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Determination and Evaluation of Ambient Air Quality

- Manual of Ambient Air Monitoring in Germany -

Third, revised Edition

von

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On behalf of the Federal Environmental Agency

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List Of Abbreviations

A	year
Ambl	Amtsblatt
AOT	Accumulation over threshold
BGBl	Bundesgesetzblatt
BImSchG	Bundes-Immissionsschutzgesetz (Federal Immission Control Act)
BImSchV	Verordnung zum BImSchG (Ordinance for the BImSchG)
BImSchVwV	Verwaltungsvorschrift zum BImSchG (General Administrative Instruction for the BImSchG)
BMU	Bundesminister für Umwelt, Naturschutz und Reaktorsicherheit
CEN	Comité Européen de Normalisation (European Committee for Standardization)
DIN	Deutsches Institut für Normung (German Institute for Normalisation)
ENV	Europäische Vornorm
EG	Europäische Gemeinschaft (EC)
EU	European Union
FDIS	Final Draft International Standard
FID	Flame Ionisation Detector
GMBl	Gemeinsames Ministerialblatt (Joint Ministerial Gazette)
IEC	International Electrotechnical Commission
HU	Height Unit
ISO	International Organisation for Standardization
IUAPPA	International Union of Air Pollution Prevention Associations
LAI	Länderaussschuss für Immissionsschutz (Federal Committee for Ambient Air Quality Protection)
LIS	Landesanstalt für Immissionsschutz (North-Rhine-Westphalia State Centre for Air Quality, Noise and Vibration Control)
LUA NRW	Landesumweltamt NRW (North-Rhine-Westphalia Environmental Agency, formerly LIS)
MIK	Maximale Immissionskonzentration (Maximum Ambient Air Quality Concentrations)
NDIR	Non-Dispersive Infrared Absorption

NMVOC	Non-Methane Volatile Organic Compounds
NRW	North-Rhine-Westphalia
PM	Particulate Matter
QM	Quality Management
TA Luft	Technische Anleitung zur Reinhaltung der Luft (Technical Instructions on Air Quality Control)
TCM	Tetrachlormercurate
TEOM	Tapered Element Oscillating Microbalance
TSP	Total Suspended Particulate Matter
TÜV	Technischer Überwachungsverein
UBA	Umweltbundesamt (Federal Environmental Agency)
UMEG	Gesellschaft für Umweltmessungen und Umwelterhebungen (Society for Environmental Measurings and Statistica)
UMK	Umweltministerkonferenz (Conference of Environmental Ministers)
UV	Ultraviolet
VDI	Verein Deutscher Ingenieure (Association of German Engineers)
WHO	World Health Organisation
WRAC	Wide Range Aerosol Classifier

List Of Symbols

a	year
d	day
fg	Femtogramme, 10^{-15} g
h	hour
K	Kelvin
kPa	kilopascal
ng	Nanogramme, 10^{-9} g
pg	Picogramme, 10^{-12} g
ppb	parts per billion, mm^3/m^3
ppm	parts per million, cm^3/m^3
µg	Microgramme, 10^{-6} g
S_D	Standard Deviation from Double Determinations
S_W	Standard Deviation of Repeated Measurements
S_{rel}	Relative Standard Deviation
$\overline{x}$	Mean Concentration

1. Introduction

Measurement of air pollution emissions and ambient air quality is an essential instrument for air quality evaluation and control. In such measurements, pollutants are registered both at their place of origin (emissions) and at the place where they may affect people and/or the environment (immissions[1]). Both types of measurement complement each other and are essential for the implementation of air quality legislation.

For the measurement of emissions, the German Federal Environmental Agency (*Umweltbundesamt*) published a "Manual of Continuous Emission Monitoring" which has been repeatedly re-edited /1/ and has also been translated into English /2/. The success of this bilingual presentation resulted in the preparation of an account of the procedures, methods and technical equipment used for ambient air measurement in the Federal Republic of Germany which provides more detailed information on discontinuous measurement, measurement planning and on the evaluation of measurement results. This "Manual of Ambient Air Quality Control in Germany" and its English translation, first published in 1992, were updated in 1997 /3, 4/.

New legal developments, particularly in connection with the implementation of EC Directives, as well as technological and analytical progress were the reasons for a new and updated edition of this manual.

Specifications for ambient air quality measurements in the Federal Republic of Germany are laid down in standards and Guidelines of the "Handbook for Air Quality Control /5/ which is prepared by the Commission on Air Pollution Prevention of the Association of German Engineers (VDI) in co-operation with the Institute for German Industrial Standards (DIN).

In 1986, 1990, 1993, 1996, 1999 and 2002, the Commission on Air Pollution Prevention held scientific colloquies on currently relevant tasks of measurements in the field of air quality control. The contributions have been published in book form /6-11/. Attention is also drawn to some (partly older) technical literature /12-17/.

This edition of the manual is modelled on the second edition and concentrates on matter-related control of outdoor air within the frame of ambient air quality control.

Chapter 2 gives an overview of basic tasks in ambient air measurement and presents the aspects treated here.

Chapter 3 outlines essential features of legal regulations which are relevant to ambient air control in Germany.

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[1] **Immission**: A German term for which there is no simple English equivalent. In the Federal Republic of Germany, immissions *(Immissionen)* are legally defined as "air pollutants, noise, vibrations, light, heat, radiations, and analogous environmental factors affecting human beings, animals, plants, or other objects".

The requirements made therein regarding ambient air control are described in more detail in Chapters 4 (Measurement Planning) and 5 (Evaluation, Assessment and Documentation). Excerpts from the original texts can be found in Appendix 1.

The part on measuring techniques (Chapter 6, Appendix 2 and 3) gives an overview of the measurement methods commonly used in Germany. The respective DIN standards and VDI Guidelines are presented in Appendix 2; Appendix 3 describes currently available (status: September 2003) suitability-tested measuring devices for the continuous control of ambient air.

Chapter 7 describes current regulations concerning quality assurance and Chapter 8 provides a concluding summary of this manual.

2. Purpose of Ambient Air Quality Measurements

The basic tasks of ambient air measurement can be categorized as follows:

- area-related / site-related measurements
- source-related measurements
- target-related / effect-related measurements

The aim of area-related / site-related measurements is to establish the pollution of an area and thereby the exposure of the population, vegetation, or material goods and property to pollutants and their depositions.

Source-related measurements determine the air pollution caused by one or several emission sources.

Examples for target-related / effect-related measurements are:

- Person-related measurements which serve to examine the effects of air pollutants on human health. Usually, sampling is carried out on human beings with portable measuring devices. The main problem with this measuring technique is a generally high detection limit necessitating a fairly long sampling time. However, this working field belongs to the research for the health protection sector rather than air quality control in the frame of ambient air quality control and is therefore not considered any further in this manual.
- Olfactometry (odour determination)
- Method of standardized lichen exposure for measurement and evaluation of phytotoxic effects of ambient air pollutants
- Method of standardized grass cultures for measurement of the response dose of ambient air fluoride and lead in plants
- Determination of immission rates (examination of the effects of air pollutants on materials)

This manual refers mainly to the measurement and evaluation of ambient air pollutants and pollutant depositions, i.e. to area- / site-related and source-related measurements.

Specific aims in ambient air quality measurements, which can be classified as belonging to one of the above categories, are:

- Monitoring of the observance of ambient air quality threshold values
- Monitoring of the efficacy of air quality control measures
- Calibration and evaluation of dispersion models for pollutants in the atmosphere
- Tracing of temporal trends of air pollutant concentrations
- Research on the transport of air pollutants

In the everyday practice of air quality surveys, several of the above-named objectives are often pursued in one measurement programme. The described tasks have to be dealt with in varying frequency, sometimes in short-term study and research programmes, sometimes in continuous long-term measurement programmes.

3. Legal Bases

3.1 Directives Issued by the Commission of the European Communities

At the end of 1996, the European Communities have passed Directive 96/62/EC concerning ambient air quality evaluation and control /18/ and have thereby created the framework for future legislatorial developments in the field of air quality control.

This so-called Air Quality Framework Directive pursues four goals in particular:

- Definition and fixing of ambient air quality targets
- Evaluation of air quality in the Member States on the basis of standardized methods and criteria
- Availability of useful information on air quality and information of the general public about the exceeding of alert threshold values
- Preservation of good air quality and improvement of air quality where this is not the case

The Framework Directive itself does not contain limit values or specifications on measuring techniques but it names air pollutants which are to be observed primarily and for which individual regulations are defined in the so-called Daughter Directives.

The current state of elaboration of EU Daughter Directives is described in the following:

1st Daughter Directive
Directive 1999/30/EC on limit values for sulphur dioxide, nitrogen oxides, particulate matter and lead in ambient air /19/

2nd Daughter Directive
Directive 2000/69/EC on limit values for benzene and carbon monoxide in ambient air /20/

3rd Daughter Directive
Directive 2002/3/EC on ozone concentration in ambient air /21/

4th Daughter Directive
Directive on arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air - draft /22/

Fixed dates for a national implementation of the Daughter Directives were 19 July 2001 (1st Daughter Directive), 13 December 2002 (2nd Daughter Directive), and 9 September 2003 (3rd Daughter Directive).

In order to meet these requirements, amendments to the Federal Immission Control Act (*Bundes-Immissionsschutzgesetz*) /23/, to the Technical Instructions on Air Quality Control (TA Luft) /24/ and to the 22nd Ordinance for the Federal Immission Control Act (22nd BImSchV) /25/ became necessary in 2002. With the implementation of the 3rd Daughter Directive, i.e. the introduction of the Ordinance on the Reduction of Summer Smog, Acidification and Eutrophication (33rd BImSchV) /26/, the 23rd Ordinance (23rd BImSchV) /27/ will cease to be in force and the 22nd Ordinance (22nd BImSchV) will be amended once more.

Beside the above-mentioned Daughter Directives, a number of older EU Directives /28, 29, 30/ containing regulations on ambient air quality control remain valid for a period of transition. Therefore, the currently valid statutory instruments are interim regulations.

The second generation of EU Directives requires a reorientation of ambient air quality control and air quality preservation planning in the Member States. In Germany, due to the specific regulation of responsibilities, a reorientation is also necessary on the level of the Federal States (*Bundesländer*).

The main criteria are:

- Considerably stricter limit values orientated towards the effect-related limit values published by the World Health Organisation WHO

- Extensive plans of action for the preservation of ambient air quality

- Comprehensive information of the general public

- Increased demands on quality and quality assurance systems for air quality data

In co-ordination between the Federal Environmental Agency in Berlin (*Umweltbundesamt*) and the Federal States (*Bundesländer*), an initial evaluation of ambient air quality had to be carried out according to Article 5 of the Framework Directive.

The aim of this initial evaluation consists in the determination of site-related pollution in the Member States according to standardized criteria and regulations, as well as the subsequent classification of areas as belonging to categories of different ambient air pollution.

Depending on the results of the initial evaluation the particular type of ambient air control for a certain area is being prescribed. For details see Chapter 4.

3.2 Federal Immission Control Act (Bundes-Immissionsschutzgesetz, BImSchG)

The authoritative law for air quality control in the Federal Republic of Germany is the Federal Immission Control Act (*Bundes-Immissionsschutzgesetz*, BImSchG) /23/.

The regulations of this law cover virtually all areas of ambient air quality control. The legal requirements for ambient air quality control are compiled in Appendix 1.

The 7th Amendment to the Federal Immission Control Act of 11 September 2002 /31/ serves, among other goals, the implementation of the relevant EU Directives on ambient air quality control. Part 5 of the BImSchG was amended; the previously valid regulations on the planning of air quality control were adjusted to the newly added regulations.

The BImSchG authorizes the Federal Minister for the Environment, Nature Conservation and Nuclear Safety as well as the individual Federal Governments (*Landesregierungen*), i.e. their responsible Ministers or Senators, to enact statutory orders (*Rechtsvorschriften*) and general administrative instructions (*Allgemeine Verwaltungsvorschriften*). As far as they concern ambient air quality control, the following regulations will be considered in detail below: the Technical Instructions on Air Quality Control /24/, the 22nd, 23rd and 33rd Ordinance for the BImSchG /25, 26, 27/ and the Fourth General Administrative Instruction on the Monitoring of Ambient Air Quality in Examination Areas /33/.

According to the BImSchG

- the responsible local authority can order ambient air quality measurements in an area affected by a certain plant if any danger of harmful environmental effects caused by this plant is to be expected (Article 26 BImSchG),

- the responsible authority can order ambient air quality measurements for plants requiring licenses for operation immediately after their start-up, or following major modifications (as defined in Article 15 or Article 16 BImSchG) and every three years thereafter (Article 28 BImSchG),

- the responsible authority can order continuous ambient air quality measurements, using recording measuring devices (Article 29 BImSchG), instead of or in addition to single measurements according to Articles 26 and 28 BImSchG,

- the responsible transport authorities can prohibit or impose restrictions on motor vehicle traffic (Article 40 BImSchG) if this is provided for in air preservation or action plans (acc. to Article 47, para. 1 or 2), or if the motor vehicle traffic contributes to an exceeding of the threshold values laid down in statutory instruments according to Article 48, para. 1a,

- the air quality is to be monitored by the responsible authorities by means of regular examinations according to the requirements described in statutory instruments acc. to Article 48a (see below); the areas which are to be examined are decided on by the Federal State Governments (*Landesregierungen*) or by authorities determined by them,

- the responsible authorities take the measures required to observe the ambient air quality values laid down in statutory instruments according to Article 48a (see below) (Article 45 BImSchG),

- the public is to be informed about ambient air quality (Article 46a BImSchG). The responsible authority is to immediately inform the general public if the alert threshold values laid down in statutory instruments according to Article 48a, para.1 are being exceeded,

- the responsible authority is to draw up air quality control plans and/or action plans, which have to be accessible for the general public, if characteristic ambient air values, as laid down in statutory instruments according to Article 48a, para.1, are being exceeded (Article 47 BImSchG),

- the Federal Government – with approval of the *Bundesrat* (Federal Upper House of Parliament) - is authorized to enact the statutory instruments concerning the determination of ambient air quality values and procedures for their registration, control and measurement, which are necessary for the implementation of legally binding resolutions issued by the European Communities (Article 48a BImSchG). In this process, the *Bundestag* (Federal Lower House of Parliament) is to be involved (Article 48b BImSchG).

A compilation of excerpts from the Federal Immission Control Act (BImSchG) concerning ambient air quality control can be found in Appendix 1.

3.3 Ordinance on Pollutant Concentrations in Ambient Air (22nd BImSchV)

The Amendment to the 22nd Ordinance for the Federal Immission Control Act /25/ dated 11 September 2002 transfers the Framework Directive /18/ and the 1st and 2nd Daughter Directives /19, 20/ into German law. Moreover, while EU Air Quality Guidelines /28, 29/ remain legally binding for a transitional period, ambient air quality values and temporally staggered margins of tolerance are determined. As far as air quality control is concerned, the entire territory is to be assessed. If ambient air threshold values are exceeded, measurement plans are to be drawn up, if alert threshold values are exceeded, action plans are to be worked out. The public is to be kept fully informed.

For the assessment of ambient air quality, different procedures are permitted on the basis of assessment threshold values (measurement, model calculations or estimations, see Chapter 4.2.).

Appendix 5 of the Ordinance provides regulations concerning reference methods for the assessment of sulphur dioxide, nitrogen dioxide, nitrogen oxide, particulate matter (PM_{10} and $PM_{2.5}$), lead, benzene and carbon monoxide concentrations.

3.4 Ordinance for the Specification of Concentration Values (23rd BImSchV)

This Ordinance concerned peak values of air pollutant concentrations near traffic routes. It came into force on 1 March 1997. If certain concentration values for nitrogen dioxide, soot or benzene were exceeded, a restriction or prohibition of traffic on certain roads was to be considered according to Article 40, para.2 BImSchG, which came into force in 1990 and has been revised in the meantime /31/.

The Ordinance will be repealed when the 3rd Daughter Directive /21/ is implemented with the introduction of the 33rd BImSchV /26/. The regulations contained in the 23rd BImSchV were included in the 22nd BImSchV and were partly tightened.

3.5 Ordinance on the Reduction of Summer Smog, Acidification and Eutrophication (33rd BImSchV)

The 33rd BImSchV /26/ supports, among other purposes, the implementation of Directive 2002/3/EC (3rd Daughter Directive) on ozone concentration in ambient air. It adds to earlier regulations on ozone concentration in ambient air based on Directive 92/72/EEC /21/, and, for the first time in the field of ambient air quality control, provides targets for the reduction of ozone concentration which are to be met until 2010 as far as possible.

The introduction of this Ordinance amends the 22nd BImSchV by repealing Articles 15 to 19 concerning ozone regulations. With its coming into effect, the 23rd BImSchV is repealed.

Concerning ambient air quality control the Ordinance contains:

- Ambient air quality values (Article 2), i.e. target values and long-term objectives for the protection of human health and vegetation against ground-level ozone

- Information threshold and alert threshold values for ground-level ozone

- Measurement regulations concerning ozone and its precursors for the evaluation of ambient air quality (Article 3)

3.6 Technical Instructions on Air Quality Control (TA Luft)

The revised Technical Instructions on Air Quality Control (TA Luft) /24/, i.e. the First General Administrative Instruction for the Federal Immission Control Act (BImSchG), has come into force on 1 October 2002. This fourth amendment serves mainly to implement various legal Guidelines issued by the EU, in particular the Air Quality Framework Directive /18/ and its Daughter Directives /19, 20, 21/ as well as the IVU Directive /32/.

Its field of application covers mainly plants requiring licenses for operation. On principle, plants which do not need a license for operation are now to be considered as well. However, requirements concerning ambient air quality control can be applied only under certain conditions.

Concerning the **monitoring of ambient air quality**, TA Luft contains

- ambient air quality values (No. 2.3) for the protection of human health (No. 4.2), for the protection against substantial impairment or considerable disadvantage through dust precipitation (No. 4.3), for the protection against considerable disadvantage, in particular the protection of vegetation and eco-systems (No. 4.4), and for the protection against harmful environmental influences caused by pollutant depositions (No. 4.5).

- guidelines for the ascertainment of characteristic ambient air quality values (No. 4.6).

- criteria for the observance of ambient air quality values (No. 4.7)

The original wording of the regulations concerning ambient air quality control in the revised TA Luft is included in Appendix 1. Compared with TA Luft 1986, the ambient air quality values have been considerably lowered in accordance with the requirements set in the relevant EU Guidelines. In addition to that, the definition of characteristic ambient air quality values has been revised. More details can be found in Chapter 5.

Pollutant concentrations in ambient air indicate the mass of pollutants in relation to the volume of polluted air (for gaseous substances relative to 293.15 K and 101.3 kPa) or the amount of depositions (of solid matter, liquid or gaseous pollutants caused by gravity within a defined area and period of time).

According to the revised version of TA Luft, characteristic ambient air quality values are no longer to be determined in *area*-related measurements, but at evaluation points where the highest impairment is to be expected. As a rule, continuous measurements are to be made, unless, for a particular pollutant, only an annual ambient air quality value has been determined. The regulations concerning the ascertainment of characteristic ambient air quality values are described in Chapter 4.2.5.

3.7 Registration of Ambient Air Quality Values in Examination Areas (4th BImSchVwV)

The Fourth General Administrative Instruction for the BImSchG of 26 November 1993 /33/ describes the determination of air pollution in “examination areas”. It is based on Articles 44, 45 BImSchG which have been revised in the meantime. It takes into account the former state of measurement regulations made in EU Guidelines at that time.

For measurements in examination areas the 4th BImSchVwV specifies

- parameters to be measured
- number and location of measuring points
- measuring methods and measuring devices
- regulations concerning the evaluation of measurements

In some points the 4th BImSchVwV is no longer compatible with currently valid legal instructions. A specific date for its repeal has not been decided on yet.

3.8 Smog Regulations

In the 1980s most Federal States have issued “Smog Regulations” (regulations for the reduction of harmful environmental influences during periods of stagnant weather conditions) on account of Articles 40 and 49 BImSchG. The Smog Regulations followed in content a “Model Regulation” issued by the Federal States’ Committee for Ambient Air Quality Protection (LAI) /34/.

Concerning ambient air quality control these Smog Regulations contain

- concentration threshold values which set off different stages of smog alert
- information on the measurement of ambient air quality

This information refers to components such as sulphur dioxide, carbon monoxide, nitrogen dioxide, and suspended particulate matter. Measures such as information of the public, restrictions and prohibition of road traffic were connected with the different alert stages.

The significant decrease of ambient sulphur dioxide and suspended particulate matter concentrations has made a future reaching of the alert stages unlikely. Subsequently, all Federal States have abrogated their Smog Regulations.

4. Measurement Planning

The aim of measurement planning is to organize the temporal and spatial distribution of measurements or sampling in such a way that representative results concerning ambient air quality are obtained of the situation in a certain area or place. It is important that the results of planned measurements be comparable to limit values or other such specifications, effect criteria or effect findings and/or to measurements taken in other areas or at an earlier point in time. The planning will depend essentially on the tasks set in specific ambient air quality measurements (Chapter 2), on the measurement method (discontinuous, continuous, or both) (Chapter 6), and on the nature and source of air pollutants.

There are numerous national and international publications - also in book form /36/ - on the planning of ambient air quality measurements. Note as examples some German works and works carried out with German participation for the implementation of EC Directives /37-48/.

4.1 Terms

The following chapters explain important terms for the planning and taking of ambient air quality measurements, which are also frequently used in regulations for ambient air quality monitoring (TA Luft /24/, EU Directives /18-21, 28-30/, 22nd and 33rd Ordinance for the BImSchG /25, 26/, 4th General Administrative Instruction for the BImSchG /33/). For details, see the original wordings (partly included in Appendix 1).

4.1.1 Measuring Points

Continuous as well as discontinuous measurements are to be taken in places where pollutant concentrations are representative of the respective environment. In the surrounding area, there should be neither obstacles, which could impair the natural airstream, nor emission sources, which could falsify the measuring results.

The height of the sampling site above the ground is relevant to the measured ambient air quality values if it has a significant influence on the distance from emission sources and thus causes a dilution of the measured pollutant. This is, for example, the case with measurements in the vicinity of road traffic.

4.1.2 Density of Measuring Points / Minimum Number of Sampling Sites

The "density of measuring points" indicates the number of measuring sites per area. This is most important in areas where random samplings are taken for the purpose of ambient air quality control. The required number of measuring points proportionally depends on the degree of temporal and spatial fluctuation of ambient air quality values within the area, and is in inverse proportion to the duration of sampling times and to the frequency of measurements. Criteria set up in EU Directives concerning the minimum number of sampling sites have been adopted into German legal Ordinances. Regulations for areas affected by industrial plants have been made in TA Luft (see Chapter 4.2.5).

4.1.3 Sampling Times / Averaging Period

The sampling time for one individual reading in discontinuous measurements corresponds to the averaging period in automatic continuous measurements.

The shorter the sampling time, the higher the *maximum values* that can be expected. The sampling time is determined by taking into account the limit values, the effect criteria of the substances to be measured, and by aspects of the measurement method (detection limits, expenditure etc.). Since the current EU regulations have been implemented in Germany, sampling times are generally set at (cf. Chapters 3.2 and 3.3)

- 1 hour,
- 8 hours
- 24 hours,
- one calendar year
- winter-time (1 October to 31 March).

Individual regulations, arranged according to pollutants and protected assets, can be found in Chapter 5.

The 30-minutes value formerly used in Germany for gaseous substances has become less significant. Similarly, most parts of VDI Guideline series 2310 (cf. Chapter 5.1) concerning maximum ambient air quality concentrations (MIK values) for the protection of human health have been withdrawn without replacement in the past years and months.

4.1.4 Duration of Measurement Programmes

For permanent ambient air quality measurements, the evaluation period is considered as the "duration of one measurement programme". Normally, this is 12 months. With the large number of measurements thus obtained, it is possible to make further divisions into monthly, three-month and half-year time intervals.

The 12 months of one measurement programme or evaluation period should cover either one calendar year or the time from 1 April to 31 March. The latter division has the advantage that it allows making separate assessments for summer (April through September) and winter (October through March).

Should the duration of a measurement programme be restricted to six months, it is advisable to carry out measurements between either January and June or July and December in order to record seasonal meteorological influences. Shorter measurement periods can provide representative measurement values if meteorological factors are negligible, as is the case for emission sources which are near the ground. For example, the mean and maximum carbon monoxide ambient air quality values next to a major traffic route obtained from measurements taken over one year are also derived with sufficient accuracy from the values of continuous measurements in each individual month /49/.

4.1.5 Measurement Times

There are systematic changes in ambient air quality depending on emission development and meteorological influences during the year, a day, or one week (weekdays/weekends) /50/.

Continuous and other permanent measurements fully register these temporal variations in ambient air quality. For discontinuous random measurements, the task of measurement plans is to avoid any falsification of the air examination results caused by the choice of measurement times. The revised version of TA Luft /24/ and the 22nd and 33rd Ordinance for the BImSchG /25, 26/ contain the relevant regulations.

4.1.5.1 Season

The highest concentrations of components of flue gases and other waste gases originating from thermal processes (above all sulphur dioxide) are reached in winter. Other pollutants are more likely to accumulate in summer, such as substances emerging from production or cleaning plants at higher temperatures due to their lower solubility in absorption solutions, substances originating from evaporation (organic gases) or substances whirled up from the ground (dust), or those which are formed in photochemical reactions in the atmosphere (ozone).

Weather conditions which slow down the dispersion of pollutants in the air, thereby producing higher ambient air pollution, occur mainly in winter.

4.1.5.2 Times of Day and Days of the Week

Variations in air pollution during the day are also caused by meteorological conditions and emission patterns. Normally, maximum values of average pollutant concentrations occur in the morning and in the afternoon while ambient air pollution is lowest during the night. The time and the relative level of the maximum values vary depending on the factors which most affect the development and dispersion of the pollutants - either the emissions (e.g. near roads) or meteorological conditions (e.g. in case of flue gases).

Differences in ambient air quality between weekdays and weekends are caused solely by differences in the emissions (which are lower at weekends).

While continuous measurements cover a duration of days and weeks, random sampling is normally being carried out (e.g. according to TA Luft 86 /51/) on working days during the daytime which excludes lower pollutant concentrations during the night and at the weekend. Therefore, higher characteristic values will be derived from these discontinuous measurements. Accordingly, the revised TA Luft /24/ as well as the 22nd BImSchV require an equal distribution of sampling times in order to avoid a misrepresentation of the results as described above.

4.1.6 Frequency of Measurements

The "measurement frequency" indicates the number of and intervals between individual measurements and samplings taken at one measuring site or in one measuring area. This term is of consequence only for discontinuous measurements; for these, however, it is of considerable importance as ambient air quality values are subject to high temporal variations (cf. Chapter 6) /36, 37/. Continuous measurements normally cover the duration of one measurement programme without any interruption.

For an accurate assessment of ambient air quality, the measurement frequency must be increased the higher the expected variations in ambient air quality, the shorter the sampling time and the less measuring points in the area (see Chapter 4.1.2).

Studies on the influence of the measurement frequency on the level of characteristic values for ambient air quality have been described repeatedly in German specialist literature, for example for sulphur dioxide /52/ and for lead in suspended particulate matter /53/. Most of these studies have been carried out with regard to the regulations of TA Luft 86 /51/. For this purpose, decreasing numbers of individual readings were taken from the total number of continuously recorded readings, and mean values and percentiles (for higher ambient air pollution) were determined from those samples.

4.2 Measurement Regulations (Measurement Plans) in the Federal Republic of Germany

In the Federal Republic of Germany, specific instructions for the planning of ambient air quality measurements are included in the following regulations (cf. Chapter 3)

- Directives issued by the Commission of the European Communities
- 22nd Ordinance for the Federal Immission Control Act
- 33rd Ordinance for the Federal Immission Control Act (in preparation)
- Technical Instructions on Air Quality Control (TA Luft)
- 4th General Administrative Instruction for the BImSchG

The Guideline Series VDI 4280 contains concrete requirements and regulations for the planning of source-related ambient air quality measurements in the vicinity of emission sources. So far, the following parts have been published:

VDI 4280 Part 1, draft, published November 1996
Planning of ambient air quality measurements - General rules /54/

VDI 4280 Part 2, published June 1999
Planning of ambient air quality measurements - Rules for planning investigations of traffic related air pollutants in key pollution areas /55/

VDI 4280 Part 3, published June 2003
Planning of ambient air quality measurements - Measurement strategies for the determination of air quality characteristics in the vicinity of stationary emission sources /56/

4.2.1 Directives Issued by the Commission of the European Communities

Detailed measurement regulations are included in the Directives on ambient air quality control issued by the Commission of the European Communities (Daughter Directives /19-21/) and in previous Directives on limit values for pollutant concentrations /28-30/.

The following terms, originally defined in EU Daughter Directives, slightly adjusted to the situation in Germany and included in the 22nd and 33rd BImSchV /25, 26/, are relevant to the field of ambient air quality control:

Agglomeration:

A zone with at least 250,000 inhabitants, consisting of one or several municipalities which each have at least 1,000 inhabitants per square kilometre in relation to the municipality's entire area

Alert threshold:

A value above which danger to human health is imminent even in case of short-term exposure, and which calls for immediate measures to be taken by the Member States (e.g. current warnings of the population, rules governing behaviour of particularly endangered parts of the population, action plans including immediate measures)

Ambient Air Quality Limit Values:

A value which, on the basis of scientific findings, is determined in order to prevent, avoid or reduce harmful effects on human health and/or the environment as a whole, and which has to be achieved within a specified time and may not be exceeded hereafter

Assessment threshold, upper:

A value below which a combination of measurements and model calculations can be applied for the assessment of ambient air quality

Assessment threshold, lower:

A value below which only model calculations or objective estimating techniques need to be applied for the assessment of ambient air quality

Information threshold:

A value above which a risk to human health is given for people of delicate health, even in case of short-term exposure, and which requires current information of the public

Long-term objective:

A value below which immediate harmful effects on human health and/or the environment are unlikely on the basis of current scientific findings. This objective is to be achieved in the long term in order to effectively protect human health and the environment, unless this can only be achieved with measures that would be out of all proportion to the result

Margin of tolerance:

The specific percentage of the limit value by which this may be exceeded. The margin of tolerance is reduced annually by a certain percentage

Target value:

A value determined in order to avoid harmful effects on human health and/or the environment on a long-term basis and which, as far as possible, has to be achieved within a certain period of time

Value:

The concentration of a certain pollutant in ambient air

Zone:

A demarcated part of the EU Member States' territory; for Germany a part of a Federal State's expanse defined by the responsible authorities

For the assessment of ambient air quality, the entire area of a Federal States is to be monitored by the responsible authorities which for this purpose have previously defined zones and agglomerations. This division into zones and agglomerations was made on the basis of an initial assessment in accordance with Article 5 of Directive 96/62/EC (Air Quality Framework Directive /18/) in co-operation with the Federal Environmental Agency. Some Federal States have published the results of their initial assessment.

The planning of fixed measurements is made on the basis of the initial assessment.

Fixed measurements are required when the lower assessment thresholds have been exceeded and – in agglomerations – in case of substances for which alert threshold have been determined.

The minimum number of measurement sites is prescribed for the individual pollutants and depends on the population density of the considered region.

Regarding the selection of site locations for the fixed measurement of pollutants such as sulphur dioxide, nitrogen dioxide, nitrogen oxides, particulate matter, lead, benzene, and carbon monoxide (1^{st} and 2^{nd} Daughter Directive), the following criteria are to be taken into consideration:

1. Macroscale siting criteria / Selection of site locations on macro-level

a) Measurements for the protection of human health

Sampling sites in zones and agglomerations are to be installed where the highest concentrations the population will presumably be exposed to are to be expected, and where in general the measured concentrations are representative of the exposure of the population. Sampling points should in general be sited to avoid measuring very small micro-environments in their immediate vicinity.

As far as possible, the sampling sites are to be representative also for similar locations which are not located in the immediate proximity. If necessary for the protection of human health, sampling sites are also to be installed on islands.

b) Measurements for the protection of eco-systems and the vegetation (not including benzene and carbon monoxide)

Sampling sites are to be installed where they are at least 20 kms away from agglomerations, or 5 kms away from other populated areas, industrial facilities or roads. One sampling site is to be representative of the ambient air quality within an area of at least 1,000 sq kms. As far as these regulations are concerned, exceptions in the individual Member States are permissible. The ambient air quality on islands is to be evaluated.

2. Microscale siting criteria / Selection of site locations on micro-level

As far as possible in practice, the following criteria are to be observed:

The air stream around the inlet sampling probe may not be impaired, minimum distances from obstacles and certain sampling heights (generally between 1.5 and 4 m above ground) are to be considered. Measurements in the immediate vicinity of emission sources and re-entry of exhaust air into the sampler inlet are to be avoided as far as possible. In areas with road traffic nearby, the sampling sites are to be installed at least 25 m away from busy crossings and at least 4 m away from the middle of the nearest traffic lane.

The 3rd Daughter Directive /21/ names the following macroscale criteria for the choice of locations for fixed measurements of ambient air quality such as ozone and its precursors, a case in which the measurement of small micro-environments is to be avoided:

In urban areas, measuring sites are to be installed which are representative of some sq kms and located without the sphere of influence of local emission sources.

For further types of measuring sites, the following propositions are made with regard to the representativeness of sampling results: for suburban areas a surrounding area of several dozen sq kms, for rural areas a surrounding area of several hundred sq kms, and for the rural background a surrounding area between 1,000 and 10,000 sq kms.

The criteria for the microscale determination of site locations correspond to a great extent with the guidelines of the 1st and 2nd Daughter Directive /19, 20/.

Due to the obligatory implementation of the Daughter Directives, the relevant measuring directives concerning sulphur dioxide, nitrogen dioxide and nitrogen oxides, particulate matter and lead (1st Daughter Directive), benzene and carbon monoxide (2nd Daughter Directive) and ozone (3rd Daughter Directive) are legally binding. Regulations made in previous EU Directives concerning sulphur dioxide and suspended particulate matter (80/779/EEC /28/), lead (82/884/EEC /29/) and nitrogen dioxide (85/203/EEC /30/) are partly still legally binding and will expire at the end of transitional periods on 1 January 2005 and 1 January 2010. The measurement regulations were included in the 22nd BImSchV and are described in more detail in Chapter 4.2.2.

4.2.2 22nd Ordinance for the Federal Immission Control Act (22nd BImSchV)

The 22nd BImSchV /25/ is divided into two parts, the first of which is based on the regulations of the Air Quality Framework Directive /18/ and the 1st and 2nd Daughter Directive (taking into account the previous EU Directives which remain legally binding for a transitional period), whereas the second part concerns ozone regulations based on Directive 92/72/EEC /35/. The ozone regulations are to be repealed with the introduction of the 33rd BImSchV /26/.

Part one refers to components such as sulphur dioxide, nitrogen dioxide and nitrogen oxides, suspended particulate matter and particles (PM_{10}), lead, benzene and carbon monoxide.

The definitions of terms correspond to a great extent with those of the 1st and 2nd Daughter Directive /28, 29/ (cf. Chapter 4.2.1).

