extinction).

The concentration  $c$  must be determined by gravimetric measurements for each site, for the reason stated above. In deciding these measurements, consider the expected plant loading and possible filter settings. Use check measurements in case of change of fuel type. Only when the above measurements are affected can the  $OD$  values be corrected to dust burden. As the dust concentration during the measuring process is subject to variation, statistical methods can be used to produce calibration curves between  $OD$  and dust burden.

The average curve determined from the measurements is obtained by means of the "smallest quadratic error" method.

These curves are also known as regression curves. Two lines ( $Y_1$  and  $Y_2$ ), running parallel to the first one, represent the reliability range. That is, the value of optical density, obtained over a long period lies with a probability of 95% within the curves  $Y_1$  and  $Y_2$ .



Two further lines ( $Y_3$  and  $Y_4$ ) define the tolerance range. This means that as a result of many gravimetric measurements at an optical density, the dust content of 75% of random samples will lie with a probability of 95% within  $Y_3$  and  $Y_4$ .

## ■ Selection of the Measuring Range

The DURAG D-R 281 AV has 5 ranges of opacity and 5 ranges of optical density. This results in a very functional and versatile instrument.

Whether the opacity or  $OD$  ranges are used, the selection of the measuring range should be considered carefully. Too high a range (e.g. measuring range 4: 100%) opacity will hardly be indicated on the chart recorder if the average stack emission is around 10%. Therefore select a lower range (e.g. range 2: 40%). The chart recorder will then be able to read more accurately.

On the other hand, if too low a range (e.g. range 1: 20%) is selected, the stack emission may frequently go above 20%. This results in the display locking itself into E.03(4) fault indication (over range) and triggering the central alarm. This can be an operational nuisance, so the instrument can be adjusted to a higher range (e.g. 40%).

**Available Systems**

**Measuring Head**

D-R 281-10 AV .....230 V - 50 Hz

D-R 281-20 AV .....115 V - 50 Hz

**Remote Control Panel**

D-R 281-21 AV .....Single Channel / 230 V - 50/60 Hz (±10%)

D-R 281-22 AV .....Dual Channel / 230 V - 50/60 Hz (±10%)

D-R 281-31 AV .....Single Channel / 115 V - 50/60 Hz (±10%)

D-R 281-32 AV .....Dual Channel / 115 V - 50/60 Hz (±10%)

**Technical Characteristics**

**Opacity Measurements** .....5 selectable ranges: 20%, 40%, 80%, 100% corrected to stack exit, and 0-100% at measuring location.

**Optical Density Measurements** .....5 selectable ranges: 0-0.1, 0-0.2, 0-0.4, 0-0.8, 0-1.6

**Accuracy** .....±2% of full scale

**Measuring Distance** .....450 - 14.000 mm (flange to flange)

**Ambient Temperature Range** .....-20 to +50° C Measuring Head  
 -5 to +50° C Remote Control Panel

**Alignment Deviation** .....±0.3° from optical axis

**Angle of Projection** .....2.8°

**Angle of View** .....3.6°

**Spectral Response** .....From 400 to 700 nm with peak and mean response within 500 to 600 nm

**Response Time, T95** .....1 to 10 seconds, adjustable in 1 second steps

**External Outputs** .....4-20 mA (representing direct and integrated values) linear signals

**Means of Calibration** .....(1) Automatic zero calibration and correction, span calibration and window check adjustable for 1, 2, 3, 4, 5, 6, 7, 8, 12, 24 hour intervals  
 (2) Manual calibration cycle initiation from remote control panel

**Zero Drift** .....Automatically corrected for each time transceiver is in calibration mode

**Span Drift** .....Less than 2% of full scale, three months for ambient temperature variations within -20 to +50°C

**Remote Control Panel** .....Alphanumeric display indicates level of direct integrated signal. Choice of signal readout in Opacity %, Optical Density or mA. Alarm indicators for 2 alarm set points each for integrated values and over limit window contamination. Alarm for filter blockage, blower failure and alpha-numeric systems faults.

**Integration** .....Digital integration on remote control panel. Integration period 1-10 minutes, selectable in 1 minute steps.

**Light Source** .....20,000 hours lamp life expectancy.

**Input Power** .....115 V / 60 Hz or 230 V / 50 Hz (± 10%), 50 VA

**Protection Class** .....IP 65

**Power Consumption** .....Approximately 1.2 kW (with 2 Purge Air Fans)

**Air Requirements** .....2.2 m<sup>3</sup>/ minute per flange

**Instrument Size** .....Please ask for dimensional drawings

**Technical Data Purge Air Fan**

**Voltage** .....standard 200-240 V<sub>D</sub> /345-415 V<sub>Y</sub> 50 Hz, 220-275 V<sub>D</sub>/380-480 V<sub>Y</sub> 60 Hz  
 optional 115/230 V 50/60 Hz single phase

**Frequency** .....50/60 Hz

**Current Input** .....4 /2.1 or 1.2 A

**Max. Flow Rate** .....2.3 m<sup>3</sup>/min at 0 mm WH

**Max. Pressure** .....1,200 mm WH

**Weights:**

**Measuring Head** .....16 kg

**Reflector** .....6 kg

**Adjustable Flange (pc)** .....4 kg

**Purge Air Fan (pc)** .....32 kg

Measuring point determination is done by your local Technical Inspection Agency or equivalent authority. Instrument calibration (gauging in mg/m<sup>3</sup>) may only be performed by a registered testing agency.

Extensive instrument descriptions with technical data, setting instructions, measurements and connection diagrams are available on request.



## Scope of Delivery

The standard version includes:

- Measuring head D-R 281 AV equipped with
- Remote Control Panel
- 2 welding pipes with adjusting flanges
- Terminal box
- Purge air fan (2 systems)

and one of

- Reflector D-R 281-I for measuring sections 0.4 - 3.2 m
- Reflector D-R 281-II for measuring sections 3 - 7.5 m
- Reflector D-R 281-III for measuring sections 7-14 m



Extensive instrument descriptions with technical data, setting instructions, measurements and connection diagrams are available on request.