For the assessment of ambient air quality, the entire area of the Federal States is to be monitored by the responsible authorities which have previously defined zones and agglomerations. This division was made on the basis of an initial assessment in accordance with Article 5 of the Framework Directive /18/. Some of the Federal States have published the results of their initial assessment (see Chapter 4.2.1). The assessment and the division into zones and agglomerations is to be reviewed at least every 5 years (or in shorter intervals if significant changes in pollutant concentrations occur).

Fixed measurements are to be carried out

- in agglomerations if the lower assessment thresholds have been exceeded
- in agglomerations in case of substances for which alert thresholds have been set
- in zones if the lower assessment thresholds have been exceeded

The alert threshold is 400 $\mu g/m^3$ for nitrogen dioxide and 500 $\mu g/m^3$ for sulphur dioxide. For both, arithmetic mean values have to be calculated over one hour, measured during three consecutive hours.

Table 4.1 shows the relevant assessment thresholds which relate to different assets to be protected (human health, vegetation, eco-systems). The values are based on the ambient air limit values defined for a particular pollutant and on the corresponding averaging period (1-hour mean values, 24-hours mean values, annual mean values, winter values). For 1-hour values and 24-hours values the assessment thresholds have been complemented by maximum numbers of exceedances permitted each calendar year.

Pollutant	Upper assessment threshold	Lower assessment threshold	Averaging period	Permissible exceedances per calendar year	Protected asset
Sulphur dioxide	75 µg/m^3	50 µg/m^3	24 hrs	3	Human health
	12 µg/m^3	8 µg/m^3	Winter	-	Eco-systems
NO$_2$	140 µg/m^3	100 µg/m^3	1 hr	18	Human health
	32 µg/m^3	26 µg/m^3	1 year	-	Human health
NO$_x$	24 µg/m^3	19.5 µg/m^3	1 year	-	Vegetation
Particulate matter	30 µg/m^2	20 µg/m^3	24 hrs	7	Human health
	14 µg/m^3	10 µg/m^3	1 year	-	Human health
Lead	0.35 µg/m^3	0.25 µg/m^3	1 year	-	Human health
Benzene	3.5 µg/m^3	2 µg/m^3	1 year	-	Human health
CO	7 mg/m^3	5 mg/m^3	1 year	-	Human health

Table 4.1: Assessment Thresholds in the 22nd BImSchV

The required minimum number of sampling sites for the measurement of urban background pollution including road traffic (diffuse sources) depends on the assessment thresholds and the population of the considered area. Table 4.2 shows these figures which relate to measurements for the assessment of the observance of ambient air quality limit values for the protection of human health and of alert thresholds.

Population of the area (in thousands)	If the maximum concentration exceeds the upper assessment threshold	If the maximum concentration is between upper and lower assessment threshold	For SO_2 and NO_2 in agglomerations where the maximum concentration is below the lower assessment threshold
0 – 250	1	1	Not applicable
250 – 499	2	1	1
500 – 749	2	1	1
750 – 999	3	1	1
1,000 - 1,499	4	2	1
1,500 - 1,999	5	2	1
2,000 - 2,749	6	3	2
1,750 – 3,749	7	3	2
3,750 – 4,749	8	4	2
4,750 – 5,999	9	4	2
> 6,000	10	5	3
	For benzene, carbon monoxide, NO_2 and particulate matter: including at least one measuring site for urban background emission sources and one measuring site for road traffic		

Table 4.2: Criteria for the Minimum Number of Sampling Sites

For the assessment of ambient air pollution within the immediate sphere of influence of stationary plants (spot emission sources) no similarly concrete requirements are included. For this field, regulations have been laid down in TA Luft (see Chapter 4.2.5). Guidelines for the planning of ambient air quality measurements can also be found in VDI Guideline 4280 Parts 1, 2 and 3 /54, 55, 56/.

For an assessment of the observance of ambient air quality limit values for the protection of eco-systems or the vegetation, the following minimum number of sampling sites is to be installed in non-agglomeration areas:

- 1 measuring station per 20,000 sq kms if the maximum concentration exceeds the upper assessment threshold
- 1 measuring station per 20,000 sq kms if the maximum concentration is between upper and lower assessment threshold

Regarding the selection of site locations for fixed measurements of pollutants such as sulphur dioxide, nitrogen dioxide, nitrogen oxides, particulate matter, lead, benzene, and carbon monoxide (1st and 2nd Daughter Directive) the following criteria are to be taken into account:

1. Macroscale siting criteria / Selection of site locations on macro-level

a) Measurements for the protection of human health

Sampling sites in zones and agglomerations are to be installed where the highest concentrations are expected to which the population will presumably be exposed directly or indirectly over a period of time which is significant in its relation to the averaging period for the relevant concentration limit values.

Sampling sites in zones and agglomerations are to be installed where pollutant concentrations are representative of the exposure of the population in general.

The measurement of very small micro-environments is to be avoided. The size of surrounding areas should be approx. 200 m² (sampling sites for road traffic emissions) or several square kilometres (sampling sites for urban background sources).

As far as possible, the sampling sites are to be representative also for similar locations which are not located in the immediate proximity. If necessary for the protection of human health, sampling sites are also to be installed on islands.

b) Measurements for the protection of eco-systems and the vegetation (not including benzene and carbon monoxide)

Sampling sites are to be installed where they are at least 20 kms away from agglomerations or 5 kms away from other populated areas, industrial facilities or roads. One sampling site is to be representative of the ambient air quality within an area of at least 1,000 sq kms. As far as these regulations are concerned, exceptions in the individual Member States are permissible. The ambient air quality on islands is to be evaluated.

2. Microscale siting criteria / Selection of site locations on micro-level

As far as possible in practice, the following criteria are to be observed:

- No impairment of the air stream around the inlet sampling probe
- Minimum distance between air inlet and possible obstacles to the air stream normally several metres
- For air quality sampling sites: minimum distance between air inlet and the nearest building 0.5 m away from the building, measured along the building's vanishing-line
- Height of air inlet between 1.5 and 4 m above ground, possibly up to 8 m
- Location of air inlet not in close proximity of emission sources
- Avoidance of re-entry of exhaust air into air inlet
- In traffic areas, sampling sites are to be installed at least 25 m away from busy crossings and at least 4 m away from the middle of the nearest traffic lane.

4.2.2.1 Sulphur dioxide

Concerning fixed measurements of sulphur dioxide the 22nd BImSchV specifies:

Averaging Period: 1 day (until 31 December 2004), 24 hours, calendar year, and winter (October to March)
Duration of one Measurement Programme (Evaluation Period): One year, 1 April to 31 March. Separate assessment for the winter (October to March).
Measurement Frequency: Continuous measurement. Random sampling if the number of measurements is sufficiently large to enable the levels observed to be determined (see Chapter 5.3.2.4).
Reference Method: ISO/FDIS 10498 (norm draft) Air – Determination of sulphur dioxide – UV Fluorescence Method

For a transitional period (until 1 January 2005), Appendix IV B of EC Directive 80/779 permits the following measurement scheme for the determination of the assigned concentration of suspended particulate matter:
Averaging Period: 24 hours
Duration of one Measurement Programme: One year
Measurement Frequency: At least 100 measurements per year, equally distributed over this period
Measurement Method: Gravimetric method (Membrane Filters or Glass Fibre Filters)

4.2.2.2 Nitrogen dioxide and nitrogen oxides

Averaging Period: One hour, one year
Duration of one Measurement Programme (Evaluation Period): One calendar year
Measurement Frequency: Continuous measurement. Random sampling if the number of measurements is sufficiently large to enable the levels observed to be determined (see Chapter 5.3.2.4).
Reference Method: ISO 7996 Air – Determination of the mass concentration of nitrogen oxides – chemiluminescence method

Appendix I of Directive 85/203/EEC on air quality standards for nitrogen dioxide /24/ contains the following specifications on measurement planning which remain valid until 1 January 2010:

Averaging Period: One hour or less
Duration of one Measurement Programme (Evaluation Period): One calendar year
Measurement Frequency: Continuous Measurement. Random sampling if the number of measurements is sufficiently large to enable the levels observed to be determined (see Chapter 5.3.2.4).

4.2.2.3 Suspended Particulate Matter and Particles (PM_{10}, $PM_{2.5}$)

Until 31 December 2004, limit values and measurement of suspended particulate matter and particles relate to suspended particulate matter, afterwards (from 1 January 2005 on) to PM_{10}.

Concerning sampling and analysis of suspended particulate matter, the regulations contained in Appendix IV, Table B of Directive 80/779/EEC apply:

Sampling Time: 24 hours
Duration of one Measurement Programme: One year
Measurement Frequency: At least 100 measurements per year, equally distributed over this period
Reference Method: Sampling on membrane filter or glass fibre filter without fractioning, gravimetric assessment

In order to evaluate the concentration of suspended particulate matter, the reference method for PM_{10} fraction (see below) can also be applied. For a comparison with the limit value for suspended particulate matter the results are to be multiplied by the factor 1.2.

The following regulations concerning the measurement of PM_{10} concentration are legally binding:

Averaging Period: 24 hours, one calendar year
Duration of one Measurement Programme (Evaluation Period): One calendar year
Measurement Frequency: Continuos Measurement. Random sampling if the number of measurements is sufficiently large to enable the levels observed to be determined (see Chapter 5.3.2.4).
Reference Method: EN 12341 Air Quality – Determination of the PM_{10} fraction of suspended particulate matter - Reference method and field test procedure to demonstrate reference equivalence of measurement methods

The above-mentioned reference method is a manual gravimetric one. The generally applied methods of continuous measurement (β-absorption and TEOM, see 6.1.3.9 and 6.1.3.10) have produced considerably reduced results in comparison with the reference method /57/. Therefore, the results have to be adjusted by means of corrective factors or functions in order to achieve the quality standard of the reference method according to DIN EN 12341.

In the process of drawing up a European standard for the gravimetric determination of $PM_{2.5}$ mass concentrations, several field tests have already been carried out the results of which are currently being evaluated. Limit values and reference methods have so far not been determined yet. Currently, a reference method is being prepared by CEN. For the mean time, i.e. until this reference method is available as a European standard, the EU Commission has issued a decision /58/ on a preliminary reference method for $PM_{2.5}$ measurements.

4.2.2.4 Lead

For fixed measurements the 22nd BImSchV provides the following regulations:

Until 31 December 2004, the Appendix of Directive 82/884/EEC, and subsequently the EN 12341 standard is to be applied for the sampling of lead. The reference method for the analysis of lead is described in ISO 9855: Ambient air - Determination of the particulate lead content of aerosols collected on filters.

Sampling Time: One day
Duration of one Measurement Programme (Evaluation Period): One year
Measurement Frequency: Until 31 December 2004: samplings on at least 15 working days per month. The sampling days are to be distributed as equally as possible over the measurement period. Afterwards: Random sampling instead of continuous measurements can be carried out if the number of measurements is sufficiently large to enable the levels observed to be determined (see Chapter 5.3.2.4).

4.2.2.5 Benzene

Averaging Determination Period: One calendar year
Duration of one Measurement Programme (Evaluation Period): One calendar year
Measurement Frequency: Continuous measurement. Random sampling if the number of measurements is sufficiently large to enable the levels observed to be determined (see Chapter 5.3.2.4).

The reference method (active sampling onto an absorption cartridge, subsequent gas-chromatographic evaluation) is currently being standardized by CEN. Until a standardized CEN reference method is available, the responsible authorities may use standard methods which are based on the same measurement method.

4.2.2.6 Carbon monoxide

Sampling Time: 1 hour
Duration of one Measurement Programme (Evaluation Period): non-overlapping moving 8-hour mean value
Measurement Frequency: Continuous Measurement. Random sampling if the number of measurements is sufficiently large to enable the levels observed to be determined (see Chapter 5.3.2.4).

The reference method (non-dispersive infrared spectrometry – NDIR) is currently being standardized by CEN. Until a standardized CEN reference method is available, the responsible authorities may use standard methods which are based on the same measurement method.

4.2.3 23rd Ordinance for the Federal Immission Control Act (23rd BImSchV)

The 23rd BImSchV, which concerns air pollution caused by motor traffic, will be superseded by the 33rd BImSchV (see Chapter 3.4). It contains the following instructions:

Measuring site locations:
Locations where presumably the highest exposition of the population occurs in places or areas where an exceeding of concentration limit values for nitrogen dioxide, soot or benzene is to be expected.

Measuring height:
Between 1.5 and 3.5 m above ground, minimum distance from buildings 1 m, at least 4 m away from the middle of the nearest traffic lane.

Measuring period:
Normally 1 year, at least 6 months

Measuring frequency:
Two 30-mins mean values (equally distributed over the day) or one 24-hrs mean value per week.

4.2.4 33rd Ordinance for the Federal Immission Control Act (33rd BImSchV)

The draft of the 33rd BImSchV /26/ specifies the following macroscale criteria for the selection of site locations for fixed measurements of ambient air ozone and its precursors for which the measurement of small micro-environments is to be avoided:

In urban areas, measuring sites are to be installed which are representative of several sq kms and which are located outside the sphere of influence of local emission sources.

As guiding points for further types of measuring sites, surrounding areas of several dozen sq kms (suburban areas), several hundred sq kms (rural areas), and between 1,000 and 10,000 sq kms (rural background) are specified as regions the sampling sites are to be representative of.

The criteria for the selection of site locations for the measurement of micro-environments laid down in the 33rd BImSchV correspond widely with the respective specifications of the 22nd BImSchV.

The minimum numbers of sampling sites for fixed continuous measurements (if these constitute the sole information threshold) are compiled in Table 4.3. The regulation supports the assessment of ambient air quality with regard to the observance of target values, of long-term targets, and of information and alert thresholds.

Population (in thousands)	Agglomerations (urban and suburban areas) [(a)]	Other areas (suburban and rural areas) [(b)]	Rural background
< 250		1	1 sampling site per 50,000 sq kms as average density for all areas per State [(b)]
< 500	1	2	
< 1,000	2		
< 1,500	3	3	
< 2,000	3	4	
< 2,750	4	5	
< 3,750	5	6	
> 3,750	1 additional sampling site for every 2 million inhabitants	1 additional sampling site for every 2 million inhabitants	

[(a)] At least 1 sampling site in suburban areas in which the presumably highest exposure of the population is reached. In agglomerations, at least 50% of the sampling sites should be located in suburban areas.

[(b)] One sampling site per 25.000 sq kms is recommended for geo-morphologically strongly structured terrain.

Table 4.3: Criteria for the Minimum Number of Fixed Ozone Sampling Sites

For zones and agglomerations in which long-term targets are observed, Appendix 5, Part II specifies regulations for the reduction of sampling sites to a third of the above-listed figures.

The measurement of ozone precursors is to include at least nitrogen oxides (at more than 50 % of the sampling sites) and suitable volatile organic compounds (NMVOC).

4.2.4.1 Ozone

The directive 92/72/EEC on Ambient Air Pollution by Ozone /35/ is to be repealed with the implementation of the 3rd Daughter Directive /21/.

Accordingly, the following specifications on measurement planning will become binding:

Averaging Period: One hour

Duration of Reference Period: One hour, 8 hours, one calendar year

Measurement Frequency: Continuous measurement

Reference Method: Method of analysing: UV photometry (ISO FDIS 13964)
Method of calibration: Reference UV photometer (ISO FDIS 13964, VDI 2468 Part 6)

4.2.5 Technical Instructions on Air Quality Control (TA Luft)

The revised TA Luft /24/ contains detailed regulations concerning planning, taking and evaluation of ambient air quality measurements. It concerns all plants requiring licences for operation (cf. Chapter 3.6 and Appendix 1). It can, however, in connection with the inspection of obligations imposed on plants which do not require a licence (Article 22 BImSchG) also be applied to this type of plant.

The measurement regulations are generally intended for the ascertainment of ambient air pollution within an area affected by emission sources. According to the revised TA Luft, characteristic ambient air values are no longer to be determined in relation to areas, but at assessment points where the highest pollution is to be expected. As a rule, continuous measurements are also to be carried out, unless the measurements concern ambient air pollutants for which only one annual ambient air quality value is required, or if the determination of short-term pollution peaks is not necessary.

Due to the considerable discretionary powers provided by the measurement regulations concerning the determination of assessment points, the measurements are to be carried out according to a measurement plan which has been drawn up in co-operation with the responsible authorities. Demands made of measurement plans with a particular focus on the selection of site locations are described in VDI Guideline 4280 Part 3 – Measurement strategies for the determination of air quality characteristics in the vicinity of stationary emission sources /56/ (cf. Chapter 4.3).

Details on the planning of ambient air quality measurements are compiled in Appendix 1 (full text) and in the following passage.

Regulations for the assessment of characteristic ambient air values contained in the Technical Instructions on Ambient Air Quality Control of 24 July 2002:

Evaluation area:

The area completely located within a circle around the emission source with a radius of 50 times the actual stack height, in which the additional load at the centre of emission amounts to more than 3.0 % of the long-term concentration value.

Measuring height:

1.50 - 4 m above ground; more than 1.50 m away from the side of buildings. In wooded areas higher measuring points may become necessary.

Measurement period:

Normally one year; at least six months.

Evaluation points:

Two (or more) points where the highest pollution is to be expected
One point if only annual mean values are to be determined

Measurement methods:

Normally continuous determination of initial load;
discontinuous measurements if only annual ambient air qualiry values are to be determined
Refer to Directives and Ordinances for the BImSchG, VDI Guidelines, DIN-, CEN-, and ISO-standards, accreditation of further, demonstrably equivalent methods.

Measurement frequency:

Minimum availability 75 % for continuous measurement of hourly mean values and determination of daily mean values of suspended particulate matter concentration; arithmetic projection of exceeding frequency if less than 90 % of the values are available
At least 52 measured values per measuring point in discontinuous measurements with equal distribution of sampling times over the entire measurement period
In case of insufficient data quality (according to EC Directives) the number of measured values is to be increased (determination of data quality acc. to DIN ISO 11222 in connection with DIN V ENV 13005).

4.2.6 Fourth General Administrative Instruction for the Federal Immission Control Act (4th BImSchVwV)

The requirements of the Fourth General Administrative Instruction (Determination of ambient air quality in examination areas) refer to continuous measurements (which should be the rule for substances that may be measured with suitability-tested equipment; cf. Chapter 6.1.1) and individual measurements.

Following previous EC Directives /28-30/ in the process of transferring them into German law, the Fourth General Administrative Instruction specifies that measuring sites shall be situated in areas where individuals may be exposed to possible danger, or where limit values laid down in EC Directives or in TA Luft 86 /51/ have been approached or are being exceeded, or where other harmful effects on the environment may be caused by ambient air pollution.

In order to support the implementation of the Fourth General Administrative Instruction, “Guidelines concerning the determination of measuring sites and the construction of automatic measuring sites in telemetric ambient air quality measurement networks” were published by the Federal Minister of the Interior in the *Gemeinsames Ministerialblatt* (Joint Ministerial Gazette) /59/. The Guidelines were compiled making use of the experience gathered by the individual testing institutes in the Federal Committee for Ambient Air Quality Protection (*Länderausschuss für Immissionsschutz* LAI) during the operation of their automatic ambient air quality measurement networks, but also of the results of scientific studies carried out by Dornier Systems on behalf of the Minister of the Interior and the Federal Environmental Agency /60/. The Guidelines deal with the following points:

1. Basic requirements concerning the choice of measuring site locations for ambient air quality measurements,
2. Requirements concerning the constructional design of measuring stations,
3. Requirements concerning the constructional design of sampling systems for gaseous and particulate ambient air pollutants; registration of meteorological parameters, and
4. Requirements concerning interfaces of measurement devices, data collection units and data transmission units.

While the 4th BImSchVwV has not been technically repealed yet, in the mean time, measurement planning is done on the basis of requirements laid down in current EU Directives and in the 22nd and 33rd BImSchV (also see Chapter 4.4).

4.3 Measurements in the Vicinity of Emission Sources

In the Federal Republic of Germany, there are no general regulations for measurements in the vicinity of emission sources. The Federal State of North Rhine-Westphalia had intended to introduce lee side measurements for oil refineries and petrochemical plants in the so-called “Refinery Guideline” (*Raffinerie-Richtlinie*) /61/. However, this regulation has been abandoned following the amendment of the Federal Immission Control Act of May 1990. Apart from the regulations laid down in TA Luft, VDI Guideline 4280 Part 3 “Planning of ambient air quality measurements - Measurement strategies for the determination of air quality characteristics in the vicinity of stationary emission sources” /56/ specifies requirements concerning measurement planning in areas affected by emission sources.

The Guideline describes two different measurement strategies:

For the assessment of possible diffusions, the so-called “Measurement Strategy A“ aims at the determination of the highest annual mean values of the total load or additional load respectively, with previous knowledge available, i.e. in cases where information on the spatial structure of the considered area is available. The choice of the site location as well as the assessment of the spatial transferability is carried out on the basis of dispersion models which comply with the requirements laid down in Guideline VDI 3782 Part 1 (Gauß model) /62/ or VDI 3945 Part 3 (Lagrange model) /63/.

“Measurement Strategy B” applies to the determination of the spatial distribution of ambient air pollutants within an examination area by means of temporally staggered or randomly distributed (discontinuous) measurements at no less than four measurement sites which are to be arranged in a grid pattern. For this type of measurement strategy, the choice of measuring site locations may take place randomly (network of measuring points arranged in a square, maximum distance of measuring points from each other between 250 m and 2,000 m) or in a staggered way (measurements immediately next to plants, source-oriented polar network).

The Guideline takes into consideration the current state of measurement regulations concerning evaluation areas (TA Luft 02 /24/), evaluation periods (1st and 2nd Daughter Directive /19, 20/), and data quality targets (DIN ISO 11 222 /64/, DIN V ENV 13 005 /65/).

4.4 Measurement Networks in the Federal Republic of Germany

In Germany, air quality monitoring is incumbent on the individual Federal States. Ambient air quality measurements have been carried out continuously in each Federal State, for decades in some cases. The installation of measurement networks has been described in technical literature, e.g. for Berlin /66/, North Rhine-Westphalia /67, 68/, Rhineland-Palatinate /69/, and Saarland /70/, as well as in information brochures published by the Ministries or responsible institutes, e.g. in Baden-Wurttemberg, Bavaria, Hesse, Lower Saxony, and Saxony-Anhalt. Information on the range and extent of on-going measurements can also be found in the measurement reports issued by the Federal States (see Chapter 5.4)

Over the years the measurement networks have undergone various changes, mostly for extensions. These had become necessary due to Smog Regulations, measurements concerning traffic in the frame of the implementation of the 23rd Ordinance for the BImSchG /27/, and the increased significance of ozone as ambient air pollutant in summer.

Reasons for a reduction of the number of measuring stations were the improvement of ambient air quality /29/, in particular the decrease of sulphur dioxide – for instance in the Rhein-Ruhr area from a yearly mean value of 206 $\mu g/m^3$ in 1964 to 17 $\mu g/m^3$ in 1994 /71/ -, as well as the abrogation of Smog Regulations (see Chapter 3.8). More recent and future changes result from the requirements laid down in EU Daughter Directives /19-21/, the 22nd and 33rd BImSchV /25, 26/ concerning the number of sampling sites and the measurements methods to be applied (in particular for PM_{10} measurement), but also from data quality targets to be achieved, and from the abrogation of the 23rd BImSchV /27/.

The Federal States' measurement activities (ambient air quality measuring stations, status: 1 January 2003) using automatic measuring equipment are compiled in Table 4.4. The measuring sites of the Umweltbundesamt (Federal Environmental Agency) are listed in table 4.5 (status August 2002). This information is updated regularly by the individual Federal States and is available on the internet at:

http://www.env-it.de/stationen/dispatcher?event=WELCOME
(German version)

Table 4.4: Ambient Air Measuring Stations in the Federal States (status: 1 January 2003)

Federal State	total	SO_2	NO_2/NO	CO	C_mH_n (NMVOC)	Benzene	Toluene	Xylene	Ozone	SPM	PM_{10}	H_2S
Baden-Wurttemberg	64	58	64	64	39	62	62	62	61	2	64	-
Bavaria	64	62	51	46	1	7	7	7	30	-	57	8
Berlin	23	11	22	21	-	6	6	6	11	11	15	-
Brandenburg	33	18	27	12	1	6	6	6	24	18	24	3
Bremen	7	5	7	5	-	1	-	-	5	1	5	-
Hamburg	20	15	19	9	-	7	7	7	7	6	11	-
Hesse	42	32	36	18	4	6	6	6	34	1	28	-
Mecklenburg-Western Pomerania	9	9	9	6	.	5	4	-	9	-	9	-
Lower Saxony	23	12	23	11	.	2	2	2	21	-	23	-
North Rhine-Westphalia	63	58	59	41	.	4	4	4	38	52	60	-
Rhineland-Palatinate	35	20	31	18	.	10	10	3	19	1	26	-
Saarland	11	8	8	5	.	-	-	-	6	-	6	-
Saxony	26	26	25	17	.	17	16	16	26	19	24	-
Saxony-Anhalt	32	29	33	28	.	11	11	11	26	10	24	2
Schleswig-Holstein	17	6	10	3	.	4	4	4	12	-	10	-
Thuringia	30	26	31	9	.	3	3	-	26	5	29	-
Total	499	395	454	313	45	151	148	134	355	126	415	13

Table 4.5: Measuring Sites of the Federal Environmental Agency (status: August 2002)

Measuring Site	Detection of Gases											Detections in suspended particulate matter					Meteorology	Deposition				Radiation	
	SO_2	NO_x	O_3	CO_2	CH_4	SF_6 N_2O	PAN	Hg	KW HCFC	VOC	Carbonyle	PM_{10}	$PM_{2,5}$	SO_4	Σ N	HM		Amount	PH LF	Ions	HM	UV	G
Aukrug	R	R	R									R					R						
Bassum	R	R	R									R					R						
Brotjacklriegel	R	R	R	R						3T	2T	R				M	R	W	W	W	W		
Deuselbach	R	R	R	R	R				T			R	T	T	T	M	R	T	T	T	W		
Falkenberg	R	R	R									R					R	W	W	W			
Forellenbach	R	R	R									R					R	W	W	W			R
Gittrup	R	R	R									R					R						
Helgoland	R	R	R									R					R	W	W	W			
Langen																						R	
Lehnmühle	R	R	R									R					R	W	W	W			
Leinefelde	R	R	R									T					R						
Lückendorf	R	R	R									R					R						
Melpitz	R	R	R									R					R	W	W	W			
Neuglobsow	R	R	R	R	R							R		T	T	M	R	W	W	W	W		
Öhringen	R	R	R									R					R	W	W	W			
Raisting	R	R	R									R					R	W	W	W			
Regnitzlosau	R	R	R									R					R	W	W	W			

Table 4.5 (continued): Measuring Sites of the Federal Environmental Agency (status August 2002)

Measuring Site	Detection of Gases											Detections in suspended particulate matter					Meteo-rology	Deposition				Radi-ation	
	SO_2	NO_x	O_3	CO_2	CH_4	SF_6 N_2O	PAN	Hg	KW HCFC	VOC	Carbo-nyle	PM_{10}	$PM_{2.5}$	SO_4	Σ N	HM	R	Amount	PH LF	Ions	HM	UV	G
Schauinsland	R	R	R	R	R	R	R		T			R	T	T	T	M	R	W	W	W	W	R	R
Schmücke	R	R	R	R	R					3T	2T	R				M	R	W	W	W	W		
Schorfheide	R	R	R									R					R						
Ueckermünde	R	R	R									R					R						
Waldhof	R	R	R	R			R	R		3T	2T	R	T			M	R	T	T	T	W		
Westerland	R	R	R	R								T		T	T	M	R	W	W	W	W		
Zingst	R	R	R	R	R		R	R		3T	2T	R		T	T	M	R	W	W	W	W	R	R
Zugspitze	R	R	R	R	R	R	R		T	3T	2T	R					R	P	P	P	P	R	R

SO_2 : Sulphur dioxide
NO_x: Nitrogen oxides
O_3: Ozone
CO_2: Carbon dioxide
CH_4: Methane
SF_6: Sulphur hexafluoride
N_2O: Nitrogen dioxide
PAN: Peroxiacetyl nitrate

Hg: Quicksilver
KW: Hydrocarbons
HCFC: Hydrochlorofluorcarbons
VOC: Volatile organic compounds
PM_{10} : Particulate matter < 10 µm -
$PM_{2,5}$: Particulate matter < 2.5 µm
SO_4: Sulfanes

Σ N: $\Sigma\ NH_3+NH_4^+$, $\Sigma\ HNO_3+NO_3$
HM: Heavy metals
Meteorology: Wind (direction./-speed), Temp., pressure, rel. humidity
ph/LF: pH-value, conducitbility
Ions: SO_4^{2-}, NO_3^-, Cl^-, K^+, NH_4^+, Mg^{2+}, Ca^{2+}
UV: UV-B-Radiation

G: Global radiation
R: Continuous registating device
T/W/M: daily-/Weekly-/ Monthly-sampling
P: Planed measurement
2T: 8h-measurment in 2 days
3T: 1 Sample in 3 days

5. Evaluation, Assessment, Documentation

5.1 Characteristic Values for the Assessment of Ambient Air Quality

Characteristic values for *average* and *maximum* pollutant concentrations in ambient air are determined in order to facilitate an assessment of ambient air quality. They are derived from the individual readings obtained in ambient air quality measurements. Normally, since the introduction of the second generation of EU Directives /19-21/, these values are one-hour, 8-hour, daily and annual mean values (see Chapter 4.1.3). The characteristic values used in the Federal Republic of Germany in line with the various official regulations are compiled in Table 5.1. Apart from the ambient air quality limit values laid down in TA Luft /24/, in the 4th General Administrative Instruction (BImSchVwV) /33/, in the 22nd and 33rd Ordinance for the BImSchG (BImSchV) /25, 26/, and in Directives issued by the EC /19-21, 28-30/, Table 5.1 also shows the maximum ambient air quality concentrations (*Maximale Immissionskonzentrationen*, MIK values) proposed by the Commission on Air Pollution Prevention in VDI and DIN.

Mean values	TA Luft	4th BImSch-VwV	22nd BImSchV	33rd BImSchV	EU Directives	VDI-MIK values
30 minutes						X
1 hour	X	X	X	X	X	
8 hours		X	X	X	X	
24 hours (day)	X	X	X		X	X
Month		X				
Year	X	X	X		X	X
Exceedances p.a	X		X		X	
AOT				X	X	
95th percentiles			X		X	
98th percentiles		X	X		X	
Medians		X	X		X	

Table 5.1: Characteristic Values Applied in Germany for the Evaluation of Ambient Air Quality Measurement Readings

The maximum ambient air quality concentrations (MIK values) worked out by the Commission on Air Pollution Prevention in VDI and DIN /5/ are not legally binding, nor are they included in government regulations. However, their limit values were set explicitly with regard to human health and were therefore frequently used for the assessment of ambient air quality measurement results, for example in measurement reports of the Federal States' official measuring institutes. In recent years, most parts of VDI Guideline series 2310 concerning MIK values for the protection of human health have been withdrawn.

Substance	Mean value over		
	30 minutes	24 hours	1 year
Sulphur dioxide	0.2	0.1	
Ozone	0.120		

Table 5.2: Maximum Ambient Air Quality Concentrations (MIK Values) for the Protection of Human Health Issued by the Commission On Air Pollution Prevention (VDI/DIN)

Accordingly, the 30-minutes mean value formerly used in Germany for the assessment of gaseous ambient air pollutants has lost its significance.

The assessment of pollution peaks on the basis of percentiles has been replaced by the assignment of a certain number of permissible exceedances per (calendar) year to hourly and daily mean values. The 95th percentile and 98th percentile included into the 22nd BImSchV were adopted from previous EU Directives which remain valid for a transitional period /28, 29/.

5.2 Technical Means of Evaluation

Obviously, evaluation methods will be very different for discontinuous and continuous ambient air quality measurements. Data from discontinuous measurements, generally derived from manual measurements, can be processed manually or with the help of simple computers.

In contrast, the mass of data produced in continuous ambient air quality measurement necessitates automatic evaluation.

The most simple (and oldest) way of recording data of continuous measurements is to register them with a dot or line recorder connected with the measurement equipment. This method is still useful for controlling measuring devices as part of the equipment maintenance, while nowadays the evaluation of readings obtained from automatic measuring equipment is carried out digitally.

For readings obtained from telemetric measurement networks, the analogous measurement results are integrated and, after digitising them, entered into a process computer. Usually the data are sent via ISDN to a central EDP unit /72-76/.

Any amount of measured values or intermediate evaluations can be expressed in numeric values and therefore be transmitted electronically.

5.3 Regulations for the Evaluation of Ambient Air Quality Measurements

5.3.1 Directives Issued by the Commission of the European Communities

The Daughter Directives /19-21/ for the Air Quality Framework Directive /18/ contains concrete regulations for the evaluation of ambient air quality measurements. Beside the regulations laid down in this second generation of EU Directives on ambient air quality, other regulations from previous EU Directives /28-30/ remain valid for a transitional period. The currently relevant procedures have for the most part been adopted into the 22nd and 33rd BImSchV /25, 26/ (see Chapter 5.3.2 and 5.3.4) and have also entered the regulations of the revised TA Luft /24/ (see Chapter 5.3.5).

Regarding particles (PM_{10}), the first Daughter Directive contains ambient air quality values which are to be observed in line with a two-stage plan. The limit values of the first stage are to be achieved as from 1 January 2005.

Not included in the 22nd BImSchV were the recommended limit values for the second stage, which are to be achieved as from 1 January 2010 under the proviso that they be reconsidered with regard to the experience gained in the Member States up until the year 2005.

Pollutant Protected asset	**Period**	**Limit value**	**Reference value**	**Permitted Exceedances per calendar year**	**Margin of tolerance**
[-]	[dd.mm.yy]	[µg/m³]	[-]	[-]	[%]
Particles (PM_{10}) Human health	As from 01.01.2010	50	Mean value over 24 hours	7	To be derived from data collected up until 2005
		20	Mean value over one calendar year	-	50 on 01.01.2005, yearly linear reduction until 01.01.2010

Table 5.3: Standard Limit Values for Suspended Particulate Matter and Particles (PM_{10})

5.3.2 22nd Ordinance for the Federal Immission Control Act (22nd BImSchV)

For the evaluation of ambient air quality, the 22nd BImSchV specifies the following characteristic values:

- Limit values and ambient air quality limit values as well as the assigned margins of tolerance
- Assessment threshold values
- Alert threshold values
- Threshold values for ozone / to be repealed by 33rd BImSchV
- Data quality targets

5.3.2.1 Limit Values and Ambient Air Quality Limit Values

The limit values and ambient air quality limit values contained in the 22nd BImSchV are based on the specifications laid down in previous EU Directives /28-30/, which remain valid for a transitional period, and in the 1st and 2nd Daughter Directive /19, 20/. The ambient air quality limit values refer to the standard state of 293.15 K and 101.3 kPa.

In the 1st and 2nd Daughter Directive, margins of tolerance are indicated as a percentage of the limit value. For their adoption into the 22nd BImSchV, the values have been converted into mass concentrations.

The margins of tolerance for pollutants refer to the period beginning with the Ordinance's coming into effect (12 September 2002) and ending on 31 December 2002. As from 1 January 2003 the margin of tolerance is gradually reduced year by year until the date when the limit value without margin of Tolerance is to be reached. For benzene this yearly reduction of the margin of tolerance begins on 1 January 2006 (cf. Table 5.8).

For the assessment of peak pollution loads, permissible annual exceeding frequencies have been assigned to the ambient air quality limit values for sulphur dioxide (daily and hourly value), nitrogen dioxide (hourly value) and particles (24-hour value). For SO_2 and NO_2 this corresponds to very high percentiles.

The assessment of peak pollution loads on the basis of 98th percentiles (sulphur dioxide, nitrogen dioxide) and 95th percentiles (suspended particulate matter) up until 31 December 2004 is based on the above-mentioned older EU Directives /28-30/.

The characteristic ambient air values for the respective pollutants are specified as follows:

Pollutant Protected asset	**Period**	**Ambient Air Quality Limit Value**	**Reference value**	**Permitted Exceedances per calendar year**	**Margin of tolerance**
[-]	[dd.mm.yy]	[µg/m³]	[-]	[-]	[µg/m³]
Sulphur dioxide	Until 31.12.04	80 in case of an assigned SPM value >150	Median of the daily mean values taken throughout the year	-	-
		120 in case of an assigned SPM value ≤ 150	Median of the daily mean values taken throughout the year	-	-
		130 in case of an assigned SPM value > 200	Median of the daily mean values taken in the winter period	-	-
		180 in case of an assigned SPM value ≤ 200	Median of the daily mean values taken in the winter period	-	-
		250 in case of an assigned SPM value > 350	98th percentile of all daily mean values taken throughout the year	-	-
		350 in case of an assigned SPM value ≤ 350	98th percentile of all daily mean values taken throughout the year	-	-
Sulphur dioxide Human health	As from 01.01.05	350	Mean value over 60 mins	24	90(1)
		125	Mean value between 00.00 and 24.00 hrs	3	-
Sulphur dioxide Eco-systems	As from 12.09.02	20	Calendar year and winter period	-	-

(1) as from 12.09.2002, annual reduction by 30 µg/m³ as from 01.01.2003 until 01.01.2005

Table 5.4: Ambient Air Quality Limit Values for Sulphur Dioxide

Pollutant Protected asset	**Period**	**Ambient Air Quality Limit Value**	**Reference value**	**Permitted Exceedances per calendar year**	**Margin of tolerance**
[-]	[dd.mm.yy]	[µg/m³]	[-]	[-]	[µg/m³]
Nitrogen dioxide	Until 31.12.09	200	98th percentile of all mean values taken throughout the year during 60 mins or less	-	-
Nitrogen dioxide Human health	As from 01.01.10	200	Mean value over 60 mins	18	80⁽¹⁾
		40	Mean value over one calendar year	-	16⁽²⁾
Nitrogen dioxide Vegetation	As from 12.09.02	30	Mean value over one calendar year	-	-

(1)as from 12.09.2002, annual reduction by 10 µg/m³ as from 01.01.2003 until 01.01.2010
(2)as from 12.09.2002, annual reduction by 2 µg/m³ as from 01.01.2003 until 01.01.2010

Table 5.5: Ambient Air Quality Limit Values for Nitrogen Dioxide and Nitrogen Oxides

Pollutant Protected asset	**Period**	**Ambient Air Quality Limit Value**	**Reference value**	**Permitted Exceedances per calendar year**	**Margin of tolerance**
[-]	[dd.mm.yy]	[µg/m³]	[-]	[-]	[µg/m³]
Suspended Particulate Matter (SPM)	Until 31.12.04	150	Arithmetic mean of daily mean values taken throughout the year	-	-
		300	95th percentile of all daily mean values taken throughout the year	-	-
Particles (PM_{10}) Human health	As from 01.01.05	50	Mean value determined over 24 hrs	35	15⁽¹⁾
		40	Mean value determined over one calendar year	-	4.8⁽²⁾

(1)as from 12.09.2002, annual reduction by 5 µg/m³ as from 01.01.2003 until 01.01.2005
(2)as from 12.09.2002, annual reduction by 1.6 µg/m³ as from 01.01.2003 until 01.01.2005

Table 5.6: Ambient Air Quality Limit Values for Suspended Particulate Matter (SPM) and Particles (PM_{10})

Pollutant Protected asset	**Period**	**Ambient Air Quality Limit Value**	**Reference value**	**Permitted Exceedances per calendar year**	**Margin of tolerance**
[-]	[dd.mm.yy]	[µg/m³]	[-]	[-]	[µg/m³]
Lead	Until 31.12.04	2	Annual mean value	-	-
Lead Human health	As from 01.01.05	0.5	Mean value over one calendar year	-	0.3⁽²⁾
Lead	As from 01.01.10	0.5[1)]	Mean value over one calendar year	-	0.04(3)

1) In the vicinity of certain areas which have over decades been subject to pollution caused by industrial plants, the ambient air quality value is set to 1.0 µg/m³ from 1 January 2005 on; for details see 22nd BImSchV Article 5.

(2) as from 12.09.2002, annual reduction by 0.1 µg/m³ as from 01.01.2003 until 01.01.2005

(3) as from 12.09.2002, annual reduction by 0.05 µg/m³ as from 01.01.2003 until 01.01.2010

Table 5.7: Ambient Air Quality Limit Values for Lead

Pollutant Protected asset	**Period**	**Ambient Air Quality Limit Value**	**Reference value**	**Permitted Exceedances per calendar year**	**Margin of tolerance**
[-]	[dd.mm.yy]	[µg/m³]	[-]	[-]	[µg/m³]
Benzene Human health	As from 01.01.10[1)]	5	Mean value over one calendar year	-	5[2)]

1) Prolongation possible by five years at the most; for details see 22nd BImSchV Article 6

2) as from 12.09.2002, annual reduction of margin of tolerance by 1 µg/m³ as from 01.01.2006

Table 5.8: Ambient Air Quality Limit Values for Benzene

Pollutant Protected asset	**Period**	**Ambient Air Quality Limit Value**	**Reference value**	**Permitted Exceedances per calendar year**	**Margin of tolerance**
[-]	[dd.mm.yy]	[µg/m³]	[-]	[-]	[µg/m³]
Carbon monoxide Human health	As from 01.01.05	10	Highest 8-hour mean value[1)]	-	6(2)

1) Non-overlapping moving 8-hour mean, calculated on the basis of hourly updated 1-hour means

2) as from 12.09.2002, annual reduction by 2 µg/m³ as from 01.01.2003 until 01.01.2005

Table 5.9: Ambient Air Quality Limit Values for Carbon Monoxide

5.3.2.2 Alert Threshold Values

As soon as alert threshold values have been exceeded, the Member States are to take immediate measures (e.g. current warnings, recommendations for the behaviour of particularly endangered parts of the population, action plans including immediate measures).

The alert threshold value is 400 µg/m³ for nitrogen dioxide, and 500 µg/m³ for sulphur dioxide, each determined as a mean value over 60 mins, measured during three consecutive hours.

5.3.2.3 Assessment Threshold Values

The monitoring of ambient air quality in zones and agglomerations is based on assessment threshold values (cf. Chapter 4.2.1 and 4.2.2). A detailed listing can be found in Table 4.1.

5.3.2.4 Data Quality Targets

The data quality targets, specified as a guiding principle for quality assurance programmes in the 22nd BImSchV, refer to the required accuracy of assessment methods (measurements, model calculations, objective estimates, see Chapter 4.2.1), to minimum requirements concerning data registration, and to the minimum duration of samplings. Data quality targets for fixed measurements are shown in Table 5.10.

	Sulphur dioxide, nitrogen dioxide and nitrogen oxides	Particles and lead	Benzene	Carbon monoxide
Continuous measurement[1)]				
Accuracy / uncertainty[2)]	15 %	25 %	25 %	15 %
Minimum data registration	90 %	90 %	90 %	90 %
Orientation measurement				
Accuracy / uncertainty[2)]	25 %	50 %	25 %	15 %
Minimum data registration	90 %	90 %	90 %	90 %
Minimum duration[3)]	14 %	14 %	14 %	14 %

[1)] Random samplings (equally distributed over the year) instead of continuous measurements may be carried out if an accuracy of 10 % can be established, within a confidence region (systematic deviation + 2 standard deviations) of 95 %, in relation to continuous measurements.

[2)] Accuracy (columns 2, 3) defined in ISO 5725-1, uncertainty (columns 4, 5) defined in ISO 1993 /76/

[3)] One measurement per week randomly selected and equally distributed over the year, or eight weeks equally distributed over the year

Table 5.10: Data Quality Targets for Fixed Measurements

5.3.3 23rd Ordinance for the Federal Immission Control Act (23rd BImSchV)

The 23rd BImSchV /27/ specifies concentration values which, if exceeded, require the consideration of reductive measures. It will be superseded by the 33rd BImSchV /26/.

The following concentration values are specified:

Nitrogen dioxide:	160 µg/m^3 (98th percentile of all 30-mins mean values of one year)
Soot:	14 µg/m^3 as from 1 July 1995 (arithmetic annual mean value) 8 µg/m^3 as from 1 July 1998 (arithmetic annual mean value)
Benzene:	15 µg/m^3 as from 1 July 1995 (arithmetic annual mean value) 10 µg/m^3 as from 1 July 1998 (arithmetic annual mean value)

5.3.4 33rd Ordinance for the Federal Immission Control Act (33rd BImSchV)

For the evaluation of ambient air pollution through ground-level ozone, the 33rd BImSchV /26/ specifies the following characteristic values:

- Ambient air quality limit values
- Target values and long-term objectives
- Information thresholds and alert thresholds
- Data quality targets

5.3.4.1 Ambient Air Quality Limit Values, Target Values and Long-term Objectives, Information Thresholds and Alert Thresholds

Ambient air quality limit values are defined as 1-hour mean values, 8-hour mean values during one day, or as AOT40 value (protection of vegetation) for the period May-July, determined as mean values over 5 years. Beside the concentration, the AOT40 value (AOT = "accumulation over threshold") also takes into account the duration of the pollution. It corresponds to the summed up difference between ozone concentrations over 80 µg multiplied with hrs per m^3, and concentrations below 80 µg multiplied with hrs per m^3. For the determination of the AOT40 value, only the daily 1-hour mean values between 08.00 and 20.00 hrs CET are used.

Ambient Air Quality Limit Value for ground-level ozone Protected asset	**Period**	**Ambient Air Quality Limit Value**	**Reference value**	**Permitted Exceedances per calendar year**
Target value Human health	As from 01.01.10	120 µg/m³	Highest 8-hour mean value during one day	25 per calendar year, mean value over 3 years
Target value Vegetation	As from 2010	$18 \cdot 10^3$ µg·h/m³	AOT for the period May-July, mean value over 5 years	-
Long-term objective Human health	-	120 µg/m³	Highest 8-hour mean value during one day	-
Long-term objective Vegetation	-	$6 \cdot 10^3$ µg·h/m³	AOT for the period May-July, mean value over 5 years	-
Information threshold	As from 09.09.03	180	1-hour mean value	-
Alert threshold	As from 09.09.03	240	1-hour mean value	-

Table 5.11: Ambient Air Quality Limit Values for Ground-Level Ozone

5.3.4.2 Data Quality Targets

Data quality targets for measurements of ground-level ozone and its precursors are specified as follows:

	For ozone, NO and NO_2
Continuous fixed measurements	
Uncertainty of single measurements[1)]	15 %
Minimum data registration	Summer: 90 %, winter: 75 %
Orientation measurement	
Uncertainty of single measurements[1)]	30 %
Minimum data registration	90 %
Minimum duration	> 10 % in summer

[1)] Uncertainty according to guiding principles laid down in the ISO Guideline on measurement uncertainties /78/ or ISO 5725-1 /77/ or equivalent method

Table 5.12: Data Quality Targets for Measurements

5.3.5 Technical Instructions on Air Quality Control (Technische Anleitung zur Reinhaltung der Luft, TA Luft)

In comparison with TA Luft 1986 /50,/ the characteristic ambient air quality values have been modified according to the specifications laid down in current EU Directives. In the revised version of TA Luft the values are defined as follows:

- **Characteristic Ambient Air Quality Values**

The **Annual Ambient Air Quality Value** is defined as the concentration or deposition value of a substance, calculated as mean value over one calendar year

The **Daily Ambient Air Quality Value** is defined as the concentration of a substance, calculated as mean value over one calendar day taking into account the assigned permissible exceeding frequency (number of days) during one calendar year

The **Hourly Ambient Air Quality Value** is defined as the concentration of a substance, calculated as mean value over 60 mins (for example 08.00 to 09.00 hrs) taking into account the assigned permissible exceeding frequency (number of hours) during one calendar year

Ambient Air Quality Values, i.e. pollutant concentrations, indicate the mass of pollutants in relation to the volume of polluted air (for gaseous substances related to 293.15 K and 101.3 kPa), or the amount of deposition (of solid, liquid or gaseous pollutants caused by gravity within a defined area and period of time).

The Ambient Air Quality Values laid down in TA Luft can be found in Table 5.13.

a) Ambient Air Quality Values for the protection of human health

Pollutant	Concentration [µg/m^3]	Averaging period	Permitted Exceedances per calendar year
Sulphur dioxide	50	1 year	-
	125	24 hrs	3
	350	1 hr	24
Nitrogen dioxide	40	1 year	-
	200	1 hr	18
Benzene	5	1 year	-
Tetrachloroethylene	10	1 year	-
Suspended particulate matter (PM$_{10}$)	40	1 year	-
	50	24 hrs	35
Lead and its inorganic compounds in suspended particulate matter (PM$_{10}$), indicated as lead	0.5	1 year	-

b) Ambient Air Quality Values for the protection against considerable disadvantages and substantial impairment caused by dust deposition

Pollutant	Deposition [g/m^{2}d]	Averaging period
Dust deposition (non-dangerous dust)	0.35	1 year

c) Ambient Air Quality Values for the protection of eco-systems and vegetation

Pollutant	Concentration [µg/m^3]	Averaging period
Sulphur dioxide	20	1 year and winter
Nitrogen oxides, indicated as nitrogen dioxide	30	1 year

d) Ambient Air Quality Values for hydrogen fluoride for the protection against considerable disadvantages

Pollutant	Concentration [µg/m^2]	Averaging period
Hydrogen fluoride and gaseous inorganic fluorides, indicated as fluorine	0.4	1 year

e) Ambient Air Quality Values for the protection against ecologically harmful pollutant depositions

Pollutant	Deposition [µg/m^{2}d]	Averaging period
Arsenic and its inorganic compounds	4	1 year
Lead and its inorganic compounds	100	1 year
Cadmium and its inorganic compounds	2	1 year
Nickel and its inorganic compounds	15	1 year
Mercury and its inorganic compounds	1	1 year
Thallium and its inorganic compounds	2	1 year

Table 5.13: Ambient Air Quality Values in the Technical Instructions On Air Quality Control

For the evaluation of ambient air quality measurements and a comparison with ambient air quality values, the Technical Instructions on Air Quality Control (TA Luft) /24/ requires the determination of the following characteristic values: annual [IJ], daily [IT] and hourly [IS] ambient air quality value (or IJV [annual], ITV [daily] and ISV [hourly] as characteristic values of the measured "initial load" and the "additional load" IJZ [annual], ITZ [daily] and ISZ [hourly] caused by a new industrial plant, which have been determined by means of a dispersion model in the course of the licensing procedure).

The determination of the total load in the monitoring procedure is performed analogously to the determination of the initial load in the course of the licensing procedure.

The ambient air quality values are observed if the following conditions are fulfilled:

Annual Ambient Air Quality Value (IJ):

The annual ambient air quality value is observed if the total of initial load and additional load for the respective pollutant is below or equal to the annual ambient air quality value.

- $IJV + IJZ \leq IJ$

Daily Ambient Air Quality Value:

The daily ambient air quality value is definitely observed if the following conditions are fulfilled additively:

- $IJV \leq 0.9\ IJ$
- $ITV \leq 0.8\ IT$
- $ITZ \leq IT$

In addition to that, the daily ambient air quality value is observed if the total load - determined by adding additional load for the year and initial load concentration values for the day – measured at the respective assessment points is below or equal to the ambient air quality value for 24 hours, or if an evaluation proves that the permissible exceeding frequency has been observed.

Hourly Ambient Air Quality Value

The hourly ambient air quality value is definitely observed if the following conditions are fulfilled additively:

- IJV $\leq$ 0.9 IJ
- Exceeding frequency (ISV) $\leq$ 0.8 permissible exceeding frequency (IS)
- ISZ $\leq$ IS - IJ

In addition to that, the daily ambient air quality value is observed if the total load - determined by adding additional load for the year and initial load concentration values for the hour - measured at the respective assessment points is below or equal to the ambient air quality value for 1 hour, or if an evaluation proves that the permissible exceeding frequency has been observed.

The possible range for using ambient air quality data obtained in discontinuous measurements according to TA Luft, in particular for air quality control plans, is described – due to the substantial amount of information gathered in North Rhine-Westphalia – in a report issued by the *Landesanstalt für Immissionsschutz* based in Essen /79/.

5.3.6 Fourth General Administrative Instruction for the Federal Immission Control Act (4th BimSchVwV)

Evaluation procedures laid down in the Fourth General Administrative Instruction (see Chapters 3.7 and 4.2.6) have been designed along the lines of the regulations in Directives issued by the Commission of the European Communities /28-30/ and those contained in TA Luft 86 /51/. The following characteristic values are to be determined:

Daily mean values	for gaseous air pollutants
Arithmetic means for months and calendar year	for gaseous air pollutants, for black smoke, for suspended particulates and components associated with suspended particulate matter
Maximum values, medians and 98th percentiles of the hourly and 8-hourly mean values for the calendar year	for ozone
Medians for the year and for the period 01/10 through 31/03, as well as 98% values for the period ¼ through 31/03 (in line with EC Directive 89/427/EEC)	for sulphur dioxide and suspended particulate matter
98% values for one calendar year	for gaseous air pollutants, for black smoke in atmospheric air, for suspended particulate matter and components associated with suspended particulate matter
Monthly means	for dust deposition
Annual means	for dust deposition and components associated with dust deposition

Table 5.14: Characteristic Values in the 4th BimSchVwV

Medians and 98% values are to be determined employing non-parametric statistics. After determining the monthly means, non-overlapping moving 12-monthly means should be worked out (i.e. 12-monthly mean values with the beginning and end shifted every month by one month).

5.3.7 Assessment Scales of the Federal Committee for Ambient Air Quality Protection (LAI)

For a number of relevant air pollutants, the Federal Committee for Ambient Air Quality Protection (LAI) has published assessment scales for the evaluation of ambient air pollution determination. Apart from the assessment scales for carcinogenic substances described in 5.3.6.1, assessments of ambient air pollution caused by ammonia and its compounds /80/, mercury and its compounds /81/, and vanadium /82/ are available.

In addition to this, a draft has been introduced concerning the evaluation of pollutants for which no ambient air quality values have been determined /83/.

5.3.7.1 Carcinogenic Air Pollutants

In a final report of the working group "Risk of Cancer Due to Air Pollution" of the Federal Committee for Air Quality Protection (LAI) /85/, the assessment scales described in Table 5.15 are defined as arithmetic mean values according to No. 2.6 TA Luft 86 (amendment in 2002) for a restriction of the risk of cancer caused by air pollutants on the basis of a total risk of 1 : 2,500.

Pollutant	Assessment scale
Arsenic and its inorganic compounds	5 ng/m³
Fibrous asbestos¹⁾	88 F/m³
Benzene	2.5 µg/m³
Cadmium and its compounds	1.7 ng/m³
Diesel soot particles	1.5 µg/m³
Polycyclic aromatic hydrocarbons, characteristic substance: benzo-(a)-pyren	1.3 ng/m³
2,3,7,8-Tetrachlorodibenzo-p-dioxin	16 fg/m³

¹⁾ Definition of a fibre: thickness $\leq 3\ \mu m$; length $\geq 5\ \mu m$; ratio: $\frac{length}{thickness} \geq \frac{3}{1}$

Table 5.15: Assessment Scales of the Federal Committee for Ambient Air Quality Protection for a limitation of cancer risk due to air pollution on the basis of a total risk of 1 : 2,500. Arithmetic mean values in accordance with the measuring and assessment guidelines of No. 2.6 TA Luft 86.

In the LAI report “Risk of Cancer Caused by Ambient Air Pollution through Inorganic Compounds” /85/, long-term values for chromium (17 ng/m³) and nickel (10 ng/m³) are specified. For toluene and xylene, annual mean values of 30 µg/m³ are defined as target values /86/.

5.3.7.2 Odour Threshold Values

The Federal Committee for Ambient Air Quality Protection has published a guideline on odour immission, the regulations of which have to be observed until the promulgation of relevant national Administrative Instructions /87, 88/. The odour threshold values included in this guideline can be found in Table 5.16.

In the current version of 13 May 1998, these odour threshold values have been cancelled. However, for orientation purposes, chemical analysing methods using these values may still be applied for odour determinations /89/. As a rule, odour emissions are to be determined in consideration of DIN EN 13725 – Determination of odour substance concentrations with dynamic olfactometry /90/.

Most Federal States have integrated the odour immission guideline as an instruction in their *Land* legislation (including the publication in their Official Gazette).

Table 5.16: Odour Threshold Values Issued by the Federal Committee for Ambient Air Quality Protection

Substance	ml/m³ (ppm)	mg/m³
Acetaldehyde	0.2	0.4
Acetic acid	1.0	2.5
Acetone	20.0	48.0
Acrolein	0.2	0.5
Acrylic ester	0.0005	0.002
Acrylonitrile	20.0	44.0
Ammonia	2.7	1.9
n-Amylacetate	0.07	0.4
Benzene	5.0	16.2
Butadiene	0.5	1.1
i-Butanol	0.7	2.2
n-Butanol	0.14	0.4
2-Butanone	2.0	6.0
Butyric acid	0.001	0.004
n-Butyl acetate	0.006	0.03

Carbon disulphide	0.2	0.6
Chlorobenzene	0.2	0.9
o-		
m-Cresol	0.001	0.004
p-		
Cyclohexanone	0.1	0.4
Dibutylamine	0.26	1.4
Diethylamine	0.02	0.06
Dimethylamine	0.05	0.09
Dimethyl formamide	100.0	303.0
Diphenyl ether	0.1	0.7
Ethanol	10.0	19.1
Ethyl acetate	6.0	22.0
Ethylene oxide	300.0	549.0
2-Ethyl hexanol	0.08	0.4
Formaldehyde	0.1	0.1
Formic acid	1.0	1.9
Hydrogen sulphide	0.002	0.003
Mercapto ethylene	0.001	0.003
Methanol	4.0	5.3
Methylene chloride	200.0	706.0
Methanethiol	0.02	0.04
Methyl acrylate	0.05	0.2
Morpholine	0.01	0.04
Nitrobenzene	0.005	0.03
i-Pentanol	0.05	0.2
n-Pentanol	0.2	0.7
Phenol	0.05	0.2
Phosgene	1.0	4.1
Propandiamine	0.01	0.03
i-Propanol	3.0	7.5
Propionic acid	0.04	0.2
i-Propylbenzene	0.008	0.04
i-Propyl ether	0.02	0.09
Propylene oxide	10.0	24.0
Pyridine	0.02	0.07
Tetrachloroethylene	5.0	34.0
Tetrachloromethane	100.0	640.0
Toluene	2.0	7.6
Toloylene 2,4-diisocyanate	2.0	14.4
Trichloroethylene	20.0	109.0
Triethylamine	0.09	0.4
Trimethylamine	0.0002	0.0005
1,3,5-Trimethylbenzene	0.4	2.0

5.4 Measurement Reports

The results of continuous ambient air quality measurements are published by the individual Federal States in monthly and/or annual reports. They are also integrated in air quality control plans and action plans according to Article 47 BImSchG.

September 2002 was the deadline for submitting the first report to the EU Commission in which established exceedings of limit values are listed /91/. The first action plans, which may be included in air quality control plans, are to be worked out until the end of 2003 /92/.

Länder (Federal States) institutions increasingly publish the results of ambient air quality measurements also by means of electronic media (viewdata, teletext, internet).

Table 5.17 lists the monthly and annual reports (status: 12 August 2003) currently published by the Federal States and by the Federal Environmental Agency (UBA) as well as links to their measurement networks (continuous updates of measured values).

The measuring institutes of the Federal States report the information gathered in their continuous measurements of ambient air quality to the Federal Environmental Agency for a central evaluation.

The *VDI-Nachrichten* (a specialist news periodical by the VDI) also publishes current ambient air quality data from measuring stations in the Federal States, as well as information on how to retrieve these data via telephone or electronically.

Table 5.17: Reports On Ambient Air Quality Measurement Results

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Baden-Wurttemberg
Ambient Air Quality Concentrations. Monthly and annual reports.
Landesanstalt für Umweltschutz Baden-Württemberg, Griesbachstr. 3, 76185 Karlsruhe

www.lfu.baden-wuerttemberg.de/lfu/abt3/umeg

Bavaria
Air Hygiene Reports. Monthly and annual reports.
Bayerisches Landesamt für Umweltschutz, Rosenkavalierplatz 3, 81925 München

www.bayern.de/lfu/luft/index.html

Berlin
Air Pollution in Berlin. Monthly and annual reports. Senatsverwaltung für Stadtentwicklung, Umweltschutz und Technologie, Am Köllnischen Park 3, 10179 Berlin

www.met.fu-berlin.de/senum/index.html

Brandenburg
Air Quality in Brandenburg. Monthy and annual reports.
Landesumweltamt Brandenburg, Berliner Str. 21 - 25, 14467 Potsdam

www.brandenburg.de/land/mlur/i/luftwert.htm

Bremen
Bremen Air Quality Monitoring System. Monthly reports.
Der Senator für Umweltschutz und Stadtentwicklung, Hanseatenhof 5, 28195 Bremen

www.umwelt.bremen.de/buisy/scripts/buisy.asp?doc=BLUES+-+Das+Bremer+Luftueberwachungssystem

Hamburg
Air Quality Measurement Network Hamburg. Monthly reports.
Freie und Hansestadt Hamburg, Umweltbehörde, Steindamm 22, 20099 Hamburg

www.hamburger-luft.de

Hesse
Monthly and annual reports on air hygiene.
Hessische Landesanstalt für Umwelt, Rheingaustr. 186, 65203 Wiesbaden

www.hlug.de/medien/luft/index.htm

Lower Saxony
Air Hygiene Monitoring System Lower-Saxony (LÜN), monthly reports (until July 1996) and annual reports. Niedersächsisches Landesamt für Ökologie, Göttinger Str. 14, 30449 Hannover

www.62.8.193/cgi-bin/dB4web_c.exe/Projekt3/Projekt3/index.htm?th=2&kn=14833&adresse=1

Mecklenburg-Western Pomerania
Monthly reports. Landesamt für Umwelt und Natur Mecklenburg-Vorpommern,
Abt. Immissionsschutz, Boldebucker Weg 3, 18273 Güstrow-Gülzow.
Air quality reports (annual reports).
Ministerium für Bau, Landesentwicklung und Umwelt, Schloßstr. 6 - 8, 19053 Schwerin

www.lung.mv-regierung.de/index_luft_1024.htm

North-Rhine Westphalia
Reports on air quality in the Rhine and Ruhr area. Annual “LQUS” reports. Annual “MILIS” reports on mobile measurements.
Landesumweltamt Nordrhein-Westfalen, Wallneyer Str. 6, 45133 Essen-Bredeney

www.lua.nrw.de/index.htm?luft/temes/stat.htm

Rhineland-Palatinate
Monthly reports on measurement results of the Central Ambient Air Quality Monitoring Network (ZIMEN) for Rhineland-Palatinate.
Landesamt für Umweltschutz und Gewerbeaufsicht, Messinstitut für Immissions-, Arbeits- und Strahlenschutz, Rheinallee 97 - 101, 55118 Mainz

www.luft-rlp.de/aktuell/messwerte

Saarland
Air quality measurements. Quarterly reports on measurement results of the Ambient Air Quality Monitoring Network Saar - IMMESA.
Ministerium für Umwelt, Energie und Verkehr des Saarlandes, Hardenbergstr. 50, 66119 Saarbrücken

www.umweltserver.saarland.de/luft/luft-pages/karten_luft/karte_frame.html

Saxony
Monthly and annual reports on ambient air quality.
Freistaat Sachsen, Landesamt für Umwelt und Geologie, Wasastr. 50, 01445 Radebeul

www.umwelt.sachsen.de/de/wu/umwelt/lfug/lfug-internat/luft-laerm/lima_1468.htm

Saxony-Anhalt
Monthly “LÜSA” reports.
Landesamt für Umweltschutz Sachsen-Anhalt, Reideburger Str. 47 - 49, 06116 Halle (Saale).
Annual reports (on ambient air quality monitoring) by the State of Saxony-Anhalt.
Ministerium für Umwelt, Naturschutz und Raumordnung des Landes Sachsen-Anhalt,
Referat für Öffentlichkeitsarbeit, Pfälzer Str. 1, 39106 Magdeburg

www.mu.sachsen-anhalt.de/lau/luesa

Schleswig-Holstein
Monthly reports “Ambient Air Quality Monitoring in Schleswig-Holstein“.
Gewerbeaufsichtsamt Itzehoe, Oelixdorfer Str. 2, 25524 Itzehoe.
„Measurement Reports“ (annual reports). Ministerium für Natur und Umwelt, Grenzstr. 1, 24149 Kiel

www.umwelt.landsh.server.de/?1451

Thuringia
Monthly and annual reports on air hygiene in Thuringia.
Thüringer Landesanstalt für Umwelt, Abt. Immissions- und Strahlenschutz,
Prüssingstr. 25, 07745 Jena-Göschwitz

www.tlug-jena/luftaktuell/421_11001_01_idx.html

Federal Environmental Agency (Umweltbundesamt, UBA)
Monthly reports from the UBA measurement network.
Umweltbundesamt, Bismarckplatz 1, 14193 Berlin

www.env.it.de/luftdaten/start.fwd

6. Measurement Principles and Measurement Methods

The measurement methods for ambient air quality measurement can be divided into

- discontinuous methods and
- continuous methods.

Discontinuous methods are mostly manual methods for which sampling on site and analysis in the laboratory are two separate steps. Continuous methods typically involve stationary automatic equipment for both sampling and analysis.

However, these distinctions do not quite take account of the great variety of air quality measurement methods. "Discontinuous" measurements can be carried out with automatic equipment at the sampling site as well as in the laboratory. The employment of automatic sampling equipment - e.g. with several, independently and subsequently controllable absorption receptacles - allows continuous and uninterrupted measurements. Analyses can be carried out with an automatic apparatus in the laboratory.

One specific example is the measurement of dust deposition. This is in principle a discontinuous, manual measurement method, but due to the long exposition time of one month without any interruptions for a single measurement, it is termed semi-continuous.

Continuous measurements have the advantage of providing uninterrupted air monitoring over a certain period of time. They are most suitable for a stationary employment but the equipment can also be installed in mobile monitoring laboratories. In case of ambient air pollution with higher *temporal* than *spatial* variations (for example in city areas with widely distributed pollutants /93, 94/), continuous measurements provide advantages for the monitoring of ambient air quality.

Expenditures for automatic continuous measurements are considerable: the measuring equipment is quite expensive and highly qualified personnel is needed for its operation. Therefore, equipment for continuous ambient air quality measurements has so far been developed only for a limited number of substances.

Discontinuous, manual ambient air quality measurement methods are most useful for random sampling and for covering many measuring sites in an examination area. Often, the measurement apparatus can be employed for the detection of several different substances. And finally, this working area covers the measurement of all those substances for which no automatic equipment is available.

6.1 Continuous Measurements

Continuous ambient air quality measurements are carried out mainly for the implementation of government regulations - in particular of the Technical Instructions on Air Quality Control (TA Luft, see Chapters 3.6, 4.2.5 and 5.3.5), of the 22nd and 33rd BImSchV (see Chapters 3.3, 3.5, 4.2.2, 4.2.4, 5.3.2 and 5.3.4) and of the Guidelines issued by the European Communities (see Chapters 3.1, 4.2.1 and 5.3.1).

Listings of suitable measuring devices for continuous measurements are published on behalf of the Federal Minister for the Environment, Nature Protection and Nuclear Safety (BMU) by the Federal Environmental Agency (*Umweltbundesamt*) following consultation with the responsible authorities of the individual Federal States. Until 2003 these publications were made in the Joint Ministerial Gazette (*Gemeinsames Ministerialblatt*), whereas today they appear in the Federal Gazette (*Bundesanzeiger*).

These publications contain information on the equipment manufacturer, the test report prepared by the testing institute as well as comments or details on restrictions concerning the use of the equipment. They do not include equipment descriptions, measurement principles or performance characteristics. These can be found in the test reports.

6.1.1 Suitability Tests

The publication of suitable equipment for continuous ambient air quality measurement by the BMU requires the successful completion of a suitability test, and the approval of the Sub-Committee on Air / Monitoring in the "Federal States' Committee for Ambient Air Quality Protection" ("Länderausschuss für Immissionsschutz", LAI) /95/. Standardized requirements for these tests were published in the Joint Ministerial Gazette /96/ as early as 1975 in the "Guidelines for the suitability test of continuously operating ambient air quality measuring equipment". A revised version was published in 1981 /97/.

These Guidelines were repealed and superseded by VDI Guideline 4202 Part 1, Minimum requirements for automated ambient air quality measuring systems – Point-related measurement methods of gaseous and particulate pollutants /98/. The minimum requirements refer to the constructive design of the device as well as performance characteristics as shown in Table 6.1. They partly relate to so-called reference values (see Table 6.2) which are based on ambient air limit values according to EU Directives.

Performance Characteristics	**Requirements**
Full scale	$\geq B_2$
Linearity	$\leq 0.05\ B_1$ (range 0 to B_1) $\leq 0.01\ B_2$ (range 0 to B_2)
Detection limit	$\leq B_0$
Response time	≤ 5 % of averaging period (180 s)
Availability	≥ 90 %
Period of unattended operation	28 days if possible, at least 14 days
Reproducibility	≥ 10
Temperature dependence at the zero point	$\leq B_0$
Temperature dependence of measured value	$\leq 0.05\ B_1$
Drift at zero point	$\leq B_0$
Drift of measured value	$\leq 0.05\ B_1$
Mains voltage	$\leq B_0$
Interference error	$\leq 0.03\ B_2$
Uncertainty of test gas	$\leq 0.01\ B_2$

Table 6.1: Minimum Requirements VDI 4202 Part 1

Pollutant	**Reference Value**		
	B_0 µg/m³	B_1 µg/m³	B_2 µg/m³
SO_2	2	40	700
NO_2	3	60	400
PM_{10}	2	40	200
CO	1×10^3	20×10^3	60×10^3
Benzene	0.5	10	100
O_3	4	80	360

Table 6.2: Reference Values for Minimum Requirements acc. to VDI 4202 Part 1

The extended measurement uncertainty (total uncertainty) is to comply with the data quality requirements laid down in EU Daughter Directives. It is determined in the course of the suitability test acc. to DIN EN ISO 14 956 /99/ from uncertainty contributions of the performance characteristics according to the law of uncertainty propagation.

A Guideline concerning optical long-path monitoring equipment (VDI 4202 Part 2) is available as a draft /100/.

Basic principles concerning test plans for automatic measuring devices are described in VDI Guideline 4203 Part 1, Issue 10/2001 /101/. Detailed specifications concerning test plans for spot measurement of gaseous and particulate ambient air pollutants are contained in the Guideline Draft VDI 4203 Part 3 /102/.

Suitability tests are normally carried out following a request by the measuring equipment manufacturer to an accredited testing institute. On completion of the suitability test, which is carried out at the manufacturer's expense, the institute provides a test report to the Federal Environmental Agency (UBA) and to the Sub-Committee for Air / Monitoring in the LAI. If their assessment is positive, the notification follows as mentioned above through the UBA on behalf of the Federal Minister for the Environment, Nature Protection and Nuclear Safety (BMU). Since 2003, the notification of measuring equipment which has successfully passed a suitability test is published no longer in the Joint Ministerial Gazette (*Gemeinsames Ministerialblatt*) but in the Bundesanzeiger (*Federal Gazette*).

Appendix 3 lists the measuring instruments for continuous measurements which have so far been suitability-tested. However, the production of some of these instruments has ceased. These instruments are marked with an asterisk (*).

Apart from a tabular listing of all measuring devices which have so far passed suitability tests, Appendix 3 includes detailed descriptions of currently (status: November 2003) available suitability-tested ambient air quality measurement devices.

6.1.2 Measurement Principles

Suitability-tested, continuously operating ambient air quality measurement devices are available for the following air pollutants (see Appendix 3):

- sulphur dioxide,
- nitrogen oxides,
- carbon monoxide,
- ozone,
- total gaseous organic compounds,
- benzene,
- toluene, ethyl benzene, xylene,
- suspended particulate matter and particles (PM_{10}),
- Soot.

The measurement principles employed by these instruments are briefly described in the following. In most cases they correspond to the methods used for continuous emission measurements /1/.

6.1.2.1 Conductometry /1, 5, 14, 103, 104/

In the conductometric measurement principle (Figure 1) the sample gas is introduced into a suitable liquid reagent. The variation in conductivity is measured after completion of the reaction between liquid and gas. The substances mainly measured with this method are sulphur dioxide and carbon monoxide.

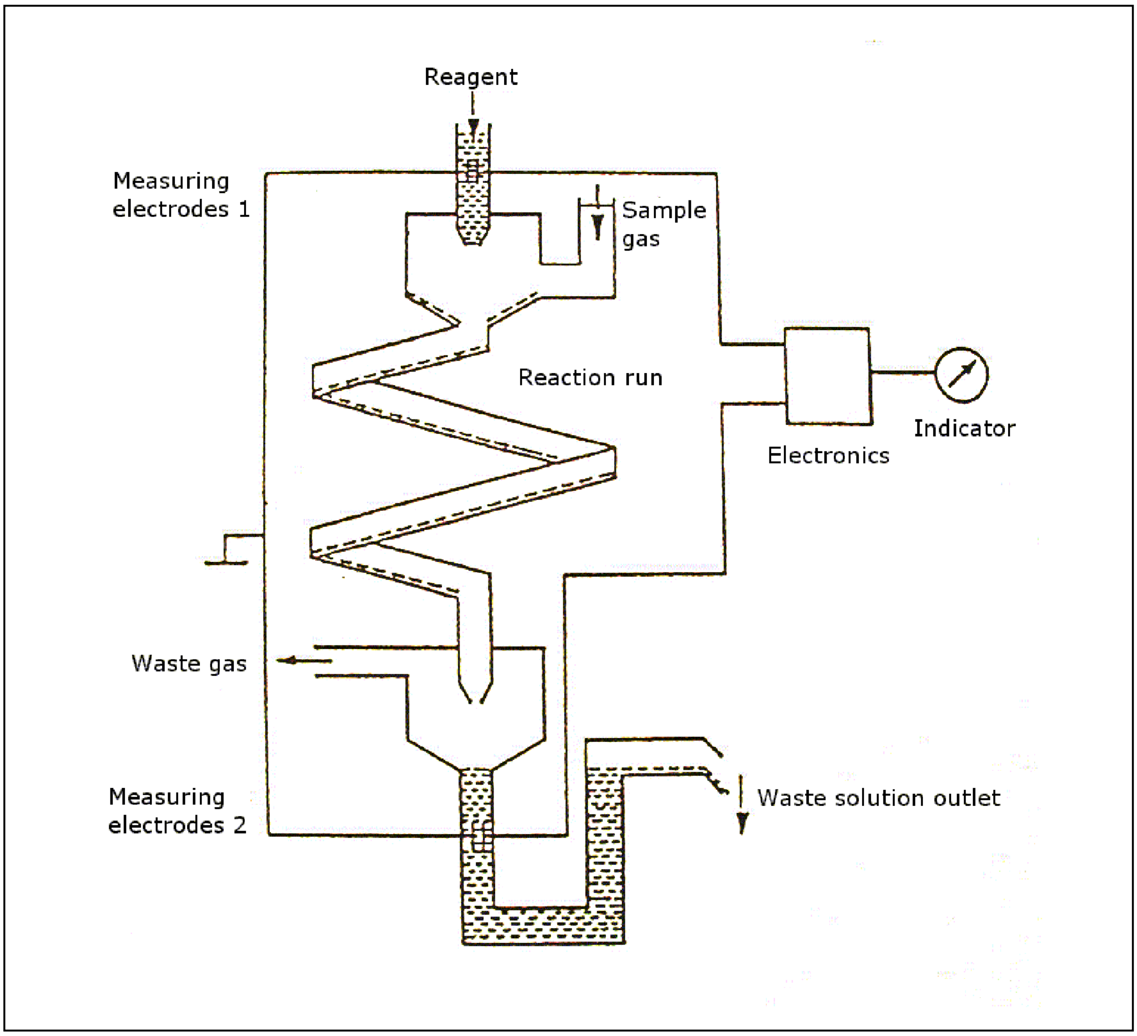

Figure 1: Conductometric Measurement

In continuous conductometry, the sample gas and the reagent liquid are continuously delivered into the reaction cell. As the conductivity depends on the ratio of sample gas to the liquid volumetric flow, suitable means must be provided to ensure that the flow of both streams is kept constant. The influence of temperature on the conductivity requires compensation.

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6.1.2.2 Chemiluminescence Measurement /1, 5, 14, 17, 106/

Some chemical gas reactions produce a characteristic radiation, the so-called chemiluminescence. The intensity of this chemiluminescence is proportional to the mass flow rate of the sample gas under constant reaction conditions, if the auxiliary gas necessary to produce the reaction is present in excess.

The chemiluminescence emitted during the oxidation of nitrogen oxide molecules with ozone is used in the determination of NO concentration: $NO + O_3 \rightarrow NO_2 + O_2 + h\nu$. The intensity peak of the chemiluminescence is reached at a wavelength of 1.2 µm.

Chemiluminescence measurements take place in a reaction chamber (Figure 2). The air, which has first passed through an ozone generator, flows into this chamber. The partial conversion of the oxygen in the air to ozone is accomplished by electrical discharge or by exposure to UV radiation. A constant flow of sample gas enters the reaction chamber via another entrance nozzle and is mixed with the ozone enriched air. An ozone filter is fitted in the outlet of the reaction chamber to prevent a pollution of the environment. The chemiluminescence, after being optically filtered, is measured with a photomultiplier. A thermostatic reaction chamber operating at a constant internal pressure is indispensable for obtaining stable measurement conditions.

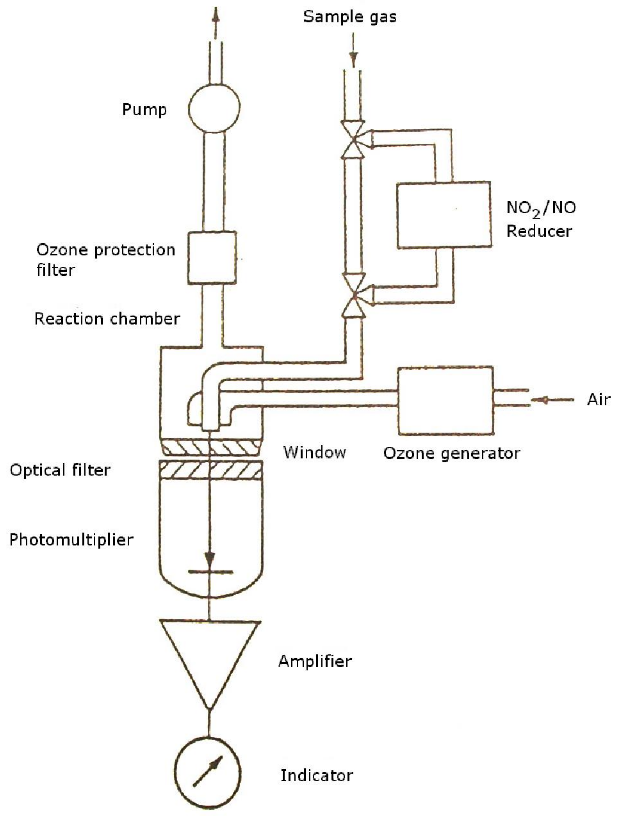


Figure 2: Chemiluminescence Measurement

For the determination of the nitrogen dioxide concentration, the sample gas is first passed through a thermocatalytic converter which reduces NO_2 to NO before the analysis.

This method is also used for measuring ammonia in ambient air. For this purpose, NH_3 is transformed into NO, and the amount of NH_3 in the sampling air is determined by measuring the difference to the previous amount of NO.

The principle of chemiluminescence is also employed for ozone in ambient air quality measurements. The reaction of O_3 and NO (in excess) described above is used here for continuous measurements as well.

6.1.2.3 UV Fluorescence Measurement /14, 102/

The sample air passes through a beam of light emitted by an UV lamp (e.g. Zn hollow cathode lamp). As a result, the molecules of the gas to be measured are excited to emit a fluorescence radiation which is led into a photomultiplier (acting as a receiver) and can be measured after amplification. An interference filter placed before the receiver filters out the specific fluorescence radiation of the gas to be measured. The fluorescence intensity is a function of the concentration of the gas to be measured and the light energy of the UV light source.

The procedure is shown in Figure 3. The method is employed as an ambient air quality measuring technique for the continuous measurement of sulphur dioxide.

This measurement principle also allows the measurement of hydrogen sulphide. Before the measurement, SO_2 is separated from the sample air, subsequently H_2S is oxidized to SO_2 which is then being measured.

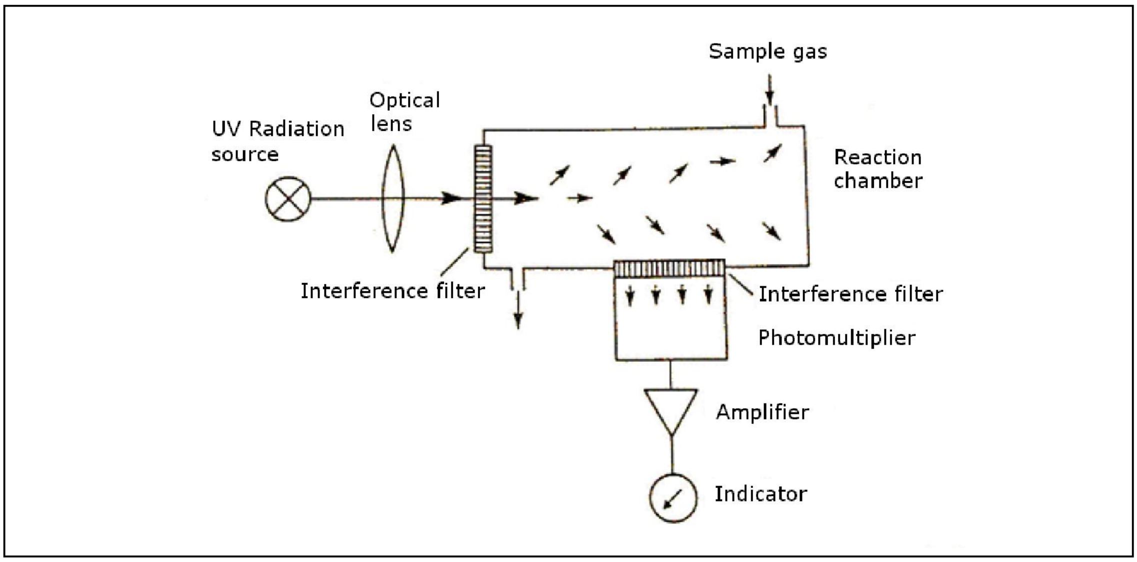


Figure 3: UV Fluorescence Measurement

6.1.2.4 Measurement by Non-Dispersive Infra-Red Absorption and Gas Filter Correlation /1, 5, 13, 14, 17/

All heteroatomic molecules such as CO, CO_2, SO_2 and NO possess a typical characteristic absorption spectrum in the infrared range. This property of gases is frequently made use of for emission measurements /1/. In ambient air quality measurements, the principle of infra-red absorption is employed exclusively for the measurement of carbon monoxide (CO) and carbon dioxide (CO_2) because the radiation absorption of these gases is high enough even in low concentrations in atmospheric air.

The non-dispersive infra-red absorption methods (NDIR) dispense with the spectral refraction and obtain the desired selectivity by the use of a sample of the measuring component stored in the instrument itself. Depending on the method of storing the sample, the non-dispersive infra-red absorption method (NDIR) and the gas filter correlation method (GFC) are distinguished.

The **NDIR method** (Figure 4) uses the radiation receiver for storing the measured components (CO, CO_2). The radiation transformed in the gas-filled receiver chambers and modulated by a revolving chopper wheel produces – due to the absorption of radiation through CO in the measuring chamber - periodic pressure and temperature variations in the receiver chambers. These are sensed either by a membrane capacitor, or in a micro flow detector which senses the pressure equalizing flow between the two receiver chambers, and converted into electrical signals.

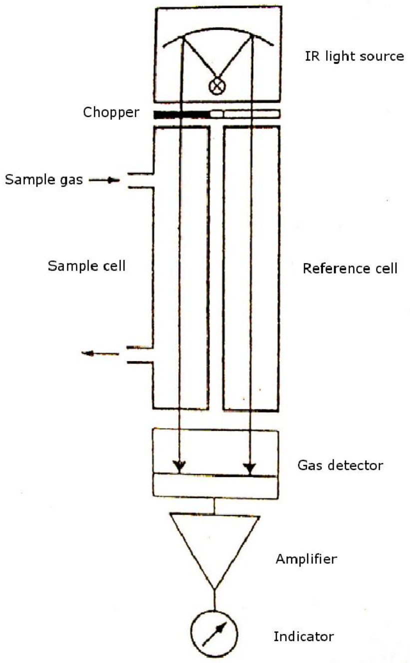


Figure 4: Non-Dispersive Infra-Red Absorption Measurement (NDIR)

The **gas filter correlation (GFC) method** (Figure 5) uses a gas-filled chamber fixed to a filter wheel for storage. This filter chamber and either an opening or a N_2 gas-filled filter are alternately and periodically brought into the light path.

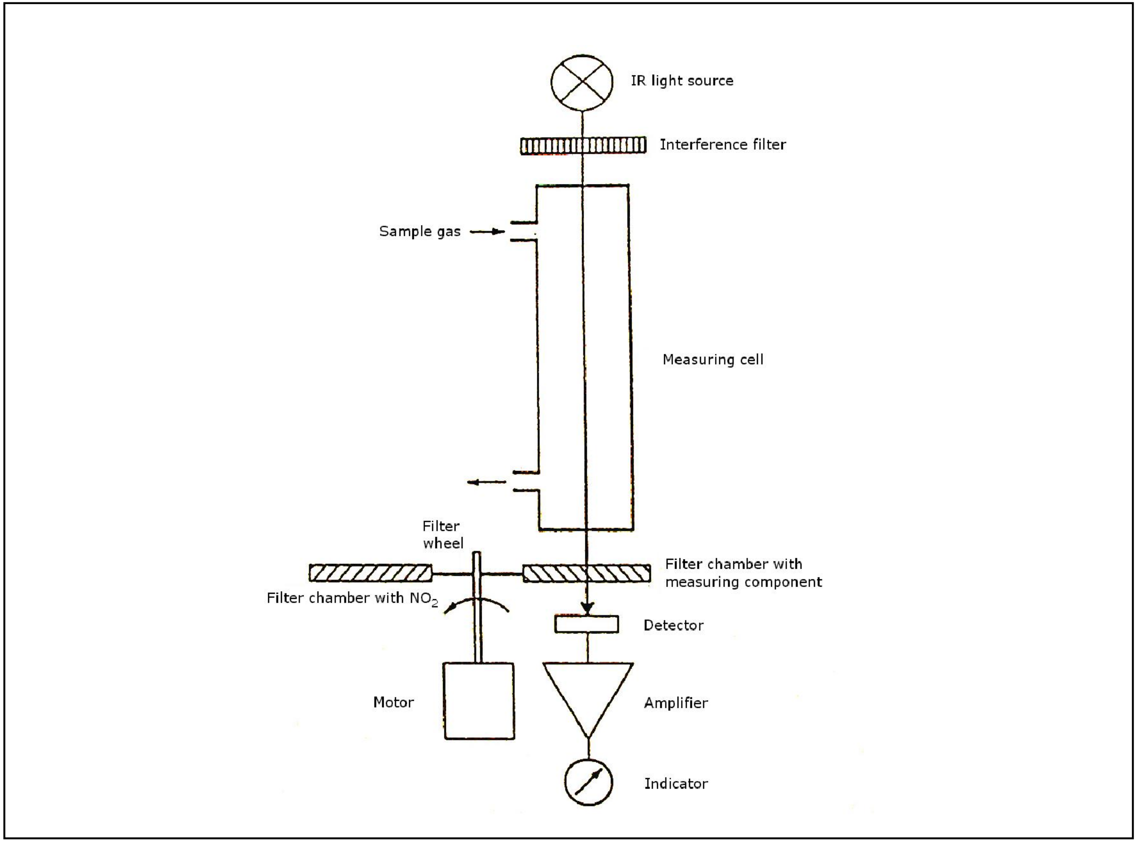


Figure 5: **Gas Filter Correlation Measurement (GFC)**

6.1.2.5 Measurement of UV Absorption /5, 14, 17/

UV absorption measurement is employed for continuous measurements of ozone in ambient air. The measurement is based on the absorption of ultraviolet light by ozone, which has a maximum wavelength of 254 nm. The procedure is shown in Figure 6.

The sample air is passed into a measurement cell, which is placed between the UV radiation source and the radiation receiver (i.e. a photomultiplier). The air is passed into the cell by means of a magnetic valve alternating between direct flow and flow through a catalytic converter, which quantitatively reduces ozone to oxygen. The radiation intensity measured in the ozone-free air is stored and subtracted from the intensity measured in the air which contains the ozone.

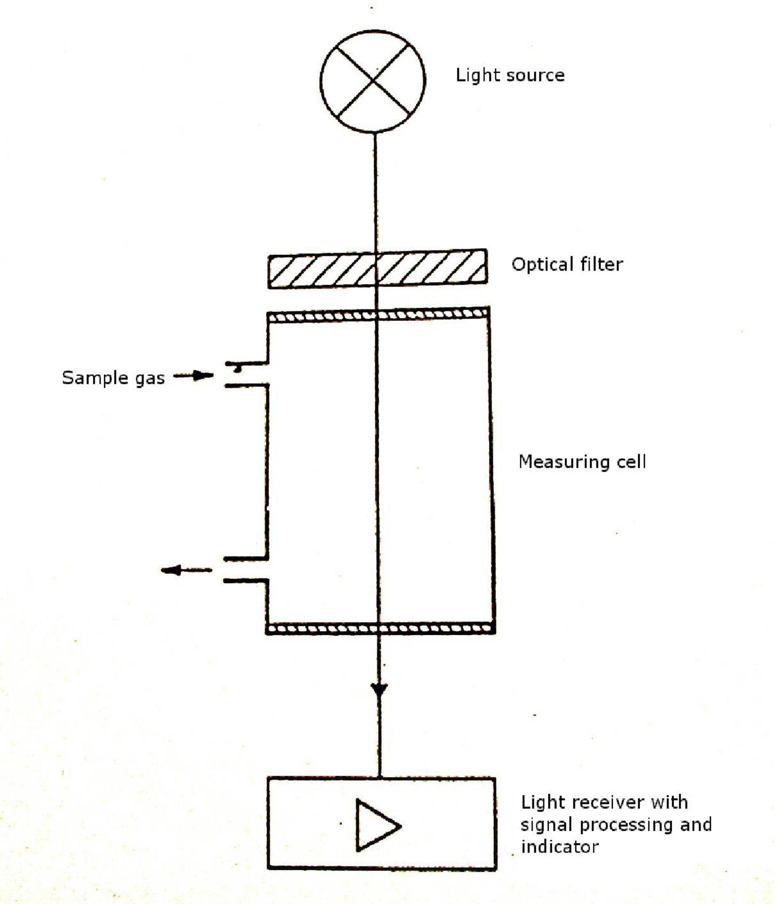


Figure 6: UV Absorption Measurement

6.1.2.6 Flame Ionisation Measurement /1, 5, 14, 17/

Organic carbon compounds can be ionized relatively easy in a hydrogen flame. In an ionization chamber, the ion cloud thus produced is extracted by applying an electric field via electrodes, and generates an electric current. This current is, to a large degree, approximately proportional to the mass flow rate of organically bound carbon atoms. There is, however, a certain dependence on the structural bond of C atoms in the respective molecule.

The flame ionization detector (Figure 7) consists of a combustion chamber. Pure hydrogen, which can be taken from a pressurized gas cylinder or produced in an electrolytic hydrogen generator unit, flows through a nozzle into the combustion chamber. Combustion air from the atmosphere is admitted via an annular slit around the nozzle. After electrical ignition, a steady hydrogen flame produces a very small ion density (zero value) in the absence of organic carbon compounds in the sample gas. The electrodes necessary to extract the ion cloud are arranged near the flame. The combustion nozzle itself can be used as one of the electrodes - as shown in Figure 7. With a sufficiently high electric potential difference, all the charge carriers will find their way onto the electrodes, i.e., the saturation current is flowing. This is raised to the desired signal amplitude by a sensitive direct current amplifier, and at the same time, the zero value is compensated. The absolute measuring sensitivity depends on the material of the combustion nozzle and the detector geometry. For continuous measurements, temperature and mass flow rate of the sample gas must be kept constant.

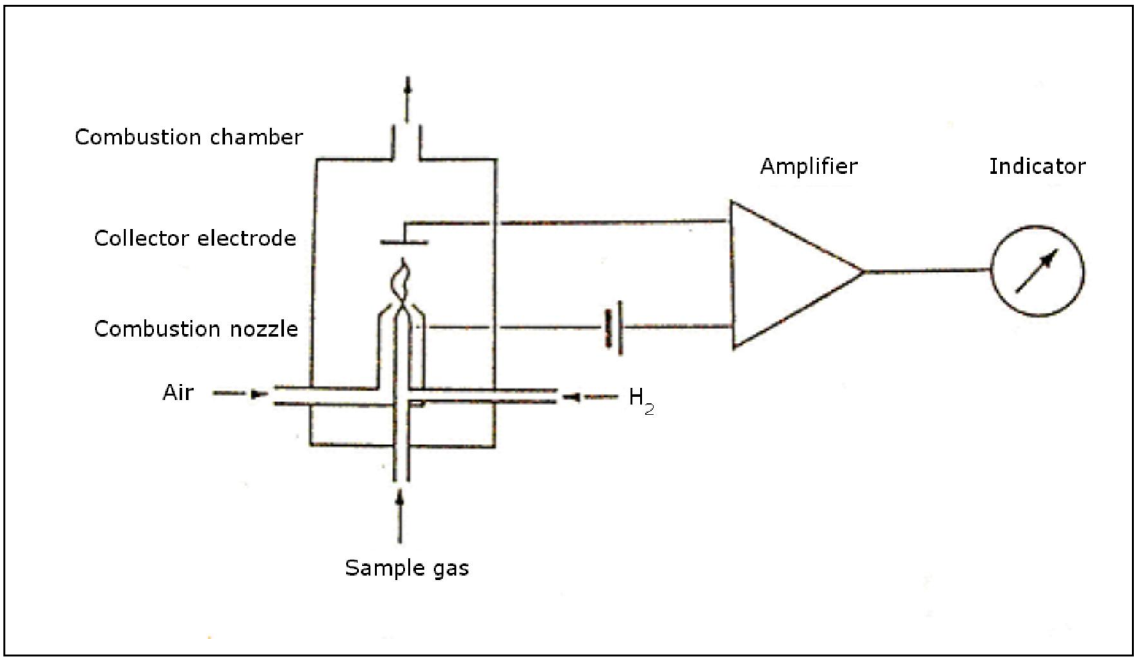


Figure 7: Flame Ionisation Detector (FID)

For ambient air quality measurements, the determination of the sum of gaseous organic compounds is performed - in line with the specification as a measuring object in the Fourth General Administrative Instruction for the BImSchG /33/ - after the separation of methane, which is always contained in samples. The separation can be obtained by placing before the FID either a short separation column (VDI 3483 Part 4, Bendix 8202 /5/) or a cooled storage column (VDI 3483 Part 2, Siemens U 100 /5/), or by catalytic burning of hydrocarbons, taking advantage of the fact that they have a larger mass than methane (Horiba APHA 360).

6.1.2.7 Optical Long-Path Monitoring (Path-Integrating Measurement)

Optical long-path monitoring techniques for air quality monitoring have already been used for years for various measuring tasks, particularly for the registration of emission rates and for air-chemical as well as meteorological research /107, 108, 109/. In a summarizing report the following optical techniques for gas long-path monitoring are listed and described /104/:

- Lidar (VDI 4210 Part 1 /5/)
- Derivative Spectroscopy
- Differential Optical Absorption Spectroscopy (DOAS)
- FTIR Spectroscopy (Fourier Transformation Infra-Red, VDI 4211 Part 1 /5/)
- Correlation Spectroscopy.

Optical long-path monitoring does not include sampling by suction of air, but measures the radiation absorption which occurs when a defined beam passes through an air path of the gas to be analysed.

In principle, long-path monitorings are closer to emission measurements than to ambient air quality measurements. Often, pollutant concentrations are being measured in the vicinity of emission sources. Detection limits and interferences caused by fog, dust and other substances limit the use of long-path monitoring for ambient air quality measurements.

The optical long-path monitoring technique (DOAS) is based on the absorption of UV light or visible light by the gas to be measured on a length up to several kilometres between a light emitter and a receiver system. It has proved efficient for ambient air quality measurements as for instance in the suitability test of an instrument for the measurement of sulphur dioxide, nitrogen dioxide and ozone (OPSIS AR 500), and of another instrument for the measurement of benzene (OPSIS AR 502 Z). The instruments’ mode of operation is described in Appendix 3.

6.1.2.8 Automated Gas Chromatography

The principle of gas chromatography (see Chapter 6.2.3) is used in suitability-tested devices also for the continuous automatic measurement of aromatic hydrocarbons (benzene, toluene, xylene, ethyl benzene) in ambient air (see Appendix 3). Minimum requirements for and testing of automatically measuring devices for single measurements of benzene in ambient air with enriching sample-taking and subsequent gas-chromatographic separation are described in DIN 33963-2 /110/.

Today, a particular focus of ambient air quality control is on benzene as an air-hygienically critical component of motor vehicle exhausts.

Suitability-tested devices for the continuous measurement of aromatic hydrocarbons and their respective mode of operation are described in Appendix 3.

6.1.2.9 Measurement with Beta-Ray Absorption /1, 5, 13, 14, 17, 111/

In dust measurements (fractioning or non-fractioning) employing beta-ray absorption, the sample air is sucked through a filter tape which can be moved along gradually. The dust quantity precipitated onto the filter tape is measured by the gradual attenuation of the beta radiation that is passing through the dust laden filter (Figure 8).

A synthetically manufactured radioactive probe of suitable activity (e.g. carbon 14 or krypton 85 isotopes) is used as a radiation source, and a Geiger-Müller counter or an ionisation chamber serves as a detector. In order to compensate for the diminishing radioactivity and the varying attenuation of the radiation caused by the filter material, absorption measurements are taken before and after, or before and during dust precipitation, and then the measured values are compared with each other. In the course of the absorption measurement during dust precipitation, the accumulating particle mass is measured and indicated. Generally, the double-beam compensation method is employed in this type of instrument (see Figure 8) which facilitates a real-time measurement of the dust concentration on the filter.

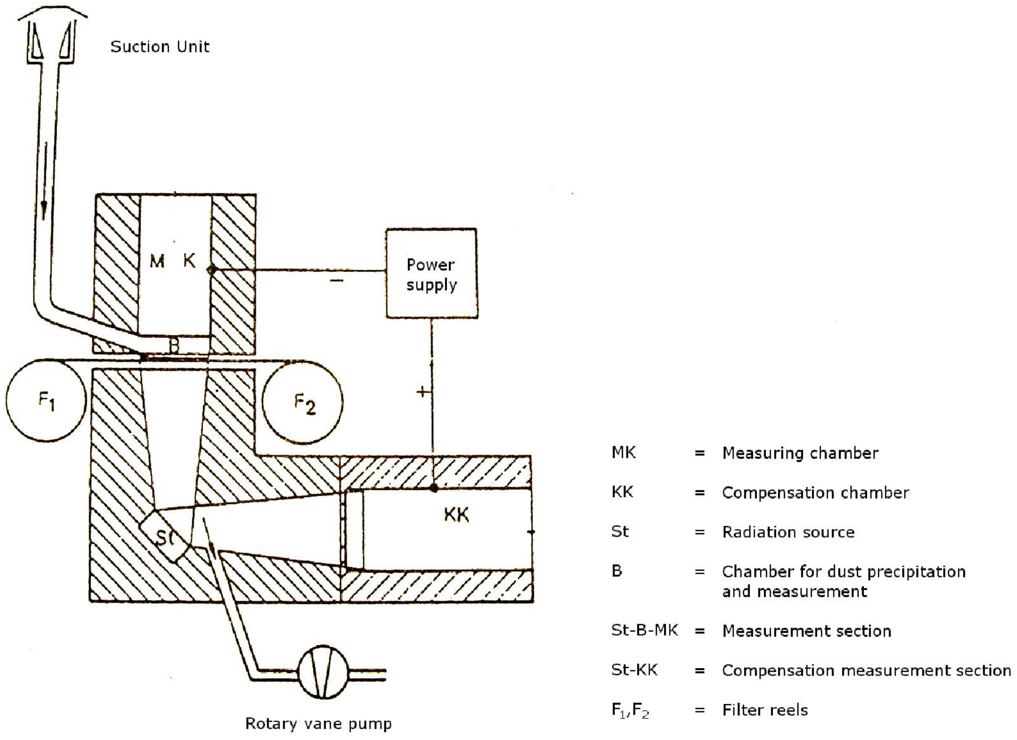


Figure 8: Suspended Particulate Matter Measurement with Beta-Ray Absorption

6.1.2.10 Measurement of Vibration of a Dust Laden Filter ("Ambient Particulate Monitor") /112, 113/

For this method of suspended particulate matter measurement, the sample air is passed through a filter which is part of a system vibrating at its characteristic resonance. It can be used for fractioning and non-fractioning measurement of suspended particulate matter, depending on the employed sampling head.

The dust separated onto the filter increases the vibrating mass and thus decreases the resonance frequency. The suspended particulate matter concentration is worked out from a calibrated relation of frequency and amount of dust, taking into account the volume of the air sample. The principle of this method is shown in a sketch in Appendix 3 for the suitability-tested measurement device TEOM 1400a (MLU Messtechnik für Luft und Umwelt) which makes use of the principle of oscillating microbalance.

6.2 Discontinuous Measurements

The methods employed for discontinuous ambient air quality measurement in the Federal Republic of Germany are to a large extent described in the Guidelines of the Commission on Air Pollution Prevention in VDI and DIN /5/. These guidelines are compiled in Appendix 2.

There are great variations in discontinuous, mostly manual, ambient air quality measurement methods, which are mostly carried out in two separate steps: *sampling* on site, and *analysis* in the laboratory.

6.2.1 Sampling

The numerous sampling methods are described in a summarized account /114/ which considers the following sampling techniques (for discontinuous as well as for continuous measurements):

1. Passive sampling without separation (In situ methods, "remote sensing");
2. Passive sampling with separation ("passive sampling" enriching methods, e.g. "*Glocken-Verfahren*" (Liesegang); lead peroxide cylinder method /15/; wet deposition; dust deposition);
3. Active sampling without separation (gas collection; some continuous measurement methods);
4. Active sampling with separation (sorption methods; dust precipitation).

The latter group dominates in discontinuous ambient air quality measurements. Common sampling apparatuses for the collection of air samples and for the separation of the air pollutants to be analysed are shown in Figure 9 for sampling

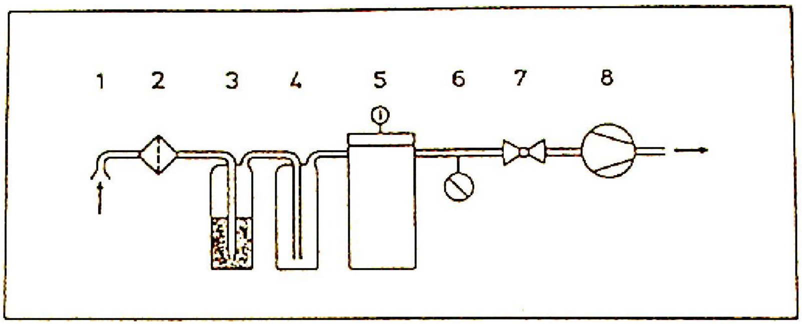
- using gas volume measurements or
- using a critical orifice.

Sampling techniques using a critical orifice do not require measurements of air flow or volumes and therefore, fairly simple equipment can be employed. When a certain atmospheric pressure difference ("critical pressure") is reached, the flow through the orifice is constant. This can be determined through calibration in the laboratory. On site, the air volume of the sampling can then be measured simply with a stop-watch. The pump used in the measurement must exceed the critical pressure. The orifice must consist of material which is not subject to temperature-related expansion (e.g. corundum). Calibration of the orifices is necessary at regular intervals.

The most common devices for ambient air quality measurements for the separation of air polluting substances from air samples are

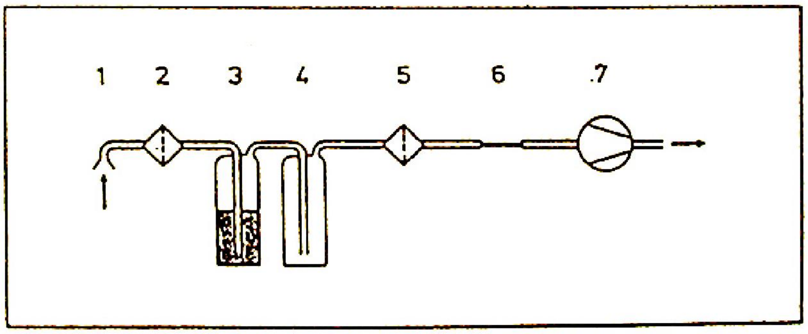
- washbottles for the absorption of (particularly inorganic) gases,
- sorption devices (charged with polymers, activated carbon, silica gel, etc.) for organic(and some inorganic) gases,
- filters for particulates,
- impactors for particle size determination of suspended particulates, and
- funnel-absorber sampling.

The various washbottle types used for ambient air quality measurements are shown in Figure 10.



Sampling Apparatus for Ambient Air Quality Measurements
(using gas volumetric measurement)

1 Inlet funnel
2 Particle filter
3 Washbottle
4 Safety bottle
5 Gas meter with thermometer
6 Manometer
7 Valve
8 Pump



Sampling Apparatus for Ambient Air Quality Measurements
(using a critical orifice)

1 Inlet funnel
2 Particle filter
3 Washbottle
4 Safety bottle
5 Fritfilter
6 Critical orifice
7 Pump

Figure 9: Sampling Apparatus for Ambient Air Quality Measurements

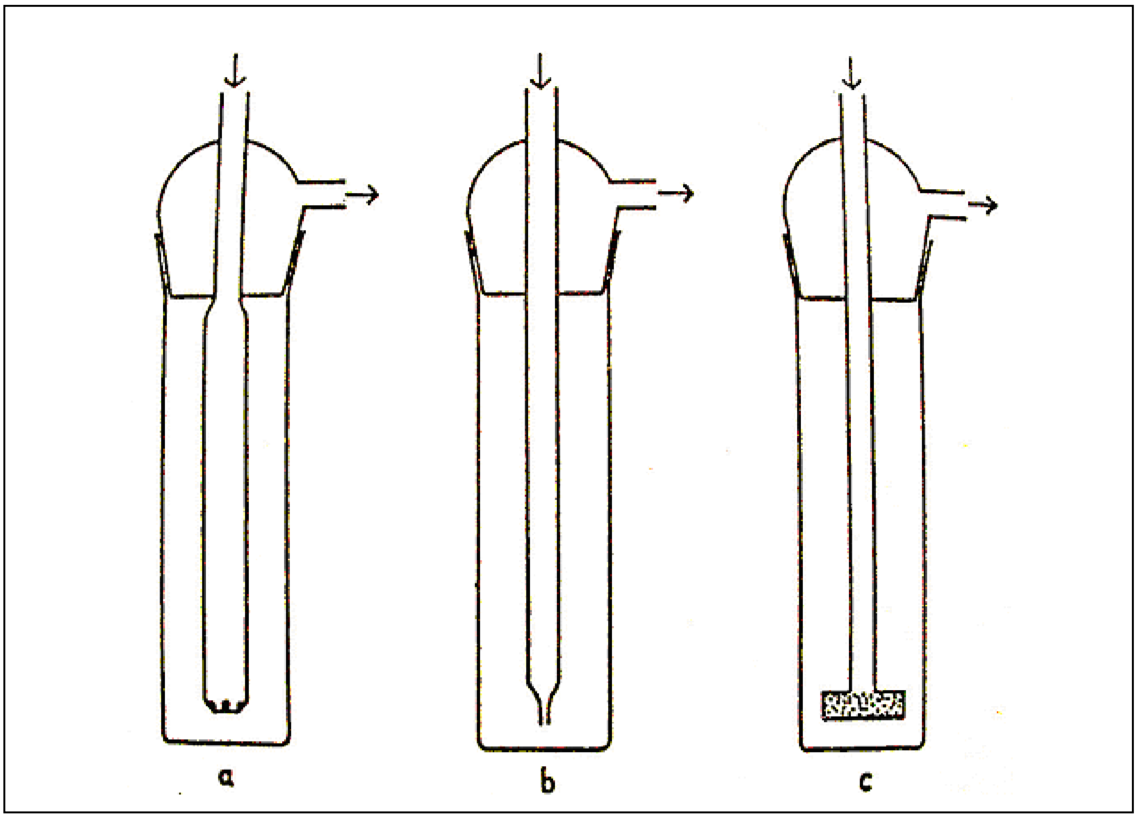


Figure 10: Sampling Washbottles for Ambient Air Quality Measurements (schematic)
a) Muenke washbottle b) Impinger c) Fritten washbottle

In an impinger, the sampled air enters the absorption liquid at high speed and is mixed with it vigorously. The absorption level in a chemical reaction between the gas to be analysed and the absorption liquid is fairly high. Advantages of the impinger are high air volume flow and easy cleaning.

Fritten washbottles are used in different constructions. The bubbles of the air sample going slowly through the absorption liquid can mean advantages in the degree of absorption.

Muenke washbottles, in which the sampled air is led sideways into the absorption liquid, are intermediate between impinger and fritten washbottles with regard to their absorption (and cleaning) qualities.

Sometimes, sampling for discontinuous ambient air quality measurements is carried out by dry sorption of the inorganic gas to be measured. Sorption materials are, for example, coated glass balls for hydrogen sulphide (VDI 2454 Part 1 /5/), or coated silver balls for hydrogen fluoride (VDI 2452 Parts 2 and 3 /5/). Filters are rarely used for sorption purposes in ambient air quality measurements in Germany.

For the separation of gaseous substances from particulates during sampling the following techniques are used:

- Filters for the separation of particulates from gases.
  Errors are incurred in particular from the separation of gases into the filter and from dust or condensate deposits on the filter.
- Denuder (diffusion separator) for the separation of gases from particulates (Figure 11).

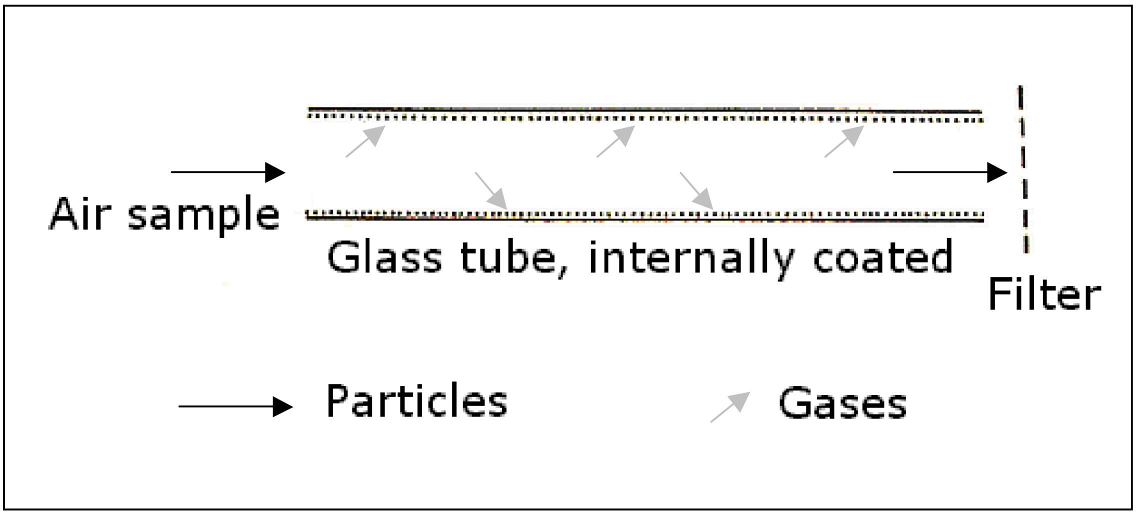


Figure 11: **Denuder (Principle)**

The air sample is drawn in, under laminar flow conditions, through a denuder pipe the interior of which is coated with an absorption substance for the gas to be measured. The gas diffuses onto the wall of the pipe and is thus separated from the sample. This method is, for example, used for the determination of aerosol sulphuric acid by means of a denuder heated to 135°C (VDI 3869 Part 1 /5/).

The sampling technique which is mentioned above under 2. "Without suction, with separation" is today mostly referred to as passive sampling. This used to be a widely spread working method /15, 115/, because other suitable sample methods were lacking and it is still (or again) used today in various measuring tasks, due to its little expenditure, particularly, for indoor air quality measurements, but also for air quality measurements. Requirements for the use of passive sampling equipment for determination purposes are available as a standard draft /116/.

The passive sampler introduced by Palmes has achieved a special significance. It is a Perspex tube of about 75 mm length (inner diameter 10 mm) which contains coated wire nettings for the absorption of the gas to be measured /117/. The Palmes tubes proved efficient for NO_2 measurements in ambient air /118, 119/.

Passive sampling is carried out without pump or additional devices and is therefore noiseless, inexpensive and easy to use. The air pollutant reaches the adsorption or absorption agent by way of diffusion, permeation or direct transfer. For this adsorptive or absorptive collection, filters or tubes (mostly impregnated with a reagent) are used which contain the adsorption or absorption agent.

With passive samplers, mean values over relatively long exposure times can be obtained (one or several days). The detection limit is usually not sufficient for the registration of short-term ambient air concentration peak values.

6.2.2 Analysis of Inorganic Gases

6.2.2.1 Photometric Methods

The main working method for the detection of inorganic gases in atmospheric air is the photometric determination of a substance collected in an aqueous absorption solution. With this method

- sulphur dioxide,
- nitrogen dioxide and nitrogen monoxide,
- hydrogen sulphide,
- chlorine,
- hydrogen chloride,
- ammonia,
- ozone,

as well as some organic gases can be determined. Table 6.3 shows a compilation of the photometric ambient air quality measurement methods commonly employed in Germany.

Component	VDI Guideline	Absorption Solution	Photometric Reagent
Sulphur dioxide	VDI 2451 Part 3	Tetrachloromercurate solution	Pararosaniline and formaldehyde
Nitrogen dioxide	VDI 2453 Part 1	Reagent solution	N-naphtyl-(1)-ethylene-diamine-chloride
Nitrogen monoxide		After oxidation to NO_2: measurement like NO_2	
Hydrogen sulphide	VDI 2454 Part 1	Cadmium hydroxide suspension	Molybdenum blue
	VDI 2454 Part 2	Cadmium hydroxide suspension	N.N-dimethyl-p-phenylene-diamine-dichloride
Fluoride ions	VDI 2452 Part 3	Silver ball sorption	Photometry
Chlorine	VDI 2458 Part 1	Acetic methyl orange solution	Measurement of colour brightening
Hydrogen chloride		0.1-mol/l-NaOH	Mercury thiocyanate and iron-(III)-salt
Ammonia	VDI 2461 Part 1	0.005-mol/l-H_2SO_4	Phenol and sodium hypochloride
	VDI 2461 Part 2	0.005-mol/l-H_2SO_4	
Ozone	VDI 2468 Part 5	5.5-indigo sulfonate acid solution	Measurement of colour brightening
Formaldehyde	VDI 3484 Part 1	Tetrachloromercurate solution	Pararosaniline and sulphite
Phenols	VDI 3485 Part 1	0.1-mol/l NaOH	P-nitroaniline

Table 6.3: Photometric Methods for the Measurement of Gaseous Air Pollutants

Generally, for photometric methods, the colouring reagent is added to the absorption solution after the sampling. For the determination of nitrogen dioxide, it is already contained in the absorption solution before the sampling. For chloride and ozone measurements, coloured absorption solutions are used and the change of colour is measured photometrically after the sampling.

Pre-requisites for photometric analysis are as follows:

- a reagent that is both highly specific and highly sensitive to the gas to be analysed,
- if possible, a colour reaction should take place within 30 minutes,
- a sharp colouring absorption maximum,
- compliance with the Lambert-Beer Law (linearity between mass of the analysed substance and extinction of colour intensity) of a large concentration range, the larger the better, and
- sufficient stability of the colour.

For sulphur dioxide and nitrogen dioxide, probably the most frequently examined gaseous inorganic air pollutants, internationally recognized methods for photometric measurement were developed decades ago: the West/Gaeke tetrachloromercurate method (TCM) /120/ for SO_2, and the Saltzman method /121/ for NO_2 determination.

6.2.2.2 Other Methods

Other methods for the analysis of absorption and extraction solutions for discontinuous ambient air quality measurements mentioned in the VDI Handbook on Air Quality Control /5/ are

- the determination of fluorides (hydrogen fluoride) with ion sensitive electrodes (VDI 2452 Part 1) and
- ion chromatography for the determination of sulphuric acid aerosols (which originate mainly from sulphur dioxide and are therefore considered together with gases; VDI 3869 Part 1).

Both methods, especially the ion chromatography, can also be employed for other measuring tasks, like the determination of anions in suspended particulates, dust deposition and rain water.

For ion chromatography (IC), the sampling solution is led through a special separation column (ion exchanger), separated inside it, and subsequently the components, on exiting from the column, are determined by a detector (conductivity detector).

6.2.3 Analysis of Organic Gases

The main method for the determination of gaseous or vaporizable organic substances in atmospheric air is the so-called gas chromatography /123/. The sample air is led through a separation column in a carrier gas stream ("mobile phase"; nitrogen, helium) and is broken down into its components in absorption and desorption processes in the charged column. "Packed columns" are filled with porous, inert, inorganic or organic material ("stationary phase": silica gel, aluminium oxide, polymers); capillary columns in the "stationary phase" are coated on the inside.

The exit time in controlled working conditions (gas flow, filling of the column, temperature, pressure) is characteristic for the substance to be analysed. Its mass is determined by a signal from a detector positioned behind the separation columns. The following detectors can be used:

- flame ionisation detectors (FID);
- flame photometric detectors (FPD);
- electron capture detectors (ECD), suitable, for example, for the determination of halogen compounds;
- photo ionisation detectors (PID), particularly suitable for aromatic hydrocarbons;
- thermo-ionic detectors (NPD), suitable for nitrogen and phosphoric compounds;
- infra-red detectors (IRD);
- atomic emission detector (AED).

The use of a mass spectrometer at the exit of the separation column facilitates the identification of single components even in unknown air samples. Today, the so-called "GC/MS" method is the most efficient method for ambient air quality measurements of organic chemical substances.

Absorption or extraction solutions containing organic compounds can be analysed using high pressure liquid chromatography (HPLC), which is very similar to gas chromatography (VDI 2467 Part 2 /5/). In this case, the sample solution is led through special separation columns in a liquid stream and the separated components are determined by a flow detector - for example by the measuring flow cell of a UV or fluorescence spectrometer. This method is employed mainly for the examination of air polluting particles.

As a new, inexpensive technique for the quick and selective determination of complex organic pollutants in ambient air, an immunological analysis is described /123/. It consists of the sampling (e.g. cryo-sampling technique) and the immunological detection reaction. There are substances to be determined which can only be analysed requiring a great deal of effort (high pre-enrichment, high separation effort). As an example the measurement of the triazine herbicide atrazine is mentioned. Other substance classes to be tested are polycyclic aromatic hydrocarbons, halogenated dibenzodioxins and dibenzofuranes, halogenated phenoxy-acetic acid and nitrated aromatic hydrocarbons.

6.2.4 Measurement of Suspended Particulate Matter and Particles (PM_{10})

Measurements of suspended particulate matter can be taken by means of suitable sampling heads with or without fractioning according to particle size.

The sampling devices most commonly used in the Federal Republic of Germany are

- the LIB device (VDI 2463 Parts 4 and 9 /5/) with a sampled air volume flow of 15 m^3/h and
- the small filter device (VDI 2463 Part 7 /5/) with a sampled air volume flow of approx. 3 m^3/h.

The VDI Handbook on Air Quality Control /5/ lists two further discontinuous filter devices, the TBF 50f (VDI 2463 Part 3; air volume flow approx. 3 m^3/h; out of production) and the High Volume Sampler HV100 (VDI 2463 Part 2).

The advantage of the High Volume Sampler, which has been developed in the USA, is a high volume flow (up to 100 m^3/h), making it possible to collect a large amount of dust that is easy to analyse. Disadvantages are the noise of the device and the measurement only of the actual volume flow (rotameter), not of the sampled air volume, unless a modified version of the device including a quantometer for measuring the volume /124/ is used.

The amount of suspended particulate matter in the sampled air is determined by weighing the filter (mostly made of fibreglass or quartz fibre) under controlled conditions /125/ before and after sampling.

The LIB device was developed for stationary use, while the small filter device was designed especially for mobile employment. The characteristics of the small filter device are:

- low weight;
- quiet operation;
- measurement of the sampled air *volume* by means of a rotating vane anemometer or by means of a measuring blind;
- controlled air throughput;
- option to preset beginning and end of sampling time;
- change of the filter *inclusive* of the sampling head, thus avoiding mistakes if the filter is changed by unskilled personnel;
- use of various sampling heads for non-fractionated and fractionated dust measurement;
- option of external positioning of the sampling head without measurement interference caused by dust separation within the sampling system.

For comparison of measurement methods of non-fractionated suspended particulates, a "standard method" is described in VDI Guideline 2463 Part 8 /5/. The suspended particulate matter contained in the air sample is separated onto a fibreglass filter in a controlled sampling system /126/, in the same procedure as in the case of the small filter device, and weighed. The sampling head used with this system is shown in Figure 12. This standard method has been specified as reference method in the standardized practice of ambient air quality monitoring in Germany /127/.

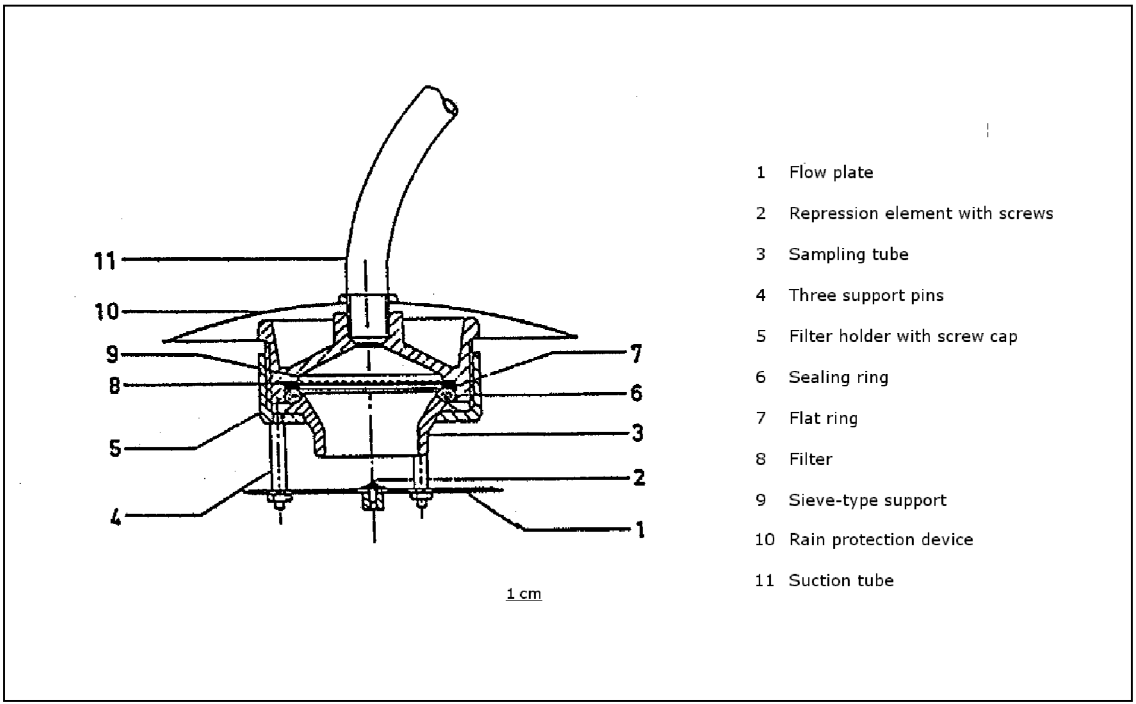


Figure 12: **Sampling Head for Non-Fractionated Suspended Particulate Matter Measurement**

Automatic filter changers can be used for continuous samplings to determine suspended particulates by means of the gravimetric method (VDI 2463 Parts 10 and 11; /5/; /128/). 37 or 15 filters can be fitted one after another for a pre-set sampling time and then stored in a magazine.

As reference method for PM_{10} measurements, a manual gravimetric method of particulate measurement has been determined according to DIN EN 12341 /5, 129/. Design and performance features of PM_{10} reference devices have been standardized for low (2.3 m^3/h), high (68 m^3/h) and very high (996 m^3/h) volume flows.

Constructional features of the sample inlets are depicted in Figures 13, 14 and 15.

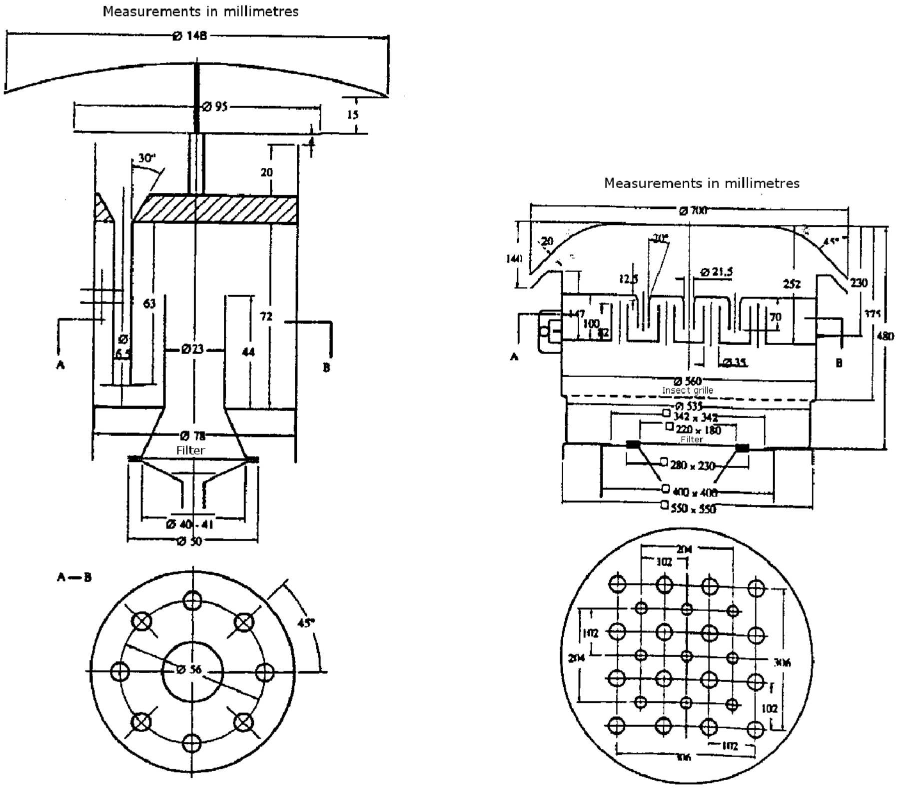


Figure 13: Sample Inlet of LVS-PM$_{10}$ Device (Volume Flow 2,3 m^3/h) and HVS-PM$_{10}$ Device (Volume Flow 68 m^3/h)

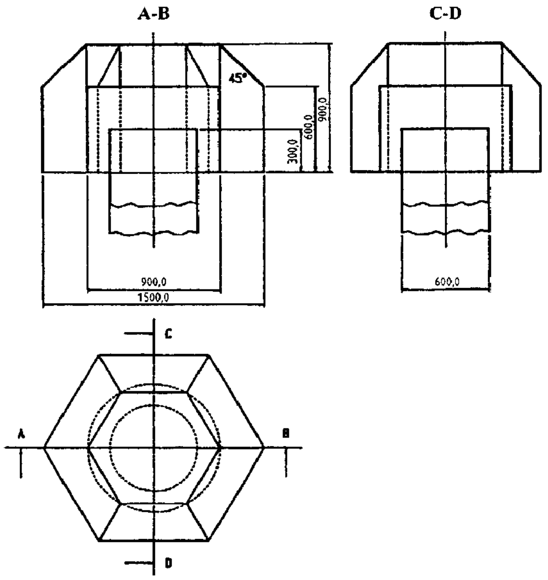


Figure 14: Sample Inlet of WRAC Device

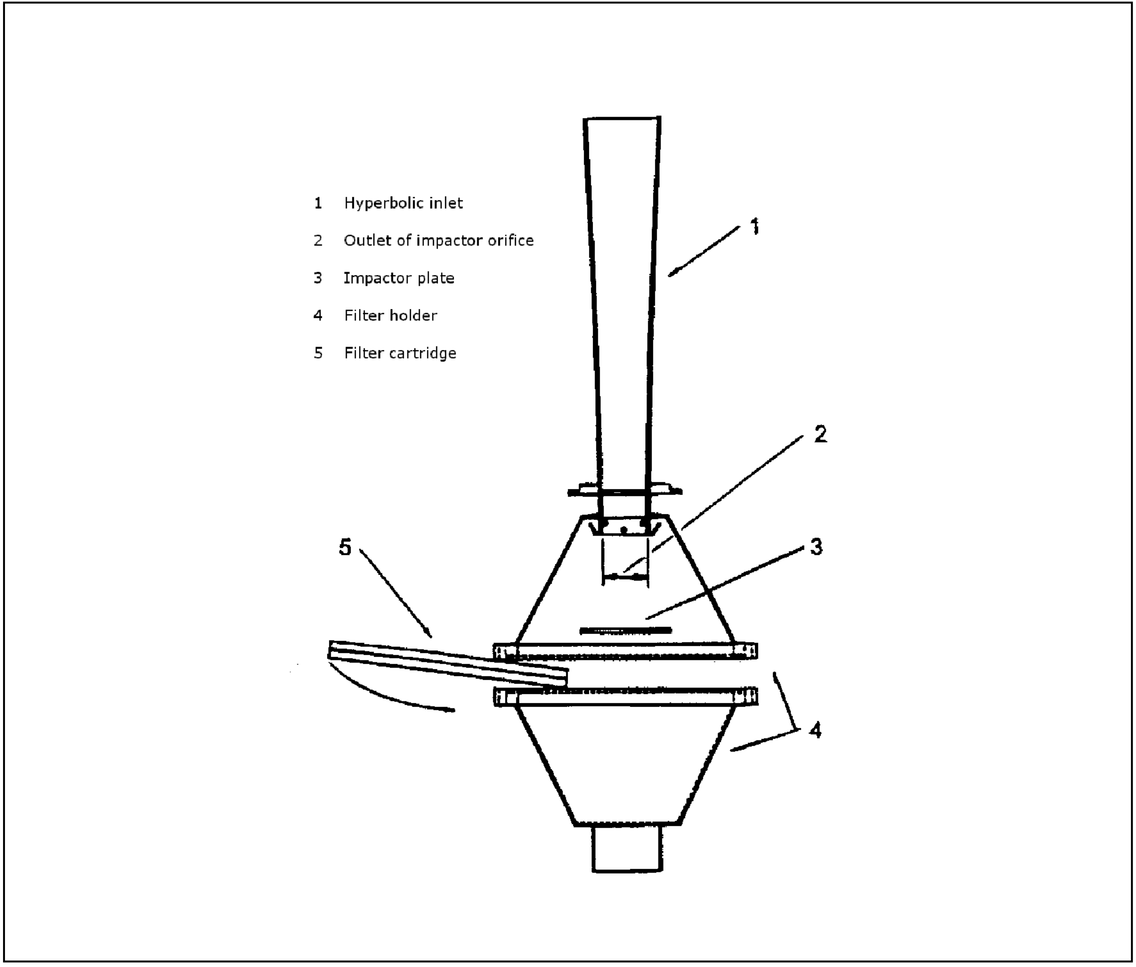


Figure 15: PM_{10} Module of WRAC Device

The PM_{10} reference devices work on the impactor principle (also see Chapter 6.2.5).

The air sample is led at high speed through 8 (LVS device) or 9 (HVS device) impactor orifices onto an impactor plate. The WRAC device has four parallel impactors with isokinetic sample inlet for different diameters and a collector for the entire amount of suspended particulate matter. Quartz fibre filters with a degree of separation over 99.5% are used as separating media.

DIN EN 12341 /5, 129/ describes field test procedures for proving the equivalence of continuous measurement methods for the determination of PM_{10} fraction with the manual gravimetric reference method.

In 2002, suspended particulate matter concentrations were measured at about 560 stations in the Federal Republic of Germany /57/. Approx. 460 of these stations reported the values as PM_{10} concentrations. About 180 stations applied the discontinuous gravimetric method of determination (number of random samplings for the determination of annual mean values between 50 and 180).

6.2.5 Black Smoke Measurement /130, 131/

For the Black Smoke method, which was developed in the United Kingdom, dust is sampled at a low volume sampling rate (2 m^3/day), deposited on a filter and measured by means of a reflectometer. These photometrically measured black smoke values are converted into gravimetric values (µg/m^3) on the basis of a calibration curve. The Black Smoke method has gained some importance in Germany because limit values for suspended particulate matter in a Directive of the Commission of the European Communities /28/ are based on measurement results obtained from this method (cf. Chapter 4.2). This Directive remains partly valid until 1 January 2005.

Comprehensive measurements comparing the Black Smoke method and the gravimetric method normally used in Germany have shown /132/ that in case of considerable temporal and spatial fluctuation, the gravimetric measurement results were about three times higher than the Black Smoke measurement results which are also indicated in µg/m^3. Gravimetric and reflectometric methods evidently record different measuring objects. Apart from other factors, the dust colour, for example, has a considerable influence on the measurement result due to the particles' different degree of reflection /133/.

For the Black Smoke method a special sampling equipment has been developed. It has 8 consecutively installable filter units and with 24h-samples allows samplings over a one week period without maintenance.

6.2.6 Particle Size Measurement

The determination of particle size distribution in suspended particulate matter has not yet been described in the VDI Guidelines for Air Quality Control /5/. It is normally carried out according to the impactor principle /134/.

In an impactor, the sample air is led at high speed through an orifice onto an impactor plate. Through inertia, the dust particles are separated according to size while the air is led away sideways with smaller fractions of dust which have not been separated. The separation of the particles depends on the stream velocity, the orifice size, and on the distance between orifice and plate. By varying any of these parameters (especially by decreasing orifice diameters) in the serially connected orifices of a "cascade impactor", it is possible to separate suspended particulates from the sample air according to their size. In a further development of the impactor principle, the "multi-orifice impactor" (e.g. Andersen impactor /135, 136/), the orifices are replaced by plates with holes of decreasing diameters. Thus, a higher sample air capacity is created and larger amounts of dust can be separated, the mass of which can then be determined directly by weighing, and which can also be used for chemical analysis. The finest dust components are filtered off after the last impactor stage.

6.2.7 Measurement of Ultra-fine Particles / Nano-Particles

In view of recent scientific findings, ultra-fine particles and nano-particles have become a matter of discussion with regard to human health aspects (respiratory and circulatory diseases) and climatic effects (greenhouse effect, global warming).

So far, methods for ambient air quality measurements concerning ultra-fine particles and nano-particles have not been laid down in statutory instruments, standards or VDI Guidelines. Neither do binding ambient air quality limit values exist.

The terms "nano-particles" and "fine particles" have not been standardized yet. In technical literature, the following particle size ranges are frequently used:

Ultra-fine particles:	from approx. 0.05 µm to 0.1 µm
Nano-particles:	< 0.05 µm

The measurement method for the determination of ultra-fine particles and nano-particles can be subdivided as follows:

- Determination of the particle mass
- Determination of the number of particles

The determination of the particle mass can be made gravimetrically or by making use of the inert mass of the particles.

In TEOM (Tapered Element Oscillation) and QCM (Quartz Crystal Microbalance) methods, the deviation of a quartz oscillator which results from the additional particle mass is being measured.

Instead of a gravimetric determination (which in case of low particle concentrations requires long measuring times), surface-based measurements by means of electrical charging of the particles before entry into a low-pressure impactor may be carried out. Inside the low pressure impactor, the gas stream is accelerated in order to increase the low inertial forces. In this measurement principle (ELPI; Electrical Low Pressure Impactor), the current arriving at the impactor module is being measured with an electrometer. The charging can be brought about by a diffusion of gas ions (DC) or by means of light (PAS, PC).

A further method for the determination of the particle mass is the aethalometer. The measured quantity is the (continuously registered) attenuation of a beam of light through a filter during its loading with aerosol particles. In this process, air is blown over a part of the filter and the particles contained in it are sucked onto the filter. A stabilized lamp evenly lights the loaded as well as the unloaded filter area. The light transmission through both filter areas is being measured by means of two photodiodes which provide a reference signal as well as the actual measured signal. The negative natural logarithm of both signals is defined as the optical attenuation. The difference of the optical attenuation at different points in time is (within a defined measuring range) in proportion to the alteration of mass loads on the filter.

Particle totals may be determined with the condensation nucleus counter principle (CNC/CPC). Since the light absorption, which is used as measuring quantity, is decreasing considerably with the particle diameter, the fine particles are artificially enlarged, mostly by taking up organic liquids. For the determination of particle sizes, an electric classifier (DMA = Differential Mobility Analyser) may be connected in front of the condensation nucleus counter. This serves to electrically charge particles contained in the measured gas stream. The measured gas stream is then put as an enveloping stream around a pure air stream and is led through an electric field. Depending on the applied voltage, only particles of a certain size category can pass the DMA. This combination of condensation nucleus counter and electrical classifier is referred to as SMPS (Scanning Mobility Particle Sizer).

In optical particle counters, single particles are transported with the sample volume stream through a lit measuring volume. In the measuring volume, the particles scatter the light which is converted into electrical signals by a photodetector. A general assumption is that only one particle is contained in the sample air volume and is scattering the light. A connected signal processing unit evaluates the signals mostly by means of defined threshold values concerning particle size and number. This principle of scattered light measurement is also referred to as nephelometry.

Diffusion batteries make use of the fact that particles of different sizes show different diffusion speeds due to the Brownian mocular movement. They do so by means of nets or diaphragms. In each stage of the diffusion battery, smaller particles are proportionally held back the most by collisions with the net or the diaphragm. From the decrease of particles between one stage and the following, the size distributions can be determined. Mostly, the particles are detected by means of condensation nucleus counters.

More recent developments include the laser-based procedures LI²SA and the photo-acoustic particle sensor.

In the incandescence method (LI²SA), the particles contained in a measured gas stream are made to glow by means of a laser. The measured quantity is the attenuation of the glowing light. The intensity of the light correlates with the number of particles, and the attenuation rate correlates with the particle size.

In photo-acoustic particle sensors, a pulsating laser beam induces expansions and contractions of the particles. The hereby created sonic oscillation is then being measured.

6.2.8 Dust Deposition Measurement

The results of dust deposition measurements can be affected considerably by the employed sampling equipment. The differences in measurement results can amount to as much as 50% /137/.

In the Federal Republic of Germany, the dominant device for dust deposition measurement is the Bergerhoff sampler (VDI 2119 Part 2 /5/) because the ambient air quality values of TA Luft 86 /51/ were based on the results obtained from this device. Other dust deposition measuring equipment is described in VDI Guideline 2119 (Hibernia device and Löbner-Liesegang device). Figure 16 shows a sketch of the Bergerhoff sampler.

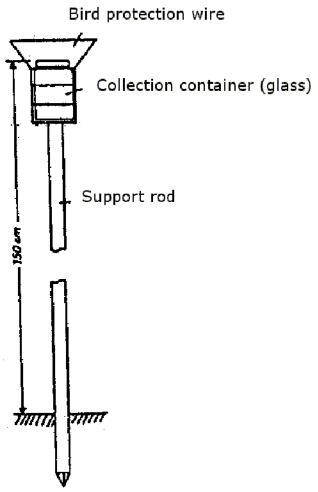


Figure 16: Bergerhoff Sampler

The collection container of the Bergerhoff sampler is an ordinary preserving-jar holding 1.5 l (inner diameter 8.9 cm, collection area 62 cm^2). The jar is placed in a wire bird protection device and set onto an iron tube of about 1.5 m in length which is fixed to the ground.

Because the production of 1.5 l preserving-jars has ceased, and also because they break very easily, comparative tests have been carried out to determine whether similar measurement results can be obtained using plastic containers in order to continue the Bergerhoff method /138/. Statistic assessments have in principle proved no significant differences in the measurement values of the two methods /138/. Therefore, the modified sampling method was included in the VDI Guidelines on Air Quality Control /5/ in 1996.

VDI Guideline 2119 Part 4 /5/ describes the measurement of particle deposition by microscopic differentiation and size-fractionated determination of the particle deposition on adhesive films (sampling device Sigma-2).

6.2.9 Measurement of Dust Components

The following substances are the components measured to be the most frequent ones in atmospheric dust:

- metals, especially heavy metals,
- polycyclic aromatic hydrocarbons, and
- anions (mainly sulphates, nitrates and chlorides).

6.2.9.1 Metals

For some metals, ambient air quality limit values have been specified in Germany. The TA Luft /24/, the 22nd BImSchV /25/, the draft for the 4th EU Daughter Directive /22/ and the Fourth General Administrative Instruction for the BImSchG specify several metals and metal compounds to be measured. The common methods of analysis for metals are /139, 140, 141, 142/:

– **Atomic Absorption Spectrometry (AAS) /143/**

An extract of the dust sample is vaporized. The light of a hollow cathode lamp of the specific wavelength at which the atoms of the metal to be measured show absorption is shone through this vapour. The decrease in light intensity is a measure for the amount of metal ions contained in the sample. The vaporization of the sample can be achieved by a flame, or by using an electrically heated graphite tube. The flame method is easier to carry out whereas the graphite tube method has a lower detection limit.

For some metals and semi-metals, more specialized techniques of atomic absorption spectrometric determinations have been developed, for example the hydride technique (converting the element into its hydride form before analysis) for arsenic, antimony, and selenium, and the cold vapour technique for volatile mercury.

Several VDI Guidelines (VDI 2267 Parts 4 and 7 /5/) describe the atomic absorption spectrometric determination of metals in suspended particulate matter and dust deposition.

– **Atomic Absorption Spectrometry (AAS) using Cold Vapour**

In this method for the determination of mercury mass concentrations, the mercury is adsorbed by amalgam formation on a coiled-up gold-platinum net. Particle-bound mercury is held back by a filter, if necessary. Due to the high vapour pressure of mercury, a determination by atomic absorption spectrometry is possible after a thermal desorption without prior atomisation. The method is described in VDI Guideline 2267 Part 8 /5/.

- **Atomic Fluorescence Spectrometry (AFS) using Cold Vapour**

  With this method for the determination of mercury mass concentrations, mercury is adsorbed by amalgam formation on a gold-coated carrier and is then transported into the light path by means of a carrier gas.

  The mercury atoms are energized (excited) and on transition to a lower energy level emit fluorescence radiation which is measured and evaluated.

  The method is described in VDI Guideline 2267 Part 9 /5/.

- **Inductively Coupled Plasma with Atomic Emission Spectrometry (ICP-AES) /145, 151/**

  With this method, an electrically heated plasma burner brings the atoms of the sample to a temperature of about 8000 K. The burner has an inductive connection to a powerful high frequency generator. Argon, being easily ionisable, allows a transformation into plasma condition. The inductively coupled plasma (ICP) is the activating medium for the atomisation of the sample. Then the emission spectrum of the atoms contained in the sample is measured.

  With the ICP method it is possible to determine a large number of elements contained in the sample. This advantage has made it a widely used method. It is described in the VDI Guideline 2267 Part 5 /5/.

- **Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES)**

  In the inductively coupled plasma optical emission spectrometry (ICP-OES), following filter sampling and breaking up in an oxidizing acid mixture, the element determination takes place by means of atomic emission spectrometry in inductively coupled plasma (VDI 2267 Parts 5 and 14 (draft) /5/).

- **Inductively Coupled Plasma Mass Spectrometry (ICP-MS) /146/**

  The mass spectrometric determination of numerous metals contained in dust, which has to be prepared like in the case of the ICP-AES method, has a much greater sensitivity than the ICP-AES method but also brings about higher expenditures on technical equipment. The draft of DIN 38406-29 /146/ describes the determination of 61 elements in aqueous media and sludge.

- **X-Ray Fluorescence Analysis (XRFA) /147/**

  The XRFA is a non-destructive method. It measures an element's characteristic fluorescence radiation after X-ray excitation of the sample dust. The method is described in the VDI Guidelines for lead determination in particles (VDI 2267 Parts 2, 11 and 12 /5/).

Further methods for the determination of metals such as

- **Polarography**
  (Measurement of current / voltage curves in redox processes with a mercury electrode) and
- **Neutron Activation Analysis**
  (a non-destructive method in which isotopes of the metal to be determined are created by neutron radiation. The characteristic gamma radiation from these isotopes is measured.)

have not become established in the field of ambient air quality control in Germany.

6.2.9.2 Polycyclic Aromatic Hydrocarbons

For the determination of polycyclic aromatic hydrocarbons (as well as further organic chemical compounds of particulate pollutants), chromatographic methods are the most widely employed, in particular gas chromatography and high pressure liquid chromatography (see Chapter 6.2.3). Sampling, sample preparation and analysis according to the gas chromatography method are described in VDI Guideline 3875 Part 1 /5/ (gas chromatography).

6.2.9.3 Polychlorinated Dibenzo-p-dioxins and Dibenzofuranes

VDI Guideline 2090 Parts 1 and 2 /5/ describe methods for the determination of PCDD/F deposition. The analysis includes Bergerhoff sampling (Part 1) or funnel absorber sampling (Part 2) followed by a gas-chromatographic separation (GC/HMRS) with subsequent mass-spectrometric determination.

For the determination of highly toxic dioxins and furans contained in indoor air, VDI Guideline 3498 Parts 1 and 2 /5/ describe a method in which these substances are sampled onto a fibreglass filter (particles) and on a piece of polyurethane foam (gases). For the analysis, filters and foams are extracted and the extracts purified. The subsequent gas-chromatographic separation is followed by a mass-spectrometric determination of the individual compounds.

6.2.9.4 Anions

For anions separated onto filters, the following measurement methods are described in the VDI Guidelines on Air Quality Control /5/:

- **Isotope dilution analysis** for sulphate (VDI 3497 Part 2)
- **Ion chromatography** for chloride, nitrate and sulphate (VDI 3497 Part 3 (suppressor technique) and Part 4 (single column technique)).

Ion chromatography has also become established as the preferred method for the determination of anions in wet deposition (cf. Chapter 6.2.2.2).

6.2.9.5 Soot

"Soot" is not defined chemically but ultimately by the measuring technique. The carcinogenic properties of soot and the monitoring of soot concentrations in ambient air introduced by the 23rd Ordinance for the Federal Immission Control Act /27/ (which has in the meantime been repealed) assigned a special significance to the measurement of soot. According to the 23rd Ordinance for the BImSchG, soot is defined as the elemental carbon contained in fine dust in outdoor ambient air which might enter the pulmonary tract. Following the repeal of the 23rd BImSchV, soot is to be registered as a part of the total amount of particles (PM_{10}) with regard to the annual mean value as laid down in the 22nd BImSchV /25/.

Various methods have been proposed for the measurement of soot in ambient air. With certain restrictions, the "Black Smoke" method (see Chapter 4.2.5) can also be interpreted as a method for soot measurement. However, comparative measurements in Germany showed only an unsatisfactory detection limit and unsatisfactory ranges of uncertainty for this method /148/.

In VDI Guideline 2465 Part 1 /5/, a method for soot measurement in ambient air quality control is described. For the sampling, a filter device is used which allows the separation of fine dust, e.g. the small filter device GS 050/3-C (VDI 2463 Part 7 /5/). The carbon contained in the separated fine dust is determined by burning the sample under oxygen and coulometrically measuring the carbon dioxide formed in this process. A preparation of the samples (liquid extraction under nitrogen aiming at the removal of extractable organic chemical compounds and thermal desorption of non-extractable organic compounds and adherent rests of solvents) specializes this method for elementary carbon.

VDI Guideline 2465 Part 2 /5/ describes a method for the thermographic determination of elementary carbon subsequent to the thermal desorption of organic carbon. The dust sampling according to DIN EN 481 /150/ and DIN ISO 7708 /151/ in connection with VDI 2463, part 7 /5/ is followed by a pyrolysis and the measurement by means of an NDIR detector.

6.2.10 Measurement of Asbestos and Inorganic Fibres /152/

In ambient air quality measurements, asbestos and other inorganic fibres are determined not as mass concentrations but according to the number of fibres per air volume. Apart from this, a classification is normally made according to fibre lengths (acc. to VDI 3492 Part 1) into

$$2.5\ \mu m \leq L < 5\ \mu m \text{ and}$$
$$5\ \mu m \leq L \leq 100\ \mu m.$$

The common method formerly used in the Federal Republic of Germany for measuring asbestos concentrations in ambient air is described in detail in VDI Guideline 3492 Part 1. For sampling, the fibres are separated onto a gold-coated nucleus pore filter. The sample is cleaned of organic material as far as possible in a specialized plasma burning method. Under a scanning electron microscope (SEM), the individual fibres are counted on a part of the filter, classified according to their size, and then chemically identified in an energy-dispersive X-ray micro analyser (EDXA).

Owing to the ban on the production and use of asbestos, measurements of asbestos fibres (especially in outdoor air) have become less significant. Instead, scientific attention has shifted onto other inorganic fibres, e.g. onto artificial mineral fibres (AMF).

The method proposed in VDI Guideline 3492 (draft of December 2002) allows measurements of fibre concentrations of fibrous particles and their assignment to fibre classes (chrysotile, amphilo asbestos, gypsum, other inorganic fibres). Counting and classification of the fibres is also done by means of REM/EDXA.

The trend towards an international standardization in the field of ambient air measurements has led to a adoption of the fibre counting guidelines issued by the WHO.

The publication of the VDI Guideline, which is expected shortly, will replace Part 1 (outdoor air) and 2 (indoor air) of the Guideline series No. 3492.

7. Quality Assurance

The implementation of ambient air quality measurements in the Federal Republic of Germany is regulated to a great extent by legal requirements (e.g. in TA Luft /24/, 22nd and 33rd BImSchV /25, 26/) and is carried out according to state-approved standards and guidelines. The examination institutes working in this field are subject to a supervising state authority. For this reason, not only the basic standards on quality assurance (ISO 9000 series) and DIN ISO/IEC 17025 /153/ (Accreditation of Examination Laboratories) apply, but also additional quality requirements as laid down in legal provisions (e.g. data quality targets contained in the 22nd and 33rd BImSchV).

Quality assurance measures in the field of ambient air control concern the following levels of action:

- Guidelines concerning measurement planning
- Application of standardized methods for ambient air measurements (VDI Guidelines, standards, reference methods, equivalent methods, calibration methods, suitability-tested measuring devices)
- Ascertainment and confirmation of competence by accreditation and official notification
- Quality control of testing institutes (ring tests, laboratory audits, quality management systems)

The various measures are described in the following.

7.1 Guidelines Concerning Measurement Planning

The purpose of guidelines on measurement planning is to obtain a standardized level of quality for measurement results by standardizing the taking of measurements. In this respect, the guidelines also include quality assurance aspects.

The measuring strategy for the assessment of various pollutant concentrations has been laid down by the EU in the so-called Daughter Directives /19, 20, 21/ and has been transferred into German legislation by amendments to the BImSchG /31/, to TA Luft /24/ and the 22nd BImSchV as well as by the introduction of the 33rd BImSchV /26/ (in preparation).

One of the most important alterations compared to the previous situation is the transition from area-related to point-related measurements and evaluations of pollution according to revised ambient air guiding values. Concerning the selection of measuring site locations, a fairly big discretionary scope is given which makes the reproducibility of the determination of site locations more difficult and contributes to the uncertainty of the measured result. Therefore, the VDI Guideline series 4280 /54, 55, 56/ has been set also with regard to a desired standardization of methods for the determination of measuring site locations.

7.2 Application of Standardized Measuring Methods

The purpose of standardizing measuring methods is to obtain reliable and comparable measuring results by defining the entire measuring process from sampling to the final analysis and laying down quality characteristics, the so-called performance characteristics (detection limit, measuring uncertainty, etc.).

7.2.1 Standardization of Measuring Methods as VDI Guidelines or Standards

In the 1950s already, the "VDI Commission On Air Quality Control" (today: "Commission on Air Quality Control in VDI and DIN standardization committee") dealt with testing and standardizing methods for the measurement of ambient air quality as VDI Guidelines. With regard to the internationalisation of air quality control within the European Union, international standards (ISO and CEN standards), which are increasingly adopted in Germany as DIN ISO or DIN EN standards, have gained more and more significance.

The decisive criterion for the selection of measuring methods is their suitability for assessing the observance of ambient air quality values or similar effect criteria laid down government regulations.

Apart from the standardization of the actual measuring methods, further regulations such as the VDI Guideline series 3490 (Measurement of gases; calibration gas mixtures), 3491 (Particulate matter measurement, test aerosols), and 2449 (Measurement methods test criteria) /5/ have to be taken into account with regard to aspects of quality assurance.

The following standards are relevant to the assessment of measuring methods /5/: DIN ISO 6879 (Performance Characteristics) /154/, DIN ISO 13752 (Assessment of the uncertainty of measuring methods) /90/ and DIN EN ISO 14956 (Evaluation of the suitability of a measurement procedure by comparison with a required measurement uncertainty) /99/. A list including titles and dates of issue can be found in Appendix 2.

7.2.2 Suitability-Tested Measuring Devices

The use of suitability-tested measuring devices is to ensure a comparable quality of data obtained in continuous ambient air measurements.

The minimum requirements are laid down in VDI Guideline 4202 Part 1 "Minimum requirements for suitability tests of automated ambient air quality measuring systems – Point-related measurement methods for gaseous and particulate pollutants" /98/. Concerning measuring uncertainty they follow the regulations laid down in EU Daughter Directives /19-21/.

A guideline concerning optical long-path measuring instruments (VDI 4202 Part 2) is available as a draft /100/.

The test plans required for the suitability test have been standardized in VDI Guideline 4203 Part 1, "Testing of automated measuring systems – general concepts", and Part 3 "Testing of automated measuring systems – testing of measuring systems for point-related measurement of gaseous and particulate pollutants" (in preparation) /101, 102/.

Suitability tests are carried out by accredited testing institutes.

7.2.3 Reference Methods, Equivalent Methods, Calibration Methods

In 1988, experts of federal and regional institutions dealing with ambient air quality control have worked out "Guidelines on the determination of reference methods, the selection of equivalent methods and the application of calibration methods" /127/ which have been published by the Federal Environmental Agency in agreement with the LAI. Apart from definitions and general information, the Guidelines provide concrete specifications of reference methods for sulphur dioxide, nitrogen dioxide, ozone, carbon monoxide and suspended particulate matter. In the meantime, i.e. since the Guidelines have been issued, the monitoring of ambient air quality has shifted to the use of continuous automated measuring devices. This, in connection with recent European regulations on ambient air control necessitates a revision of the Guidelines.

7.3 Ascertainment and Confirmation of Competence for Measuring Institutes By Notification and Official Accreditation

According to Articles 26 and 28, only those measuring institutes are to be entrusted with the taking of ambient air quality measurements within the sphere of influence of installations, which have been designated by the highest *Länder* authorities for ambient air quality control. This official designation is called notification and indicates that a measuring institute’s competence for carrying out these tasks has been established and officially recognized.

At the beginning of the 1990s, the accreditation of testing and calibration laboratories according to the European standard EN 45001 /115/, which is valid in all EU member states, was introduced. It has in the meantime been superseded by the international standard DIN/ISO/IEC 17025 "General requirements for the competence of testing and calibration laboratories" /153/. For laboratories licensed according to the old standard, DIN/ISO/IEC 17025 provides transition periods. One particular requirement for the accreditation is the implementation of an internal quality management with regard to the international standard series DIN ISO EN 9000.

The 47th German Conference of Environmental Ministers decided that the competence of a laboratory working in the legally regulated environmental field as a pre-condition for the notification according to the applicant's request may be established by a private evaluated accreditation agency or an agency which has been designated for this task by the responsible *Land* authorities.

The proof of competence is to be produced according to the European standard DIN EN 45001 /155/ or the subsequent DIN/ISO/IEC 17025 /153/ "General demands on the competence of testing and calibration laboratories" /148/.

The co-operation of private agencies and state authorities is regulated by the "Agreement on the co-operation of the *Länder* (Federal States) with participating accreditation agencies in the environmental sector" /157/ and the "Administrative agreement on the proof of competence and the notification of testing laboratories and measuring institutes in the legally regulated environmental sector" /158/. Both agreements have been put into force by *Länder* authorities and accreditation agencies, and have been published in the *Bundesanzeiger* (Federal Gazette).

Apart from these decisions which cover the entire legally regulated environmental sector, specific regulations were drawn up concerning ambient air quality control.

For the necessary standardization of requirements made by private and state accreditation agencies, the LAI has worked out the "Proof of competence for evaluations in the field of ambient air quality protection", which is also known as "ambient air quality protection module" /159/.

The LAI Guidelines on notification and licensing of expert agencies in the field on ambient air quality protection /160/ were revised with the version of 17 October 2000. An updated version was issued on 20 May 2001.

Accordingly, the establishment of competence is to suffice in future as a basis for notification and accreditation.

Final agreements on this matter are currently being worked out between the three major German accreditation agencies DACH (Deutsches Akkreditiersystem Chemie), DAP (Deutsches Akkreditiersystem Prüfwesen) and DASMIN (Deutsche Akkreditierungsstelle Mineralöl), and the highest environmental *Länder* authorities.

7.4 Quality Control of Laboratories

7.4.1 Ring tests

One essential element of the quality control of measuring institutes notified according to Article 26 BImSchG is the obligatory participation in ring tests.

In accordance with a LAI agreement, these ring tests are carried out since 1989 by the Landesumweltamt Nordrhein-Westfalen (North Rhine-Westphalian State Environmental Agency) in Essen for all measuring institutes recognized in the various Federal States.

In 1996, the LAI passed a resolution which, within the context of a progressive harmonization of European accreditation practice, introduced a new mode of evaluation, the so-called z-score procedure.

In this case, the estimated value for the "true" result is the median of all the participants' results per component and level of concentration. For statistical reasons, a minimum number of 10 participants is required.

As guiding point for the derivation of the so-called precision target, i.e. the precision value to be observed by the ring test participant, the demands on reproducibility taken from minimum requirements for continuous ambient air quality monitoring devices were applied, similar to the previous evaluation system.

For the evaluation of the ring test result, the difference between the measured value obtained by the participant and the estimated value for the true result is related to the respective value of the precision target. This so-called z-score value of each participant is evaluated according to an internationally used scheme, taking measured values of the different concentration levels into account, so that a definite statement can be made on whether a measuring institute has successfully passed the ring test or not.

Measuring institutes which once have failed a ring test are called upon to repeat the test. In case of repeated failure, a revocation of the notification by the highest State authority is to be expected.

Detailed foundations for the current implementation of ring tests are laid in the following LAI regulations:

- Regulations on the implementation of ring tests for measuring institutes according to Article 26 /161/
- Recommendations for the evaluation of ring tests for measuring institutes according to Article 26 /161/

Since today the reference measuring methods prescribed in Germany for ambient air pollution measurements of SO_2 and NO_2 are used for the prescribed ring tests only, but have otherwise almost completely lost their significance in measurement practice, a revision of these ring test guidelines has become necessary. In accordance with a LAI resolution, the preparation of a revised version has begun, a binding revised regulation is, however, not available yet.

The expected changes will presumably concern the following aspects:

1. Due to the small number of expected future participants, a pre-determined value will be used as target value instead of the participants' average.

2. Concentration ranges are being adopted to actual ambient air pollution values and to the new limit values.

3. Precision targets will presumably be tightened with regard to the ring tests carried out in the European research centre in Ispra (Italy)

4. An increased standardization of practice in the various Federal States is intended.

7.4.2 Quality Management Systems

The introduction of accreditation according to the European standard EN 45001 has made quality management systems (QM systems) a prerequisite for the ascertainment of competence for laboratories. The international standard DIN/ISO/IEC 17025 /153/ describes a QM systems which in principle is suitable also for ambient air quality measuring institutes (supplemented if necessary by VDI Guideline 4220 /162/ and the ambient air quality protection module /146/).

Furthermore, for practical work attention is drawn to the Model Quality Management Manual issued by the LAI on 29 March 2001 /163/ and to further information obtainable at the accreditation agencies.

The most important features of quality management systems are:

- The implementation of a QM system requires the appointment of an authorized person who acts independently of other tasks and has direct access to the management
- The essential item of the system is the so-called Quality Management Manual

This Manual has to include:

- Basic regulations, systems, programmes, methods, instructions as well as technical procedures
- The laboratory's obligation to good technical practice and quality as well as a service offer
- A definition of tasks for the quality manager and the technical management

- Regulations for the implementation of internal audits and corrective measures for detected deficiencies
- The QM system is to take into consideration the requirements laid down in the above-mentioned standards and in the module concerning personnel, rooms, laboratory equipment, methods for the validation and estimation of measuring uncertainties, final reports etc.

8. Summary

This Manual of Ambient Air Quality Control in Germany gives an overview of the methods employed for the measurement of ambient air pollution in the Federal Republic. It describes the relevant regulations contained in the Federal Immission Control Act (BImSchG), in the Technical Instructions on Air Quality Control (TA Luft), and in the Fourth General Administrative Instruction (4. Allgemeine Verwaltungsvorschrift) in consideration of the Directives of the European Community.

The tasks of ambient air quality measurement are outlined, and discontinuous as well as continuous measurement methods are described. The Guidelines on measuring techniques issued by the Commission on Air Pollution Prevention in VDI and DIN, and a list of suitability-tested measuring devices are included as Appendices. Furthermore, a summary is given of the results of suitability tests.

Special attention is paid to the quality assurance of ambient air quality measurements, concerning both measurement methods and testing institutes. The sections on measurement planning contain the most important terms, measurement regulations and measurement plans for the Federal Republic of Germany, measurements in the vicinity of emission sources and measurement networks in Germany.

Details are given on technical means and national regulations relevant for the evaluation of ambient air quality measurement data and the evaluation of measurements taken in the vicinity of emission sources. Furthermore, the measurement reports published by the national institutions of the Federal administration and in particular those of the individual Federal States are being described.

In comparison with the 2nd edition, this Manual includes new legal provisions (Amendments to the Federal Immission Control Act, 22nd and 33rd Ordinance and 4th General Administrative Instructions for the BImSchG, Framework Directive and Daughter Directives issued by the European Union), additional measuring methods and Guidelines of the Commission on Air Pollution Prevention in VDI and DIN, international standards (ISO and CEN) which have been adopted as DIN standards as well as further descriptions of suitability-tested automated continuous measuring devices. The chapter on "Quality Assurance" and the list of references have been updated. The index shall make it easier to find one’s way through the text.

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APPENDIX 1

Legal and Administrative Instructions

1. Excerpt from the Bundes-Immissionsschutzgesetz (BImSchG)

Act on the Prevention Of Harmful Effects On the Environment caused By Air Pollution, Noise, Vibration, and Similar Phenomena
(Federal Immission Control Act)

Bundesgesetzblatt Jahrgang 2002 (BGBl. I Nr. 71, p. 3841)
-no official translation available yet-

§ 26
Messungen aus besonderem Anlass

Die zuständige Behörde kann anordnen, dass der Betreiber einer genehmigungsbedürftigen Anlage oder, soweit § 22 Anwendung findet, einer nicht genehmigungsbedürftigen Anlage Art und Ausmaß der von der Anlage ausgehenden Emissionen sowie die Immissionen im Einwirkungsbereich der Anlage durch eine der von der nach Landesrecht zuständigen Behörde bekannt gegebenen Stellen ermitteln lässt, wenn zu befürchten ist, dass durch die Anlage schädliche Umwelteinwirkungen hervorgerufen werden. Die zuständige Behörde ist befugt, Einzelheiten über Art und Umfang der Ermittlungen sowie über die Vorlage des Ermittlungsergebnisses vorzuschreiben.

§ 28
Erstmalige und wiederkehrende Messungen bei genehmigungsbedürftigen Anlagen

Die zuständige Behörde kann bei genehmigungsbedürftigen Anlagen

1. nach der Inbetriebnahme oder einer Änderung im Sinne des § 15 oder des § 16 und sodann
2. nach Ablauf eines Zeitraums von jeweils drei Jahren

Anordnungen nach § 26 auch ohne die dort genannten Voraussetzungen treffen. Hält die Behörde wegen Art, Menge und Gefährlichkeit der von der Anlage ausgehenden Emissionen Ermittlungen auch während des in Nummer 2 genannten Zeitraums für erforderlich, so soll sie auf Antrag des Betreibers zulassen, dass diese Ermittlungen durch den Immissionsschutzbeauftragten durchgeführt werden, wenn dieser hierfür die erforderliche Fachkunde, Zuverlässigkeit und gerätetechnische Ausstattung besitzt.

§ 29
Kontinuierliche Messungen

(1) Die zuständige Behörde kann bei genehmigungsbedürftigen Anlagen anordnen, dass statt durch Einzelmessungen nach § 26 oder § 28 oder neben solchen Messungen bestimmte Emissionen oder Immissionen unter Verwendung aufzeichnender Messgeräte fortlaufend ermittelt werden. Bei Anlagen mit erheblichen Emissionsmassenströmen luftverunreinigender Stoffe sollen unter Berücksichtigung von Art und Gefährlichkeit dieser Stoffe Anordnungen nach Satz 1 getroffen werden, soweit eine Überschreitung der in Rechtsvorschriften, Auflagen oder Anordnungen festgelegten Emissionsbegrenzungen nach der Art der Anlage nicht ausgeschlossen werden kann.

(2) Die zuständige Behörde kann bei nicht genehmigungsbedürftigen Anlagen, soweit § 22 anzuwenden ist, anordnen, dass statt durch Einzelmessungen nach § 26 oder neben solchen Messungen bestimmte Emissionen oder Immissionen unter Verwendung aufzeichnender Messgeräte fortlaufend ermittelt werden, wenn dies zur Feststellung erforderlich ist, ob durch die Anlage schädliche Umwelteinwirkungen hervorgerufen werden.

§ 40
Verkehrsbeschränkungen

(1) Die zuständige Straßenverkehrsbehörde beschränkt oder verbietet den Kraftfahrzeugverkehr nach Maßgabe der straßenverkehrsrechtlichen Vorschriften, soweit ein Luftreinhalte- oder Aktionsplan nach § 47 Abs. 1 oder 2 dies vorsehen. Die Straßenverkehrsbehörde kann im Einvernehmen mit der für den Immissionsschutz zuständigen Behörde Ausnahmen von Verboten oder Beschränkungen des Kraftfahrzeugverkehrs zulassen, wenn unaufschiebbare und überwiegende Gründe des Wohls der Allgemeinheit dies erfordern.

(2) Die zuständige Straßenverkehrsbehörde kann den Kraftfahrzeugverkehr nach Maßgabe der straßenverkehrsrechtlichen Vorschriften auf bestimmten Straßen oder in bestimmten Gebieten verbieten oder beschränken, wenn der Kraftfahrzeugverkehr zur Überschreitung von in Rechtsverordnungen nach § 48a Abs. 1a festgelegten Immissionswerten beiträgt und soweit die für den Immissionsschutz zuständige Behörde dies im Hinblick auf die örtlichen Verhältnisse für geboten hält, um schädliche Umwelteinwirkungen durch Luftverunreinigungen zu vermindern oder deren Entstehen zu vermeiden. Hierbei sind die Verkehrsbedürfnisse und die städtebaulichen Belange zu berücksichtigen. § 47 Abs. 6 Satz 1 bleibt unberührt.

(3) Die Bundesregierung wird ermächtigt, nach Anhörung der beteiligten Kreise (§ 51) durch Rechtsverordnung mit Zustimmung des Bundesrates zu regeln, dass Kraftfahrzeuge mit geringem Beitrag zur Schadstoffbelastung von Verkehrsverboten ganz oder teilweise ausgenommen sind oder ausgenommen werden können, sowie die hierfür maßgebenden Kriterien und die amtliche Kennzeichnung der Kraftfahrzeuge festzulegen. Die Verordnung kann auch regeln, dass bestimmte Fahrten oder Personen ausgenommen sind oder ausgenommen werden können, wenn das Wohl der Allgemeinheit oder unaufschiebbare und überwiegende Interessen des Einzelnen dies erfordern.

§ 44

Überwachung der Luftqualität

(1) Zur Überwachung der Luftqualität führen die zuständigen Behörden regelmäßige Untersuchungen nach den Anforderungen der Rechtsverordnungen nach § 48a Abs. 1 oder 1a durch.

(2) Die Landesregierungen oder die von ihnen bestimmten Stellen werden ermächtigt, durch Rechtsverordnungen Untersuchungsgebiete festzulegen, in denen Art und Umfang bestimmter nicht von Absatz 1 erfasster Luftverunreinigungen in der Atmosphäre, die schädliche Umwelteinwirkungen hervorrufen können, in einem bestimmten Zeitraum oder fortlaufend festzustellen sowie die für die Entstehung der Luftverunreinigungen und ihrer Ausbreitung bedeutsamen Umstände zu untersuchen sind.

§ 45

Verbesserung der Luftqualität

(1) Die zuständigen Behörden ergreifen die erforderlichen Maßnahmen, um die Einhaltung der durch eine Rechtsverordnung nach § 48a festgelegten Immissionswerte sicherzustellen. Hierzu gehören insbesondere Pläne nach § 47.

(2) Die Maßnahmen nach Absatz 1

a) müssen einem integrierten Ansatz zum Schutz von Luft, Wasser und Boden Rechnung tragen;

b) dürfen nicht gegen die Vorschriften zum Schutz von Gesundheit und Sicherheit der Arbeitnehmer am Arbeitsplatz verstoßen;

c) dürfen keine erheblichen Beeinträchtigungen der Umwelt in anderen Mitgliedstaaten verursachen.

§ 46a

Unterrichtung der Öffentlichkeit

Die Öffentlichkeit ist nach Maßgabe der Rechtsverordnungen nach § 48a Abs. 1 über die Luftqualität zu informieren. Überschreitungen von in Rechtsverordnungen nach § 48a Abs. 1 als Immissionswerte festgelegten Alarmschwellen sind der Öffentlichkeit von der zuständigen Behörde unverzüglich durch Rundfunk, Fernsehen, Presse oder auf andere Weise bekannt zu geben.

§ 47

Luftreinhaltepläne, Aktionspläne, Landesverordnungen

(1) Werden die durch eine Rechtsverordnung nach § 48a Abs. 1 festgelegten Immissionsgrenzwerte einschließlich festgelegter Toleranzmargen überschritten, hat die zuständige Behörde einen Luftreinhalteplan aufzustellen, welcher die erforderlichen Maßnahmen zur dauerhaften Verminderung von Luftverunreinigungen festlegt und den Anforderungen der Rechtsverordnung entspricht.

(2) Besteht die Gefahr, dass die durch eine Rechtsverordnung nach § 48a Abs. 1 festgelegten Immissionsgrenzwerte oder Alarmschwellen überschritten werden, hat die zuständige Behörde einen Aktionsplan aufzustellen, der festlegt, welche Maßnahmen kurzfristig zu ergreifen sind. Die im Aktionsplan festgelegten Maßnahmen müssen geeignet sein, die Gefahr der Überschreitung der Werte zu verringern oder den Zeitraum, während dessen die Werte überschritten werden, zu verkürzen. Aktionspläne können Teil eines Luftreinhalteplans nach Absatz 1 sein.

(3) Liegen Anhaltspunkte dafür vor, dass die durch eine Rechtsverordnung nach § 48a Abs. 1a festgelegten Immissionswerte nicht eingehalten werden, oder sind in einem Untersuchungsgebiet im Sinne des § 44 Abs. 2 sonstige schädliche Umwelteinwirkungen zu erwarten, kann die zuständige Behörde einen Luftreinhalteplan aufstellen. Bei der Aufstellung dieser Pläne sind die Ziele der Raumordnung zu beachten; die Grundsätze und sonstigen Erfordernisse der Raumordnung sind zu berücksichtigen.

(4) Die Maßnahmen sind entsprechend des Verursacheranteils unter Beachtung des Grundsatzes der Verhältnismäßigkeit gegen alle Emittenten zu richten, die zum Überschreiten der Immissionswerte oder in einem Untersuchungsgebiet im Sinne des § 44 Abs. 2 zu sonstigen schädlichen Umwelteinwirkungen beitragen. Werden in Plänen nach Absatz 1 oder 2 Maßnahmen im Straßenverkehr erforderlich, sind diese im Einvernehmen mit den zuständigen Straßenbau- und Straßenverkehrsbehörden festzulegen. Werden Immissionswerte hinsichtlich mehrerer Schadstoffe überschritten, ist ein alle Schadstoffe erfassender Plan aufzustellen. Werden Immissionswerte durch Emissionen überschritten, die außerhalb des Plangebiets verursacht werden, hat in den Fällen der Absätze 1 und 2 auch die dort zuständige Behörde einen Plan aufzustellen.

(5) Die nach den Absätzen 1 bis 4 aufzustellenden Pläne müssen den Anforderungen des § 45 Abs. 2 entsprechen. Die Öffentlichkeit ist bei ihrer Aufstellung zu beteiligen. Die Pläne müssen für die Öffentlichkeit zugänglich sein.

(6) Die Maßnahmen, die Pläne nach den Absätzen 1 bis 4 festlegen, sind durch Anordnungen oder sonstige Entscheidungen der zuständigen Träger öffentlicher Verwaltung nach diesem Gesetz oder nach anderen Rechtsvorschriften durchzusetzen. Sind in den Plänen planungsrechtliche Festlegungen vorgesehen, haben die zuständigen Planungsträger dies bei ihren Planungen zu berücksichtigen.

(7) Die Landesregierungen oder die von ihnen bestimmten Stellen werden ermächtigt, bei der Gefahr, dass Immissionsgrenzwerte überschritten werden, die eine Rechtsverordnung nach § 48a Abs. 1 festlegt, durch Rechtsverordnung vorzuschreiben, dass in näher zu bestimmenden Gebieten bestimmte

1. ortsveränderliche Anlagen nicht betrieben werden dürfen,
2. ortsfeste Anlagen nicht errichtet werden dürfen,
3. ortsveränderliche oder ortsfeste Anlagen nur zu bestimmten Zeiten betrieben werden dürfen oder erhöhten betriebstechnischen Anforderungen genügen müssen,
4. Brennstoffe in Anlagen nicht oder nur beschränkt verwendet werden dürfen,

soweit die Anlagen oder Brennstoffe geeignet sind, zur Überschreitung der Immissionswerte beizutragen. Absatz 4 Satz 1 und § 49 Abs. 3 gelten entsprechend.

§ 48

Verwaltungsvorschriften

Die Bundesregierung erlässt nach Anhörung der beteiligten Kreise (§ 51) mit Zustimmung des Bundesrates zur Durchführung dieses Gesetzes und der auf Grund dieses Gesetzes erlassenen Rechtsverordnungen des Bundes allgemeine Verwaltungsvorschriften, insbesondere über

1. Immissionswerte, die zu dem in § 1 genannten Zweck nicht überschritten werden dürfen,
2. Emissionswerte, deren Überschreiten nach dem Stand der Technik vermeidbar ist,
3. das Verfahren zur Ermittlung der Emissionen und Immissionen,
4. die von der zuständigen Behörde zu treffenden Maßnahmen bei Anlagen, für die Regelungen in einer Rechtsverordnung nach § 7 Abs. 2 oder 3 vorgesehen werden können, unter Berücksichtigung insbesondere der dort genannten Voraussetzungen.

Bei der Festlegung der Anforderungen sind insbesondere mögliche Verlagerungen von nachteiligen Auswirkungen von einem Schutzgut auf ein anderes zu berücksichtigen; ein hohes Schutzniveau für die Umwelt insgesamt ist zu gewährleisten.

§ 48a

Rechtsverordnungen über Emissionswerte und Immissionswerte

(1) Zur Erfüllung von bindenden Beschlüssen der Europäischen Gemeinschaften kann die Bundesregierung zu dem in § 1 genannten Zweck mit Zustimmung des Bundesrates Rechtsverordnungen über die Festsetzung von Immissions- und Emissionswerten einschließlich der Verfahren zur Ermittlung sowie Maßnahmen zur Einhaltung dieser Werte und zur Überwachung und Messung erlassen. In den Rechtsverordnungen kann auch geregelt werden, wie die Bevölkerung zu unterrichten ist.

(1a) Über die Erfüllung von bindenden Beschlüssen der Europäischen Gemeinschaften hinaus kann die Bundesregierung zu dem in § 1 genannten Zweck mit Zustimmung des Bundesrates Rechtsverordnungen über die Festlegung von Immissionswerten für weitere Schadstoffe einschließlich der Verfahren zur Ermittlung sowie Maßnahmen zur Einhaltung dieser Werte und zur Überwachung und Messung erlassen. In den Rechtsverordnungen kann auch geregelt werden, wie die Bevölkerung zu unterrichten ist.

(2) Die in Rechtsverordnungen nach Absatz 1 festgelegten Maßnahmen sind durch Anordnungen oder sonstige Entscheidungen der zuständigen Träger öffentlicher Verwaltung nach diesem Gesetz oder nach anderen Rechtsvorschriften durchzusetzen; soweit planungsrechtliche Festlegungen vorgesehen sind, haben die zuständigen Planungsträger zu befinden, ob und inwieweit Planungen in Betracht zu ziehen sind.

(3) Zur Erfüllung von bindenden Beschlüssen der Europäischen Gemeinschaften kann die Bundesregierung zu dem in § 1 genannten Zweck mit Zustimmung des Bundesrates in Rechtsverordnungen von Behörden zu erfüllende Pflichten begründen und ihnen Befugnisse zur Erhebung, Verarbeitung und Nutzung personenbezogener Daten einräumen, soweit diese für die Beurteilung und Kontrolle der in den Beschlüssen gestellten Anforderungen erforderlich sind.

§ 48b

Beteiligung des Bundestages beim Erlass von Rechtsverordnungen

Rechtsverordnungen nach § 7 Abs. 1 Satz 1 Nr. 2, § 23 Abs. 1 Satz 1 Nr. 2, § 43 Abs. 1 Satz 1 Nr. 1, § 48a Abs. 1 und § 48a Abs. 1a dieses Gesetzes sind dem Bundestag zuzuleiten. Die Zuleitung erfolgt vor der Zuleitung an den Bundesrat. Die Rechtsverordnungen können durch Beschluss des Bundestages geändert oder abgelehnt werden. Der Beschluss des Bundestages wird der Bundesregierung zugeleitet. Hat sich der Bundestag nach Ablauf von drei Sitzungswochen seit Eingang der Rechtsverordnung nicht mit ihr befasst, wird die unveränderte Rechtsverordnung dem Bundesrat zugeleitet.

§ 49

Schutz bestimmter Gebiete

(1) Die Landesregierungen werden ermächtigt, durch Rechtsverordnung vorzuschreiben, dass in näher zu bestimmenden Gebieten, die eines besonderen Schutzes vor schädlichen Umwelteinwirkungen durch Luftverunreinigungen oder Geräusche bedürfen, bestimmte

1. ortsveränderliche Anlagen nicht betrieben werden dürfen,
2. ortsfeste Anlagen nicht errichtet werden dürfen,
3. ortsveränderliche oder ortsfeste Anlagen nur zu bestimmten Zeiten betrieben werden dürfen oder erhöhten betriebstechnischen Anforderungen genügen müssen oder
4. Brennstoffe in Anlagen nicht oder nur beschränkt verwendet werden dürfen,

soweit die Anlagen oder Brennstoffe geeignet sind, schädliche Umwelteinwirkungen durch Luftverunreinigungen oder Geräusche hervorzurufen, die mit dem besonderen Schutzbedürfnis dieser Gebiete nicht vereinbar sind, und die Luftverunreinigungen und Geräusche durch Auflagen nicht verhindert werden können.

(2) Die Landesregierungen werden ermächtigt, durch Rechtsverordnung Gebiete festzusetzen, in denen während austauscharmer Wetterlagen ein starkes Anwachsen schädlicher Umwelteinwirkungen durch Luftverunreinigungen zu befürchten ist. In der Rechtsverordnung kann vorgeschrieben werden, dass in diesen Gebieten

1. ortsveränderliche oder ortsfeste Anlagen nur zu bestimmten Zeiten betrieben oder
2. Brennstoffe, die in besonderem Maße Luftverunreinigungen hervorrufen, in Anlagen nicht oder nur beschränkt verwendet

werden dürfen, sobald die austauscharme Wetterlage von der zuständigen Behörde bekannt gegeben wird.

(3) Landesrechtliche Ermächtigungen für die Gemeinden und Gemeindeverbände zum Erlass von ortsrechtlichen Vorschriften, die Regelungen zum Schutz der Bevölkerung vor schädlichen Umwelteinwirkungen durch Luftverunreinigungen oder Geräusche zum Gegenstand haben, bleiben unberührt.

§ 51

Anhörung beteiligter Kreise

Soweit Ermächtigungen zum Erlass von Rechtsverordnungen und allgemeinen Verwaltungsvorschriften die Anhörung der beteiligten Kreise vorschreiben, ist ein jeweils auszuwählender Kreis von Vertretern der Wissenschaft, der Betroffenen, der beteiligten Wirtschaft, des beteiligten Verkehrswesens und der für den Immissionsschutz zuständigen obersten Landesbehörden zu hören.

2. Excerpt from the Technische Anleitung zur Reinhaltung der Luft (TA Luft) (Technical Instructions on Air Quality Control)

Erste Allgemeine Verwaltungsvorschrift zum Bundes-Immissionsschutzgesetz (Technische Anleitung zur Reinhaltung der Luft)

24 Juli 2002 (GMBl. 2002, p. 511)

-no official translation available yet-

4.6 *Ermittlung der Immissionskenngrößen*

4.6.1 Allgemeines

4.6.1.1 Ermittlung im Genehmigungsverfahren

Die Bestimmung der Immissions-Kenngrößen ist im Genehmigungsverfahren für den jeweils emittierten Schadstoff nicht erforderlich, wenn

a) die nach Nummer 5.5 abgeleiteten Emissionen (Massenströme) die in Tabelle 7 festgelegten Bagatellmassenströme nicht überschreiten und

b) die nicht nach Nummer 5.5 abgeleiteten Emissionen (diffuse Emissionen) 10 vom Hundert der in Tabelle 7 festgelegten Bagatellmassenströme nicht überschreiten,

soweit sich nicht wegen der besonderen örtlichen Lage oder besonderer Umstände etwas anderes ergibt. Der Massenstrom nach Buchstabe a) ergibt sich aus der Mittelung über die Betriebsstunden einer Kalenderwoche mit dem bei bestimmungsgemäßem Betrieb für die Luftreinhaltung ungünstigsten Betriebsbedingungen.

In die Ermittlung des Massenstroms sind die Emissionen im Abgas der gesamten Anlage einzubeziehen; bei der wesentlichen Änderung sind die Emissionen der zu ändernden sowie derjenigen Anlagenteile zu berücksichtigen, auf die sich die Änderung auswirken wird, es sei denn, durch diese zusätzlichen Emissionen werden die in Tabelle 7 angegebenen Bagatellmassenströme erstmalig überschritten. Dann sind die Emissionen der gesamten Anlagen einzubeziehen.

4.6.1.2 Ermittlung im Überwachungsverfahren

Zur Ermittlung der Gesamtbelastung im Überwachungsverfahren ist wie bei der Ermittlung der Vorbelastung im Genehmigungsverfahren (s. Nummer 4.6.2) vorzugehen. Kommen Anordnungen gegenüber mehreren Emittenten in Betracht, sind die von diesen verursachten Anteile an den Immissionen zu ermitteln, soweit dies zur sachgerechten Ermessensausübung erforderlich ist. Dabei sind neben der Messung der Immissionen auch die für die Ausbreitung bedeutsamen meteorologischen Faktoren gleichzeitig zu ermitteln. Die Sektoren der Windrichtung sowie die Lage der Messstellen und der Aufpunkte sind so zu wählen, dass die gemessenen bzw. gerechneten Immissionen den einzelnen Emittenten zugeordnet werden können.

Tabelle 7: Bagatellmassenströme

Schadstoffe	**Bagatellmassenstrom kg/h**
Arsen und seine Verbindungen, angegeben als As	0,0025
Benzo(a)pyren*) (als Leitkomponente für Polyzyklische Aromatische Kohlenwasserstoffe)	0,0025
Benzol	0,05
Blei und seine Verbindungen, angegeben als Pb	0,025
Cadmium und seine Verbindungen, angegeben als Cd	0,0025
Fluorwasserstoff und gasförmige anorganische Fluorverbindungen, angegeben als F	0,15
Nickel und seine Verbindungen, angegeben als Ni	0,025
Quecksilber und seine Verbindungen, angegeben als Hg	0,0025
Schwefeloxide (Schwefeldioxid und Schwefeltrioxid), angegeben als SO_2	20
Staub (ohne Berücksichtigung der Staubinhaltsstoffe)	1
Stickstoffoxide (Stickstoffmonoxid und Stickstoffdioxid), angegeben als NO_2	20
Tetrachlorethen	2,5
Thallium und seine Verbindungen, angegeben als Tl	0,0025

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*) Der Bagatellmassenstrom für diesen Schadstoff kommt erst zur Anwendung, wenn in Nummer 4 ein Immissionswert für Polyzyklische Aromatische Kohlenwasserstoffe festgelegt wird. Dies ist spätestens dann der Fall, wenn nach Nummer 4.2.1 Absatz 2 ein entsprechender Immissionswert gilt.

4.6.2 Ermittlung der Vorbelastung

4.6.2.1 Kriterien für die Notwendigkeit der Ermittlung der Vorbelastung

Die Ermittlung der Vorbelastung durch gesonderte Messungen ist mit Zustimmung der zuständigen Behörde nicht erforderlich, wenn nach Auswertung der Ergebnisse von Messstationen aus den Immissionsmessnetzen der Länder und nach Abschätzung oder Ermittlung der Zusatzbelastung oder auf Grund sonstiger Erkenntnisse festgestellt wird, dass die Immissionswerte für den jeweiligen Schadstoff am Ort der höchsten Belastung nach Inbetriebnahme der Anlage eingehalten sein werden.

Ferner ist die Ermittlung vorbehaltlich des Absatzes 3 nicht erforderlich, wenn auf Grund sonstigen Vorwissens, z. B. ältere Messungen, Messergebnisse aus vergleichbaren Gebieten, Ergebnisse orientierender Messungen oder Ergebnisse von Ausbreitungsrechnungen oder -schätzungen, festgestellt werden kann, dass für den jeweiligen Schadstoff am Ort der höchsten Vorbelastung

- der Jahresmittelwert weniger als 85 vom Hundert des Konzentrationswertes,
- der höchste 24-Stunden-Wert weniger als 95 vom Hundert des 24-Stunden-Konzentrationswertes (außer Schwebstaub (PM-10)) und
- der höchste 1-Stunden-Wert weniger als 95 vom Hundert des 1-Stunden-Konzentrationswertes

beträgt,

- für Schwebstaub (PM-10) eine Überschreitungshäufigkeit des 24-Stunden-Konzentrationswertes von 50 µg/m^3 Luft als Mittelwert der zurückliegenden drei Jahre mit nicht mehr als 15 Überschreitungen pro Jahr verzeichnet wird.

Absatz 2 gilt nicht, wenn wegen erheblicher Emissionen aus diffusen Quellen oder besonderer betrieblicher, topographischer oder meteorologischer Verhältnisse eine Überschreitung von Immissionswerten nicht ausgeschlossen werden kann.

4.6.2.2 Messplanung

Die Messungen sind nach einem mit der zuständigen Behörde abgestimmten Messplan durchzuführen, in dem die Beurteilungspunkte, die Messobjekte, der Messzeitraum, die Messverfahren, die Messhäufigkeit, die Messdauer von Einzelmessungen in Abhängigkeit von den jeweiligen Quellen bzw. Quellhöhen unter Berücksichtigung der meteorologischen Situation festgelegt werden.

4.6.2.3 Messhöhe

Die Immissionen sind in der Regel in 1,5 m bis 4 m Höhe über Flur sowie in mehr als 1,5 m seitlichem Abstand von Bauwerken zu messen. In Waldbeständen kann es erforderlich sein, höhere Messpunkte entsprechend der Höhe der Bestockung festzulegen.

4.6.2.4 Messzeitraum

Der Messzeitraum beträgt in der Regel 1 Jahr. Der Messzeitraum kann auf bis zu 6 Monate verkürzt werden, wenn die Jahreszeit mit den zu erwartenden höchsten Immissionen erfasst wird. Im Übrigen ist ein kürzerer Messzeitraum möglich, wenn auf Grund der laufenden Messungen klar wird, dass der Antragsteller von Immissionsmessungen entsprechend Nummer 4.6.2.1 freigestellt werden kann.

4.6.2.5 Beurteilungsgebiet

Beurteilungsgebiet ist die Fläche, die sich vollständig innerhalb eines Kreises um den Emissionsschwerpunkt mit einem Radius befindet, der dem 50fachen der tatsächlichen Schornsteinhöhe entspricht und in der die Zusatzbelastung im Aufpunkt mehr als 3,0 vom Hundert des Langzeitkonzentrationswertes beträgt.

Absatz 1 gilt bei einer Austrittshöhe der Emissionen von weniger als 20 m über Flur mit der Maßgabe, dass der Radius mindestens 1 km beträgt.

4.6.2.6 Festlegung der Beurteilungspunkte

Innerhalb des Beurteilungsgebietes sind die Beurteilungspunkte nach Maßgabe der folgenden Absätze so festzulegen, dass eine Beurteilung der Gesamtbelastung an den Punkten mit mutmaßlich höchster relevanter Belastung für dort nicht nur vorübergehend exponierte Schutzgüter auch nach Einschätzung der zuständigen Behörde ermöglicht wird. Messungen, die nur für einen sehr kleinen Bereich repräsentativ sind, sollen vermieden werden. Bei der Auswahl der Beurteilungspunkte sind somit die Belastungshöhe, ihre Relevanz für die Beurteilung der Genehmigungsfähigkeit und die Exposition zu prüfen.

Zunächst werden der nach Anhang 3 durchgeführten Ausbreitungsrechnung im Genehmigungsverfahren bzw. einer entsprechenden Ausbreitungsrechnung im Überwachungsverfahren die Aufpunkte mit maximaler berechneter Zusatzbelastung entnommen. Für Schadstoffe, für die nur ein Immissionswert als Jahresmittelwert festgesetzt worden ist, ist nur der berechnete Jahresmittelwert zu berücksichtigen, für Schadstoffe mit maximalen Tages- oder Stundenwerten sind auch diese zu berücksichtigen.

In einem zweiten Schritt ist die im Beurteilungsgebiet vorhandene Vorbelastung durch andere Quellen (einschließlich Hausbrand und Verkehr) unter Berücksichtigung der Belastungsstruktur abzuschätzen. Insbesondere ist der mögliche Einfluss vorhandener niedriger Quellen einschließlich Straßen abzuschätzen. Dabei ist das Vorwissen heranzuziehen. Zusätzliche Ermittlungen zur Abschätzung der Vorbelastung sind nur durchzuführen, soweit dies mit verhältnismäßigem Aufwand möglich ist.

In einem dritten Schritt sind auf Grund der Ermittlungen nach den Absätzen 2 und 3 die

Punkte mit der zu erwartenden höchsten Gesamtbelastung festzulegen. Daraus sind in der Regel zwei Beurteilungspunkte auszuwählen, so dass sowohl eine Beurteilung des vermutlich höchsten Risikos durch langfristige Exposition als auch durch eine Exposition gegenüber Spitzenbelastungen ermöglicht wird. Falls es sich um einen Schadstoff handelt, für den nur ein Immissionswert für jährliche Einwirkung festgelegt ist, genügt im Regelfall 1 Beurteilungspunkt.

Bei sehr inhomogener Struktur der Vorbelastung (z. B. bei stark gegliedertem Gelände, besonderen meteorologischen Verhältnissen, Einfluss mehrerer niedriger Emittenten im Beurteilungsgebiet) können mehr als zwei Beurteilungspunkte erforderlich sein. Wenn sich zeigt, dass die Immissionsstruktur bezüglich kurzfristiger Spitzenbelastungen und langzeitiger Belastungen gleichartig ist, kann auch 1 Beurteilungspunkt genügen.

Beurteilungspunkte zur Überprüfung der Immissionswerte nach Nummer 4.4.1 sind so festzulegen, dass sie mehr als 20 km von Ballungsräumen oder 5 km von anderen bebauten Gebieten, Industrieanlagen oder Straßen entfernt sind.

Die Festlegung der Beurteilungspunkte ist im Messplan zu begründen.

4.6.2.7 Messverfahren

In der Regel ist die Vorbelastung kontinuierlich zu bestimmen, da mit diskontinuierlichen Messmethoden nur die Jahresmittelwerte mit ausreichender Genauigkeit abgeleitet werden können. Insoweit kommen diskontinuierliche Messungen nur dann in Betracht, wenn für den jeweiligen Schadstoff nur ein Immissionswert für jährliche Einwirkung festgelegt ist oder wenn eine Bestimmung kurzzeitiger Spitzenbelastungen entbehrlich ist.

Neben den Verfahren, die in Verordnungen oder Verwaltungsvorschriften zum Bundes-Immissionsschutzgesetz, in VDI-Richtlinien, DIN-, CEN- oder ISO-Normen beschrieben sind, können auch andere, nachgewiesen gleichwertige Verfahren angewandt werden.

4.6.2.8 Messhäufigkeit

Bei kontinuierlicher Messung muss bezogen auf die Stundenmittelwerte eine Mindestverfügbarkeit von 75 vom Hundert gewährleistet sein. Sind weniger als 90 vom Hundert der Stundenmittelwerte verfügbar, ist die Zahl der Überschreitungen des Grenzwertes (gemäß den Nummern 4.7.2 Buchstabe b) und 4.7.3 Buchstabe b) ermittelt) auf 100 vom Hundert hochzurechnen. Diese Anforderungen an die Verfügbarkeit gelten auch für Tagesmittelwerte der Schwebstaubbelastungsmessung.

Bei diskontinuierlicher Messung beträgt die Zahl der Messwerte pro Messpunkt mindestens 52. Sofern die Anforderung einer EG-Richtlinie an die Datenqualität des Jahresmittelwertes durch 52 Messwerte erfahrungsgemäß nicht

Messmethoden nur die Jahresmittelwerte mit ausreichender Genauigkeit abgeleitet werden können. Insoweit kommen diskontinuierliche Messungen nur dann in Betracht, wenn für den jeweiligen Schadstoff nur ein Immissionswert für jährliche Einwirkung festgelegt ist oder wenn eine Bestimmung kurzzeitiger Spitzenbelastungen entbehrlich ist.

Neben den Verfahren, die in Verordnungen oder Verwaltungsvorschriften zum Bundes-Immissionsschutzgesetz, in VDI-Richtlinien, DIN-, CEN- oder ISO-Normen beschrieben sind, können auch andere, nachgewiesen gleichwertige Verfahren angewandt werden.

4.6.2.8 Messhäufigkeit

Bei kontinuierlicher Messung muss bezogen auf die Stundenmittelwerte eine Mindestverfügbarkeit von 75 vom Hundert gewährleistet sein. Sind weniger als 90 vom Hundert der Stundenmittelwerte verfügbar, ist die Zahl der Überschreitungen des Grenzwertes (gemäß den Nummern 4.7.2 Buchstabe b) und 4.7.3 Buchstabe b) ermittelt) auf 100 vom Hundert hochzurechnen. Diese Anforderungen an die Verfügbarkeit gelten auch für Tagesmittelwerte der Schwebstaubbelastungsmessung.

Bei diskontinuierlicher Messung beträgt die Zahl der Messwerte pro Messpunkt mindestens 52. Sofern die Anforderung einer EG-Richtlinie an die Datenqualität des Jahresmittelwertes durch 52 Messwerte erfahrungsgemäß nicht

erfüllt wird, ist die Zahl der Messwerte entsprechend zu erhöhen. Zur Ermittlung der Datenqualität eines Jahresmittelwertes ist DIN ISO 11222 (Entwurf, Ausgabe April 2001) in Verbindung mit DIN V ENV 13005 (Ausgabe Juni 1999) heranzuziehen. Die Probenahmezeiten sind gleichmäßig über den Messzeitraum zu verteilen, um eine zeitlich repräsentative Probenahme sicherzustellen.

4.6.2.9 Messwerte

Die Messwerte sind entsprechend den Zeitbezügen der Immissionswerte als Jahresmittelwert, Tagesmittelwert und Stundenmittelwert festzustellen. Bei diskontinuierlichen Messungen soll die Probenahmezeit in der Regel 1 Stunde betragen.

4.6.2.10 Orientierende Messungen

Eine Verminderung des Messaufwands nach den Nummern 4.6.2.7 und 4.6.2.8 kommt in Betracht, um

- bei vorhandenem Vorwissen einen von der Größenordnung her bekannten Jahresmittelwert abzusichern oder
- an Standorten mit vermuteter Unter- oder Überschreitung der Belastungskriterien gemäß Nummer 4.6.2.1 diese durch orientierende Messung nachzuweisen. Je nach Ergebnis sind dann ggf. Messungen nach Nummer 4.6.2.7 vorzunehmen.

4.6.3 Kenngrößen für die Vorbelastung

4.6.3.1 Allgemeines

Immissionsmessungen oder vergleichbare Feststellungen über die Immissionsbelastung dürfen herangezogen werden, wenn sie nicht länger als 5 Jahre zurückliegen und sich die für die Beurteilung maßgeblichen Umstände in diesem Zeitraum nicht wesentlich geändert haben.

Die Kenngrößen für die Vorbelastung sind aus den Stundenmittelwerten der kontinuierlichen Messungen bzw. diskontinuierlichen Messungen für jeden Beurteilungspunkt zu bilden.

4.6.3.2 Ermittlung der Kenngrößen für die Vorbelastung

Die Kenngröße für die Immissions-Jahres-Vorbelastung (IJV) ist der Jahresmittelwert, der aus allen Stundenmittelwerten gebildet wird.

Die Kenngröße für die Immissions-Tages-Vorbelastung (ITV) ist die Überschreitungshäufigkeit (Zahl der Tage) des Konzentrationswertes für 24-stündige Immissionseinwirkung.

Die Kenngröße für die Immissions-Stunden-Vorbelastung (ISV) ist die Überschreitungshäufigkeit (Zahl der Stunden) des Konzentrationswertes für 1-stündige Immissionseinwirkung.

4.6.3.3 Auswertung der Messungen

Aus den Messwerten sind die Kenngrößen IJV, ITV, ISV zu bilden, soweit für die jeweiligen Schadstoffe Immissionswerte für jährliche, tägliche und stündliche Einwirkung festgelegt sind.

Bei der Angabe von ITV und ISV ist gleichzeitig der jeweils höchste gemessene Tagesmittelwert bzw. Stundenmittelwert anzugeben.

4.6.4 Kenngrößen für die Zusatzbelastung

4.6.4.1 Allgemeines

Die Kenngrößen für die Zusatzbelastung sind durch rechnerische Immissionsprognose auf der Basis einer mittleren jährlichen Häufigkeitsverteilung oder einer repräsentativen Jahreszeitreihe von Windrichtung, Windgeschwindigkeit und Ausbreitungsklasse zu bilden. Dabei ist das im Anhang 3 angegebene Berechnungsverfahren anzuwenden.

4.6.4.2 Ermittlung der Kenngrößen für die Zusatzbelastung

Die Kenngröße für die Immissions-Jahres-Zusatzbelastung (IJZ) ist der arithmetische Mittelwert aller berechneten Einzelbeiträge an jedem Aufpunkt.

Die Kenngröße für die Immissions-Tages-Zusatzbelastung (ITZ) ist

- bei Verwendung einer mittleren jährlichen Häufigkeitsverteilung der meteorologischen Parameter das 10fache der für jeden Aufpunkt berechneten arithmetischen Mittelwerte IJZ oder
- bei Verwendung einer repräsentativen meteorologischen Zeitreihe der für jeden Aufpunkt berechnete höchste Tagesmittelwert.

Die Kenngröße für die Immissions-Stunden-Zusatzbelastung (ISZ) ist der berechnete höchste Stundenmittelwert für jeden Aufpunkt.

4.7 *Einhaltung der Immissionswerte*

4.7.1 Immissions-Jahreswert

Der für den jeweiligen Schadstoff angegebene Immissions-Jahreswert ist eingehalten, wenn die Summe aus Vorbelastung und Zusatzbelastung an den jeweiligen Beurteilungspunkten kleiner oder gleich dem Immissions-Jahreswert ist.

4.7.2 Immissions-Tageswert

a) Der Immissions-Tageswert ist auf jeden Fall eingehalten,
  - wenn die Kenngröße für die Vorbelastung IJV nicht höher ist als 90 vom Hundert des Immissions-Jahreswertes und
  - wenn die Kenngröße ITV die zulässige Überschreitungshäufigkeit des Immissions-Tageswertes zu maximal 80 vom Hundert erreicht und
  - wenn sämtliche für alle Aufpunkte berechneten Tageswerte ITZ nicht größer sind, als es der Differenz zwischen dem Immissions-Tageswert (Konzentration) und dem Immissions-Jahreswert entspricht.

b) Im Übrigen ist der Immissions-Tageswert eingehalten, wenn die Gesamtbelastung – ermittelt durch die Addition der Zusatzbelastung für das Jahr zu den Vorbelastungskonzentrationswerten für den Tag – an den jeweiligen Beurteilungspunkten kleiner oder gleich dem Immissionskonzentrationswert für 24 Stunden ist oder eine Auswertung ergibt, dass die zulässige Überschreitungshäufigkeit eingehalten ist, es sei denn, dass durch besondere Umstände des Einzelfalls, z. B. selten auftretende hohe Emissionen, eine abweichende Beurteilung geboten ist.

4.7.3 Immissions-Stundenwert

a) Der Immissions-Stundenwert ist auf jeden Fall eingehalten,
  - wenn die Kenngröße für die Vorbelastung IJV nicht höher ist als 90 vom Hundert des Immissions-Jahreswertes und
  - wenn die Kenngröße ISV die zulässige Überschreitungshäufigkeit des Immissions-Stundenwertes zu maximal 80 vom Hundert erreicht und
  - wenn sämtliche für alle Aufpunkte berechneten Stundenwerte ISZ nicht größer sind, als es der Differenz zwischen dem Immissions-Stundenwert (Konzen-

tration) und dem Immissions-Jahreswert entspricht.

b) Im Übrigen ist der Immissions-Stundenwert eingehalten, wenn die Gesamtbelastung – ermittelt durch die Addition der Zusatzbelastung für das Jahr zu den Vorbelastungskonzentrationswerten für die Stunde – an den jeweiligen Beurteilungspunkten kleiner oder gleich dem Immissionskonzentrationswert für 1 Stunde ist oder eine Auswertung ergibt, dass die zulässige Überschreitungshäufigkeit eingehalten ist, es sei denn, dass durch besondere Umstände des Einzelfalls, z. B. selten auftretende hohe Emissionen, eine abweichende Beurteilung geboten ist.

4.8 *Prüfung, soweit Immissionswerte nicht festgelegt sind, und in Sonderfällen*

Bei luftverunreinigenden Stoffen, für die Immissionswerte in den Nummern 4.2 bis 4.5 nicht festgelegt sind, und in den Fällen, in denen auf Nummer 4.8 verwiesen wird, ist eine Prüfung, ob schädliche Umwelteinwirkungen hervorgerufen werden können, erforderlich, wenn hierfür hinreichende Anhaltspunkte bestehen.

Die Prüfung dient

a) der Feststellung, zu welchen Einwirkungen die von der Anlage ausgehenden Luftverunreinigungen im Beurteilungsgebiet führen; Art und Umfang der Feststellung bestimmen sich nach dem Grundsatz der Verhältnismäßigkeit;

und

b) der Beurteilung, ob diese Einwirkungen als Gefahren, erhebliche Nachteile oder erhebliche Belästigungen für die Allgemeinheit oder die Nachbarschaft anzusehen sind; die Beurteilung richtet sich nach dem Stand der Wissenschaft und der allgemeinen Lebenserfahrung.

Für die Beurteilung, ob Gefahren, Nachteile oder Belästigungen erheblich sind, gilt:

a) Gefahren für die menschliche Gesundheit sind stets erheblich. Ob Gefahren für Tiere und Pflanzen, den Boden, das Wasser, die Atmosphäre sowie Kultur- und sonstige Sachgüter erheblich sind, ist nach den folgenden Buchstaben b) und c) zu beurteilen.

b) Nachteile oder Belästigungen sind für die Allgemeinheit erheblich, wenn sie nach Art, Ausmaß oder Dauer das Gemeinwohl beeinträchtigen.

c) Nachteile oder Belästigungen sind für die Nachbarschaft erheblich, wenn sie nach Art, Ausmaß oder Dauer unzumutbar sind.

Bei der Beurteilung nach den Buchstaben b) und c) sind insbesondere zu berücksichtigen:

- die in Bebauungsplänen festgelegte Nutzung der Grundstücke,
- landes- oder fachplanerische Ausweisungen,
- Festlegungen in Luftreinhalteplänen,
- eine etwaige Prägung durch die jeweilige Luftverunreinigung,
- die Nutzung der Grundstücke unter Beachtung des Gebots zur gegenseitigen Rücksichtnahme im Nachbarschaftsverhältnis,
- vereinbarte oder angeordnete Nutzungsbeschränkungen und
- im Zusammenhang mit dem Vorhaben stehende Sanierungsmaßnahmen an Anlagen des Antragstellers oder Dritter.

Bei der Prüfung, ob der Schutz vor erheblichen Nachteilen durch Schädigung empfindlicher Pflanzen (z. B. Baumschulen, Kulturpflanzen) und Ökosysteme durch die Einwirkung von Ammoniak gewährleistet ist, ist Anhang 1 Abbildung 4 heranzuziehen. Dabei gibt die Unterschreitung der Mindestabstände einen Anhaltspunkt für das Vorliegen erheblicher Nachteile.

Liegen ferner Anhaltspunkte dafür vor, dass der Schutz vor erheblichen Nachteilen durch Schädigung empfindlicher Pflanzen (z. B. Baumschulen, Kulturpflanzen) und Ökosysteme (z. B. Heide, Moor, Wald) durch Stickstoffdeposition nicht gewährleistet ist, soll dies ergänzend geprüft werden. Dabei ist unter Berücksichtigung der Belastungsstruktur abzuschätzen, ob die Anlage maßgeblich zur Stickstoffdeposition beiträgt. Als ein Anhaltspunkt gilt die Überschreitung einer Viehdichte von 2 Großvieheinheiten je Hektar Landkreisfläche. Bei dieser Prüfung sind insbesondere die Art des Bodens, die Art der vorhandenen Vegetation und der Grad der Versorgung mit Stickstoff zu berücksichtigen.

Ergeben sich Anhaltspunkte für das Vorliegen erheblicher Nachteile durch Schädigung empfindlicher Pflanzen (z. B. Baumschulen, Kulturpflanzen) und Ökosysteme auf Grund der Einwirkung von Ammoniak oder wegen Stickstoffdeposition, soll der Einzelfall geprüft werden.

Ist eine Sonderfallprüfung aufgrund der Nummer 4.5.2 Buchstabe d) durchzuführen, ist insbesondere zu untersuchen, ob und inwieweit die Depositionen bei der derzeitigen oder geplanten Nutzung (z. B. als Kinderspielfläche, Wohngebiet, Park- oder Freizeitanlage, Industrie- oder Gewerbefläche sowie als Ackerboden oder Grünland) zu schädlichen Umwelteinwirkungen durch eine mittelbare Wirkung auf Menschen, Tiere, Pflanzen, Lebens- und Futtermittel führen können. Die Depositionswerte stellen im Regelfall den Schutz von Kinderspielflächen und Wohngebieten sicher. Für die übrigen Flächen können höhere Depositionswerte herangezogen werden. Dabei geben die in Tabelle 8 bezeichneten Depositionswerte Anhaltspunkte für das Vorliegen schädlicher Umwelteinwirkungen bei Ackerboden oder Grünland.

Tabelle 8: Depositionswerte als Anhaltspunkte für die Sonderfallprüfung

Stoff/Stoffgruppe	Ackerböden $\mu g/(m^2 \cdot d)$	Grünland $\mu g/(m^2 \cdot d)$
Arsen	1 170	60
Blei	185	1 900
Cadmium	2,5	32
Quecksilber	30	3
Thallium	7	25

3. Fourth General Administrative Instruction for the Federal Immission Control Act (Determination of Ambient Air Quality in Areas Subject to Investigation)

Vierte Allgemeine Verwaltungsvorschrift zum Bundes-Immissionsschutzgesetz (Ermittlung von Immissionen in Untersuchungsgebieten – 4. BImSchVwV)

of 26th November 1993

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Pursuant to Art. 45 of the Federal Immission Control Act (BImSchG) in the version promulgated on 14 May 1990 (Federal Law Gazette BGBl. I, p. 880), the Federal Minister for the Environment, Nature Conservation and Nuclear Safety issues the following General Administrative Instruction:

1. Scope of application

This General Administrative Instruction shall apply to the implementation of Measurements pursuant to Art. 44 § 1 of the Federal Immission Control Act and the Directives of the Council of the European Communities. It contains provision of the test objects, the number and location for measuring points, the measuring methods and measuring devices, the evaluation of measuring results and on information for the general public.

2. Definitions

Within the meaning of the Instruction, the following definitions shall apply:

2.1 Test objects

Test objects shall be deemed to mean the types of air pollution referred to in no. 3.1 below and the meteorological factors referred to in no. 3.2 below.

2.2 Measuring areas

Measuring areas shall be deemed to mean the areas subject to investigation or parts thereof laid down in ordinances of the *Länder* pursuant to Art. 44 § 3 of the Federal Immission Control Act, as well as the areas where ambient air quality must be measured pursuant to the Directives of the European Communities referred to in Annex A hereof.

2.3 Measuring points

Measuring points shall be deemed to mean those points in which ambient air quality is measured.

2.4 Ambient air quality

Ambient air quality, within the meaning of this Instruction, shall be deemed to mean any air pollution having an impact on humans, animals and plants, soil, water, the atmosphere as well as on cultural objects and other material good.

2.5 Ambient air quality values

Ambient air quality values shall be deemed to mean the values laid down in no. 2.5 of the 1st General Administrative Instruction pursuant to the Federal Immission Control Act (Technical Instructions on Air Quality Control - TA Luft) of 27th February 1986 (Joints Ministerial Gazette GMBl., p. 95, 202) for the protection against health risks, considerable disadvantages and substantial impairments, as well as the standards laid down in Art. 1 of the 22nd Ordinance for the Implementation of the Federal Immission Control Act (Ordinance on Ambient Air Quality Values - 22. BImSchV) of 26th October 1993 (Federal Law Gazette BGBl. I, p.1819).

2.6 Threshold values

Threshold values shall be deemed to mean those values laid down in Directive 92/72/EEC of the Council of the European Communities on air pollution from ozone.

3. Parameters to be measured

3.1 Air pollution

3.1.1 Principal components

- sulphur dioxide;
- nitrogen dioxide;
- carbon monoxide;
- ozone;
- suspended particulate matter;
- dust depositions.

3.1.2 Special components

- selected volatile organic compounds (e.g. toluene, xylene, or, if this is not possible, the total of volatile organic compounds (methane-free));
- substances contained in suspended particulate matter
- substances contained in dust depositions (e.g. lead, cadmium);
- soot in the air.

3.2 Meteorological factors

- wind direction;
- wind velocity;
- air temperature;
- air pressure;
- air humidity;
- deposition levels;
- global radiation.

3.3 Selection of test objects

Each test object of significance for the measuring area shall be measured at least at one measuring point within the measuring area. Annex B provides details on the assignment of test objects to measuring points.

3.4 Further test objects

The *Länder* may specify further test objects in addition to those referred to in no. 3.1 above, insofar as these measuring objects are of significance for assessing air pollution levels in the measuring areas.

4. Measuring points

4.1 Installation of measuring points

Within the measuring areas, measuring points shall be established in which the selected test objects are determined by means of continuous measurements or individual measurements.

Minimum requirements on the establishment of continuous measuring points are contained in the Directives on site selection and the construction of automatic measuring station in telemetric measuring networks, referred to in Annex C, insofar as this Administrative Instruction does not provide otherwise.

4.2 Location of measuring points

Within the measuring areas, measuring points shall be established in places where the ambient air quality standards laid down in the 22nd Ordinance for the Implementation of the Federal Immission Control Act (Ordinance on Ambient Air Quality Values - 22. BImSchV) of 26 October 1993 (Federal Law Gazette BGBl. I, p.1819) and, if they are not covered by the 22. BImSchV, in the 1st General Administrative Instruction pursuant to the Federal Immission Control Act (Technical Instructions on Air Quality Control - TA Luft) of 27 February 1986 (Joint Ministerial Gazette GMBl., p.95, 202) are exceeded or humans may be continuously exposed to air pollution over a long period of time and where threshold values of the Directives of the European Communities (Annex A) are likely to be almost reached or exceeded, or where any other adverse effects of air pollution on the environment are to be expected.

The objective of the measurements is to provide a uniform assessment of the current air pollution situation and trends in the territory of the Federal Republic of Germany and to determine the nature and extent of certain types of air pollution which may have adverse effects on the environment, and to answer with reasonably certainty, the question of the extent to which there is a risk that the ambient air quality standards of the TA Luft or the ambient air quality standards of Art. 1 of the 22. BImSchV or the threshold values of a Directive of the Council of the European Communities will be exceeded. Therefore, measuring points should, in particular, be established in places in which the highest level of environmental pollution is assumed. The selection of measuring points is covered by Annex B.

4.3 Number of measuring points

If several measuring points are established, these measuring points have all at first be assigned to the different cases pursuant to Annex B. Where several measuring points of the same category are determined, the number of measuring points shall be calculated in proportion to the relevant pollution levels.

5. Measurements

5.1 Principles

The ambient air quality shall be determined by means of continuous measurements or individual measurements. The parameters to be measured referred to in no. 3.1.1 above shall be permanently measured at least at one measuring point within the measuring area. In addition to the measuring of principal components pursuant to no. 3.1.1, special components pursuant to no. 3.1.2 may be measured depending on pollution levels in the areas subject to investigation. The parameters to be measured referred to in no. 3.1.2 may also be measured for a limited period of time only, if this is sufficient for assessing the measuring results and if measurements are repeated after an appropriate period of time.

5.2 Continuous measurements

Measurements at stationary measuring points shall, if possible, be carried out without major gaps. The minimum availability of the measuring systems shall be 75 % of the annual measurement period, with 90 % being the ultimate goal.

5.3 Individual measurements

Measurements with a limited collection time shall be carried out at the measuring points. The number of individual measurements shall be determined in such a way that the results of the evaluation established in no. 7 below may be recorded with reasonable certainty. To determine the arithmetical annual mean value and the 98% value for a year, at least one individual measurement per week shall be deemed necessary. In the case of high pollution levels (i.e. more than 80 % of an ambient air quality standard laid down in the TA Luft or in Art. 1 of the 22. BImSchV), at least two individual measurements per week shall be deemed necessary to determine the arithmetical annual mean values and the 98% value for a year. Where daily mean values are measured, at least five measurements, and in the case of high pollution levels, ten measurements per month, shall be deemed necessary. When determining lead concentrations in the air, at least 15 measurements per month shall be deemed necessary if the limit for lead concentrations in the air referred to in Art. 1 of the 22. BImSchV is likely to be almost reached or exceeded. The individual measurements shall be evenly distributed over the measurement period (cf. no 5.5 below).

5.4 Measuring methods and measuring devices

Reference methods or equivalent measuring methods shall be applied to calibrate the measuring devices and take the measurements; for this purpose, account shall be taken of the guidelines on reference methods and equivalent measuring methods listed in Annex C. For measurements pursuant to the guidelines of the Council of the European Communities referred to in Annex A, the reference measuring methods specified there shall be applied. The measuring devices for determining air pollution levels shall meet the requirements of the guidelines on construction of and suitability tests for measuring devices referred to in Annex C and shall have been promulgated in advance by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety after consultation with the competent highest Land authorities. The measurements shall be carried out in accordance with one of the methods described in the guidelines referred to in Annex C. Other or complementary measuring methods shall be admissible if they have been declared to be suitable and promulgated in the Joint Ministerial Gazette by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety after consultation with the highest Land authorities responsible for air quality control, or if they are in line with the generally acknowledged state of the art of measuring technology. During calibration, the air volume shall be standardised at a temperature of 273 K and a pressure of 101.3 kPa.

5.5 Measurement period

The measurement period shall, as a rule, be at least one year. It may be shortened only if this has no systematic influence on the measuring results. The measurement period should not be any shorter than six months. If a reduced period of time is applied, the total number of individual measurements laid down in no. 5.3 above for the measurement period shall be maintained.

5.6 Meteorological measurements

The determination of meteorological factors shall be carried out in accordance with the guidelines referred to in Annex C. The determination of meteorological factors may be dispensed with if any data from other measuring points (e.g. stations of the German Meteorological Service) are available and may be used in conjunction with the measurements of air pollution levels in areas subject to investigation in such a way that the characteristic values laid down in no. 7 below may be reported with reasonable certainty.

6. Units of measurement and measuring results

6.1 Units of measurement

Air pollution levels shall be given as mass concentrations measured in mg/m^3, dust depositions and the substances contained therein as mass concentrations measured in g/(m^{2}d) or in any relevant larger order of magnitude, wind direction measured in degrees, wind velocity measured in m/s, air temperature in degrees centigrade and air pressure measured in kPa. The measured values of air pollution levels shall be specified with at least the same number of digits as the relevant ambient air quality or threshold values.

6.2 Measured values

Mass concentrations shall be given as half-hourly mean values in the case of gaseous air pollution, as half-hourly or hourly mean values in the case of ozone and as half-hourly or annual mean values in the case of benzene and selected volatile organic compounds. Mass concentrations of suspended particulate matter, soot in the air and substances contained in suspended particulate matter shall be measured as daily mean values. The meteorological factors shall be measured in such a way that they may be used in conjunction with the mean values referred to in sentences 1 and 2 above.

7. Evaluation of measurements

7.1 Assessment of the air pollution situation

The following characteristic values shall be determined from the measurements of air pollution levels:

a) the arithmetical daily mean values shall be measured for the continuously measured air pollution levels;

b) the arithmetical mean values for the months and the calendar year shall be measured for gaseous air pollution, soot in the air, suspended particulate matter and the substances contained therein;

c) with respect to ozone (pursuant to Art. 6 of EC Directive 92/72/EEC), measurements shall be taken of the peak value, the median and the 98% value of hourly and eight-hour mean values for the calendar year, as well as of the number, time and duration of incidents of non-compliance with the threshold values laid down in Annex I of the Directive and the hourly peak concentrations measured during each individual period of non-compliance;

d) with respect to sulphur dioxide and suspended particulate matter (pursuant to EC Directive 89/427/EEC, Annex), measurements shall be taken of the medians for the period from 1 October to 31 March and the 98% values (on the basis of the ranking method set out in Annex D) for the period from 1 April to 31 March;

e) the 98% values for the calendar year (on the basis of the ranking method set out in Annex D) shall be measured for gaseous air pollution, soot in the air and suspended particulate matter; and

f) with respect to dust depositions, measurements shall be taken of the highest monthly values and the annual values, and with respect to the substances contained in dust depositions, of the annual values;

g) with respect to sulphur dioxide (pursuant to EC Directive 89/427/EEC, Annex, footnote 1), measurements shall be taken every single day on which the value of 250 µg/m^3 (98% value of the cumulative frequency of all daily mean values measured during the year) for an assigned value for suspended particulate matter of more than 350 µg/m^3 (98% value of the cumulative frequency of all daily mean values measured during the year), or 350 µg/m^3 (98% value of the cumulative frequency of all daily mean values measured during the year) for an assigned value for suspended particulate matter of smaller than or equal to 350 µg/m^3 (98% value of the cumulative frequency of all daily mean values measured during the year) has been exceeded, and the relevant hourly peak values shall be determined.

The characteristic values shall be marked if the availability of the continuous measuring systems was at a level below 75 % of the measurement period of if downtime of more than one week at a time has occurred.

7.2 Assessment of trends in air pollution

These monthly mean values shall be used to form overlapping mean values for 12-month periods (sliding 12-month values). Under this evaluation procedure, the beginning and end of the assessment period are both postponed by one month.

7.3 Assessment of circumstances relevant for the formation and dispersion of air pollution

Data from emission inventories shall be used with respect to the circumstances which are of relevance for the formation of air pollution. With regard to the dispersion of air pollution relevant measured values shall be kept in the records as a time series for a minimum period of ten years. Ambient air quality-related climatological observations shall be evaluated in accordance with the requirements of dispersion modelling. In the event that the limits for sulphur dioxide laid down in Table A footnote 1 of the Annex of EC Directive 89/427/EEC are exceeded, the source of such air pollution shall be determined.

7.4 Details of measuring results

7.4.1 Annual data

The results of measurements and evaluations shall be specified in accordance with the specimen form appended in Annex E. The location of the measuring point, information on its surroundings as well as any other details of significance for the assessment of the measuring results shall be specified in the description of the measuring point (Annex E). In reports to the EC Commission and in the report of the Federal Government to the Bundestag pursuant to Art. 61 of the Federal Immission Control Act, measuring results shall be specified in accordance with the specimen forms appended in Annex E. The competent highest Land authorities shall transmit to the Federal Environmental Agency a set of the completed forms contained in E 1 to E 2.7.4 (or corresponding data carriers). The measuring results for sulphur dioxide and suspended particulate matter as well as for dust depositions and substances contained therein shall be reported annually by 15 August; the measuring results for nitrogen oxide, lead and ozone shall be reported annually by 31 May, and the remaining measuring results shall be reported by 1 August.

7.4.2 Transmission of information in case of exceedance of threshold values

a) In the event that the threshold value for the regulation of information to the general public laid down in Annex I no. 3 of EC Directive 92/72/EEC on air pollution through ozone is exceeded during one calendar month, the competent *Land* authorities shall, before the 25th day of the month following such event, report to the Federal Environmental Agency, in accordance with specimen form E 2.7.3 or on corresponding data carriers, data with regard to the time of the incident(s) of non-compliance, the duration of the incident(s) of non-compliance and the hourly peak concentrations measured during each individual period of non-compliance.

b) In the event that the threshold value for triggering off the alert system laid down in Annex I no. 4 of EC Directive 92/72/EEC is exceeded during one week (i.e. between Monday and the following Sunday), the competent *Land* authorities shall, before the 25th day of the month following such event, report to the Federal Environmental Agency, in accordance with specimen form E 2.7.4 or on corresponding data carriers, data with regard to the time of the incident(s) of non-compliance, the duration of the incident(s) of non-compliance and the hourly peak concentrations measured during each individual period of non-compliance as well as any relevant data to explain the non-compliance.

7.5 Information for the general public

The following data shall be provided to be published for the information of the general public :

a) the daily mean value and the highest half-hourly mean value shall be specified in the case of continuous measurements; in the case of ozone, the highest hourly value shall be published instead of the highest half-hourly mean value; publication of the ozone data may be limited to the summer semester (April to September);

b) on a monthly basis, the monthly mean value and the 98% value;

c) on an annual basis, the annual mean value, the highest daily and monthly means values, the 98% value and

d) the data pursuant to Annex IV of EC Directive 92/72/EEC of 21 September 1992 shall be specified in the case of ozone.

8. Abrogation of regulations

The 4th General Administrative Instruction pursuant to the Federal Immission Control Act (Determination of Ambient Air Quality Levels in Pollution Areas - 4. BImSchVwV) of 8 April 1975 (Joint Ministerial Gazette GMB1., p. 358) shall be abrogated.

9. Coming into force

This General Administrative Instruction shall enter into force on the day following its promulgation.

The Bundesrat has given its consent.
Bonn, 26 November 1993

The Federal Minister for the Environment, Nature Conservation and Nuclear Safety
Dr Klaus Töpfer

APPENDIX 2

GUIDELINES AND STANDARDS CONCERNING AMBIENT AIR QUALITY MEASURING TECHNIQUE OF THE COMMISSION ON AIR QUALITY CONTROL IN VDI AND DIN

Alphabetical Register of Substances for Guidelines and Standards on Ambient Air Quality Measuring Technique of the Commissions on Air Quality Control in VDI and DIN (status: October 2003)

Substance	Guideline No./Standard
Aluminium	VDI 2267 (14 E)
Amines	VDI 2467 (1), (2)
Ammonia	VDI 2461 (1), (2), 3794 (2), 3869 (3 E), (4 E)
Antimony	VDI 2267 (1), (5)
Aromatic Hydrocarbons	DIN ISO 12884, DIN ISO 16362
Arsenic	VDI 2267 (1), (14 E)
Asbestos	VDI 3492 (E), 3492 (1), (2)
Benzene	DIN 33963 (2), E DIN EN 14662 (1), (2), (3), (4), (5)
Beryllium	VDI 2267 (1), (5)
Cadmium	VDI 2267 (1), (4), (5), (14 E), 3956 (2)
Carbon Dioxide	VDI 4300 (9)
Carbon Monoxide	VDI 2455 (1), (2) E DIN EN 14626
Chlorides	VDI 3497 (1 E), (3), (4), 3870 (13)
Chromium	VDI 2267 (1), (5), (12 E), (14 E)
Cobalt	VDI 2267 (1), (5), (14 E)
Copper	VDI 2267 (1), (5), (12 E), (14 E)
Dust Deposition	VDI 2463 (1), (2), (3), (4), (5), (6), (7), (8), (9), (10), (11) DIN ISO 7708, E DIN ISO 10473
Dust (PM 10)	DIN EN 12341
Fibrous Particles	VDI 3492 (E), 3492 (1), (2)
Fluorine Ions	VDI 2452 (1), (2), (3)
Formaldehyde	VDI 3484 (1), (2), 4300 (3)
Free Acidity in Rain Water	VDI 3870 (11)
Gaseous Pollutants	VDI 2449 (1), (2), (3), 2450 (1), (2), (5 E)
Gaseous Acid Pollutants	VDI 2449 (1), (2), (3), 2450 (1), (2), (5 E)
Hexachlorocyclohexane	VDI 4300 (4), 4301, (2), (3)

Substance	Guideline No./Standard
Hydrocarbons	VDI 3483 (1), (2), (4), 3495 (1)
Hydrogen Peroxide	VDI 2468 (9), (10)
Hydrogen Sulphide	VDI 2454 (1), (2) DIN ISO 4219
Indoor Air	VDI 4300 (1), (2), (3), (4), (5), (6), (7), (8), (9) VDI 4301 (1), (2), (3)
Inorganic Fibrous Particles	VDI 3492 (1), (2)
Iron	VDI 2267 (5), (12 E), (14 E)
Lead	VDI 2267 (1), (2), (4), (5), (11), (14 E)
Lindane	VDI 4300 (4), 4301, (2), (3)
Lower Carboxylic Acids	VDI 3869 (5 E)
Manganese	VDI 2267 (1), (5), (12 E), (14 E)
Mercury	VDI 2267 (8), (9)
Nickel	VDI 2267 (1), (5), (12 E), (14 E), 3956 (3 E)
Nitric Acid	VDI 3869 (2 E)
Nitrates	VDI 3497 (1 E), (3), (4), 3870 (13)
Nitrogen Dioxide	VDI 2453 (1), (2), (3), 4300 (5), 4301 (1) E DIN EN 14211, E DIN EN 14212, DIN ISO 7796
Nitrogen Monoxide	VDI 2453 (2), (3) E DIN EN 14211, DIN ISO 7796
Nitrogen Oxide	VDI 2453 (1), (2), (3) DIN ISO 7996, E DIN EN 14211, E DIN EN 14212
Organic Compounds	VDI 2100 (1), (2), (3), (4), 4300 (6) DIN EN ISO 16017 (1) (2), DIN 33963 (1), DIN 19739 (2)
Ozone	VDI 2468 (4), (5), (6) DIN ISO 13964, E DIN EN 14625
Particles in Ambient Air	VDI 2269 (1 E) VDI 2463 (1), (2 E), (3 E), (4), (5), (6), (7), (8), (9), (10),(11)
Pentachlorphenol (PCP)	VDI 4300 (4), 4301 (2), (3)
Peroxyacetyl Nitrate (PAN)	VDI 2468 (7), (7 E), (8), (8 E)
Phenols	VDI 3485 (1)
pH Value (rain water)	VDI 3870 (10)
Polychlorinated Biphenyls (PCB)	VDI 4300 (2)
Polychlorinated Dibenzofurans (PCDF)	VDI 2090 (1), (2), 3498 (1), (2 E), 4300 (2)

Substance	Guideline No./Standard
Polychlorinated Dibenzo-p-dioxins (PCDD)	VDI 2090 (1), (2), 3498 (1), (2), 4300 (2)
Polycyclic Aromatic Hydrocarbons (PAH)	VDI 3875 (1), 4300 (2), DIN ISO 12884
Potassium	VDI 2267 (14 E)
Rain Water Components	VDI 3870 (1 E), (2), (10), (11), (13)
Sodium	VDI 2267 (14 E)
Soot	VDI 2465 (1), (2)
Sulphates	VDI 3497 (1 E), (3), (4) VDI 3870 (13)
Sulphur dioxide	VDI 2451(3), 3869 (1) DIN ISO 4219, DIN ISO 4221, E DIN EN 14212
Suspended Particulate Matter	VDI 2463 (1), (2), (3), (4), (5), (6), (7), (8), (9), (10), (11) DIN ISO 7708, E DIN ISO 10473, DIN EN 12341
Thallium	VDI 2267 (1), (7), VDI 3796 (1)
Vanadium	VDI 2267 (5), (14 E)
Zinc	VDI 2267 (1), (5), (12 E), (14 E)

E:	Entwurf (Draft)

VDI No./Part	Edi-tion	Object	Method resp. Topic	Detection Limit		Standard Deviation	Remarks
				PCDD/F	**DL** pg/(m^2 d)	**s_{rel}** **%**	
2090/1	01.01	Ambient air measurement Deposition measurement of low volatile organic compounds	Determination of PCDD/F deposition Bergerhoff sampling device and GC/HRMS analysis	2,3,7,8-TCDD	1	19.8	
				1,2,3,7,8-PeCDD	1	18.9	
				1,2,3,7,8-/1,2,3,4,8-PeCDF	1	6.8	
				2,3,4,7,8-PeCDF	1	5.6	
				1,2,3,4,7,8-HxCDD	1	29.4	
				1,2,3,6,7,8-HxCDD	2	20.9	
				1,2,3,7,8,9-HxCDD	2	22.0	
				1,2,3,4,7,8-/1,2,3,4,7,9-HxCDF	1	5.2	
				1,2,3,6,7,8-HxCDF	1	3.2	
				1,2,3,7,8,9-HxCDF	2	13.6	
				2,3,4,6,7,8-HxCDF	2	5.2	
				2,3,7,8-TCDF	1	9.7	
				1,2,3,7,8-PeCDF	1	5.6	
				1,2,3,4,6,7,8-HpCDD	4	3.7	
				1,2,3,4,6,7,8-HpCDF	2	44	
				1,2,3,4,7,8,9-HpCDF	3	2.5	
				OCDD	10	8.8	
				OCDF	10	26.0	

VDI No./Part	Edition	Object	Method resp. Topic	Detection Limit		Standard Deviation	Remarks
2090/2	12.02	Ambient air measurement Deposition measurement of low volatile organic compounds	Determination of PCDD/F deposition Funnel absorbation sampling device and GC/HRMS analysis	**PCDD/F**	**DL** pg/(m^2 d)	s_{rel} **%**	
				2,3,7,8-TCDD	1	8.9	
				1,2,3,7,8-PeCDD	1	18.3	
				1,2,3,7,8-/1,2,3,4,8-PeCDF	1	10.2	
				2,3,4,7,8-PeCDF	1	9.0	
				1,2,3,4,7,8-HxCDD	1	22.7	
				1,2,3,6,7,8-HxCDD	2	9.3	
				1,2,3,7,8,9-HxCDD	2	12.0	
				1,2,3,4,7,8-/1,2,3,4,7,9-HxCDF	1	6.6	
				1,2,3,6,7,8-HxCDF	1	6.9	
				1,2,3,7,8,9-HxCDF	2	8.9	
				2,3,4,6,7,8-HxCDF	2	7.8	
				2,3,7,8-TCDF	1	11.9	
				1,2,3,7,8-PeCDF	1	9.0	
				1,2,3,4,6,7,8-HpCDD	4	7.2	
				1,2,3,4,6,7,8-HpCDF	2	7.0	
				1,2,3,4,7,8,9-HpCDF	3	23.0	
				OCDD	10	10.8	
				OCDF	10	21.8	
2100/1	06.01	Determination of gaseous compounds in ambient air; Determination of indoor air pollutants	Gas chromatographic determination of organic compounds; Fundamentals				
2100/2	06.01	Determination of gaseous compounds in ambient air; Determination of indoor air pollutants	Gas chromatographic determination of organic compounds, Active sampling by accumulation on activated charcoal; Solvent extraction				
2100/3	11.02	Determination of gaseous compounds in ambient air; Determination of indoor air pollutants	Gas chromatographic determination of organic compounds, Active sampling by accumulation on sorbents; Thermal desorption				

VDI No./Part	Edi-tion	Object	Method resp. Topic	Detection Limit	Standard Deviation	Remarks
2100/4	06.01	Determination of gaseous compounds in ambient air; Determination of indoor air pollutants	Gas chromatographic determination of organic compounds; Calibration procedures as a measure for quality assurance			
2119/1	06.72	Measurement of dustfall	Survey			
2119/2	09.96	Measuring of particulate precipitations	Determination of the dust precipitation with collecting pots made of glass (Bergerhoff method) or plastic	1.5 mg/ device 5-8 mg/m^2d	S_D = 14-33 8 mg/m^2d in the range 6-530 mg/m^2d	
2119/3	06.72	Measurement of dustfall	Hibernia and Loebner-Liesegang instruments	Hib.: 20 mg/ device 0,0133 g/m^2d L-L.: 20 mg/ device 0.0091 g/m^2d	S_D = 0.025 g/m^2d at $\overline{x}$ = 0.65 S_D = 0.027 g/m^2d at $\overline{x}$ = 0.54	
2119/4	08.97	Measurement of Particulate Precipitations	Microscopic differentiation and size fractionated determination of particle deposition on adhesive collection plates Sigma-2 sampler	25.6 g/m^2d	S_D = ± 7.1 mg/m^2d	

VDI No./Part	Edition	Object	Method resp. Topic	Detection Limit		Standard Deviation			Remarks
2267/1	04.99	Determination of suspended matters in ambient air - Measurement of As, Be, Cd, Co, Cr, Cu, Mn, Ni, Pb, Sb, Tl, Zn	Atomic absorption spectrometry (AAS) after sampling on filters and digestion in an oxidizing acid mixture		ng/m^3	ng/m^3	$\overline{x}$	s_o	Differences in performance characteristics due to used filter (membrane, quartz fibre), atomisation (electro thermal, Flame), and digestion variant
				As	0.08-0.7	As	1.9-3.5	0.23-0.6	
				Be	0.003-0.08	Be	0.014	0.002	
				Cd	0.02-0.05	Cd	0.8-1.4	0.1-0.33	
				Co	0.2-0.4	Co	0.36	0.1	
				Cr	0.2-3	Cr	5.4-16.4	2-3.1	
				Cu	0.5-8	Cu	22.2-177	1-26	
				Mn	0.16	Mn	14.7	0.7	
				Ni	0.3-2	Ni	6.1-12.4	0.6-2.5	
				Pb	0.0002-2	Pb	46.5-304	4-46	
				Sb	0.16-0.8	Sb	5.7-6.8	0.4	
				Tl	0.06-0.3	Tl	no data	no data	
				Zn	0.003-2.6	Zn	119.5-154	3-6	
2267/2	02.83	Determination of suspended particulates in ambient air	Measurement of lead by X-ray fluorescence	0.03-02 µg/m^3 due to sampling		$S_{rel.}$ < 15% in the range 0.3-30 µg/m^3			
2267/4	03.87	Chemical analysis of particulates in ambient air; determination of lead, cadmium and their inorganic compounds	Dust precipitation by atomic absorption spectrometry	Lead Pb 2 µg/m^3 Cadmium Cd 0.1 µg/m^3		in the vicinity of a source: S_D: 147µg/(m^2 d) = 10%MW in cities: S_D: 15 µg/(m^2 d) = 10% MW in the vicinity of a source:S_d: 1.4 µg/(m^2 d) = 10% MW in cities: S_D: 0.6 µg/(m^2 d) = 10% MW			
2267/5	11.97	Determination of suspended matter in ambient air - Determination of the mass concentration of Be, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Sb, V, Zn	Optical emission spectrometry (ICP-OES) after sampling on filters and digestion in an oxidising agent		ng/m^3	ng/m^3	$\overline{x}$	s_o	Due to emission lines, wave lengths, and interfering elements
				Sb	3	Sb	3.1	0.6	
				Be	0.01	Be	0.046	0.005	
				Pb	6	Pb	63.1	5.6	
				Cd	0.7	Cd	1.2	0.2	
				Cr	7	Cr	5.7	0.4	
				Fe	55	Fe	944	49	
				Co	0.4	Co	0.6	0.1	
				Cu	0.3	Cu	16.6	1.1	
				Mn	0.7	Mn	33.2	3.8	
				Ni	4.3	Ni	5.4	0.6	
				V	2	V	3.9	0.6	
				Zn	10	Zn	98.1	8.8	

<table>
<tr><th>VDI No./Part</th><th>Edition</th><th>Object</th><th>Method resp. Topic</th><th>Detection Limit</th><th>Standard Deviation</th><th>Remarks</th></tr>
<tr><td>2267/7</td><td>11.88</td><td>Chemical analysis of particulates in ambient air; determination of thallium and its inorganic compounds</td><td>Dust precipitation by atomic absorption spectrometry</td><td>Graphite Tube:
0.1 $\mu gm^{-2}d^{-1}$
Flame:
5 $\mu gm^2/d$</td><td>S_D: = 30%</td><td></td></tr>
<tr><td>2267/8</td><td>03.00</td><td>Determination of suspended particles in ambient air - Measurement of the mass concentration of mercury</td><td>Sampling by sorption as amalgam and determination by atomic absorption spectrometry (AAS) with cold vapour technique</td><td>0.14-0.15 ng/m^3
quantification limits
0.27-0.31 ng/m^3</td><td>S_{rel} = 1.4-9.3 %
at various mercury masses of 0.5-10 ng</td><td>Calibration with $Hg(NO_3)_2$-standard-solution or mercury-saturated air</td></tr>
<tr><td>2267/9</td><td>07.02</td><td>Determination of suspended particulates in ambient air - Measurement of the mass concentration of mercury</td><td>Sampling as amalgam by sorption and determination by atomic fluorescence spectrometry (AFS) with cold vapour technique.</td><td>0.03-0.05 ng
quantification limits
0.07-0.11 ng
=>Detection-Limit$_{rel}$ = 0.6-1 ng/m^3</td><td>S_{rel} = 0,4-2%
at various mercury masses of 0.2-11.9 ng</td><td>Due to used Lamp and data analyis of peak</td></tr>
<tr><td>2267/11</td><td>01.86</td><td>Determination of suspended particulates in ambient air</td><td>Measurement of the mass concentration of lead energy dispersive X-ray fluorescence-analysis</td><td>0.05 $\mu g/m^3$</td><td>S_D: = 0.04 $\mu g/m^3$
at $\overline{x}$ = 0.5 $\mu g/m^3$</td><td></td></tr>
<tr><td>2267/12 E</td><td>11.89</td><td>Analysis of suspended particulates in ambient air; determination of the mass concentration of chromium, iron, copper, manganese, nickel and zinc</td><td>Energy dispersive X-ray fluorescence-analysis</td><td><table>
<tr><th></th><th>DL_{abs} ng/cm^2</th><th>DL_{rel} ng/m^3</th></tr>
<tr><td>Cr</td><td>20</td><td>3.6</td></tr>
<tr><td>Fe</td><td>230-260</td><td>41-46.3</td></tr>
<tr><td>Cu</td><td>30-50</td><td>5.4-9</td></tr>
<tr><td>Mn</td><td>30-55</td><td>5.4-9.8</td></tr>
<tr><td>Ni</td><td>10-20</td><td>2-3.6</td></tr>
<tr><td>Zn</td><td>110-300</td><td>19.6-54</td></tr>
</table></td><td><table>
<tr><th></th><th>S_D [%]</th></tr>
<tr><td>Cr</td><td>10</td></tr>
<tr><td>Fe</td><td>2-4</td></tr>
<tr><td>Cu</td><td>2-3</td></tr>
<tr><td>Mn</td><td>5</td></tr>
<tr><td>Ni</td><td>18-20</td></tr>
<tr><td>Zn</td><td>4-7</td></tr>
</table></td><td>Differences in Performance Characteristics due to used Filter (Glass fibre, Membrane, Quartz Fibre),
Membrane-filter: result for iron not detected</td></tr>
</table>

VDI No./Part	Edi- tion	Object	Method resp. Topic	Detection Limit		Standard Deviation		Remarks
2267/14 E	10.02	Analysis of suspended particulates in ambient air; determination of the mass concentration of Al, As, Ca, Cd, Co, Cr, Cu, Fe, K, Mg. Mn, Na, Ni, Pb, V, Zn as part of dust precipitation	Optical emission spectrometry (ICP OES)		µg/(m^2 d)		µg/(m^2 d)	Due to emission lines, wave lengths, and interfering elements
				Al	14.13	Al	27	
				As	1.08	As		
				Pb	1.05	Pb	56	
				Cd	0.05	Cd	189	
				Cr	0.28	Cr	0.5	
				Fe	14.1	Fe	107	
				K	11.	K	59	
				Co	0.	Co	2.9	
				Cu	0.5	Cu	2.9	
				Mg	9.7	Mg	48	
				Mn	0.7	Mn	8.6	
				Na	44.6	Na	423	
				Ni	0.1	Ni	0.3	
				V	0.03	V	0.3	
				Zn	7.72	Zn	217	
2269/1 E	11.72	Microscopic investigation methods for particulate matter	Fundamentals					
2449/1	02.95	Measurement methods test criteria	Determination of performance characteristics for the measurement of gaseous pollutants (immission)					
2449/2	01.87	Basic concepts for characterization of a complete measuring procedure	Glossary of terms					
2449/3	09.01	Measurement methods test criteria	General method for the determination of the uncertainty of calibratable measurement methods	Definition and determination of the detection limit				
2450/1	09.77	Measurement of air pollutant emission, transmission, and immission	Definitions and glossary of terms					
2450/2 E	09.77	Measurement of air pollutant emission, transmission, and immission	Measurement design; fundamentals					

VDI No./Part	Edition	Object	Method resp. Topic	Detection Limit	Standard Deviation	Remarks
2450/5 E	09.77	Measurement of air pollutant emission, transmission, and immission	Methodical treatment of univariates; quantiles			
2451/3	09.96	Measurement of gaseous immissions - Measurement of sulphur dioxide concentration	Tetrachloromercurate Pararosaniline (TCM) Method	0.2 μg SO_2 6.6 $\mu g/m^3$	± 3 $\mu g/m^3$ dispersion of individual measurements in the range of 140-400 $\mu g/m^3$	
2452/1	03.78	Air pollution measurement; measurement of total fluoride ion concentration	Impinger method	0.5-1 $\mu g/m^3$	± 0.5 $\mu g/m^3$ in the range of 10 $\mu g/m^3$	Differences due to device used
2452/2	02.75	Gaseous air pollution measurement; determination of fluoric ion concentration	Preseparation and electrometric detection	instead of DL quantification limits: 0.07 $\mu g/5ml_{\text{Lösung}}$	S_D: = 0.098-0.364 $\mu g/m^3$ at 0-35 F^- $\mu g/m^3$	
2452/3	07.87	Gaseous air pollution measurement; measurement of fluoride ion concentration	Sorption method with prepared silver balls and heated membrane filter	0.5 μg => DL_{rel} = 0,5 ng/m^3	Photometry S_D: = ± 0.35-0.7 $\mu g/m^3$ at 0-10 F^- $\mu g/m^3$ Electrometry S_D: = ± 0.19-0.30 $\mu g/m^3$ at 0-6 F^- $\mu g/m^3$	
2453/1	10.90	Gaseous air pollution measurement; determination of nitrogen dioxide concentration	Photometric manual standard method (Saltzmann)	3 $\mu g/m^3$	S_D: = 1.0-1.1 $\mu g/m^3$	Differences due to sample volume
2453/2	10.02	Gaseous pollution measurement - Measurement of nitrogen monoxide and nitrogen dioxide	Calibration of NO/NOx-chemiluminescence analysers using gas phase titration		S_{rel} < 3 % of calibration gas at 50-200 ppb	
2453/3	10.95	Gaseous air pollution measurement - Determination of the nitrogen monoxide and nitrogen dioxide	Preparation of the calibration gas mixtures and determination of their concentration			
2454/1	03.82	Gaseous air pollution measurement; measurement of hydrogen sulphide concentration	Molybdenum blue sorption method	0.4 $\mu g/m^3$ at 1 m^3 sample volume	± 0.5-1.4 $\mu g/m^3$ at 4.7-11.6 $\mu g/m^3$	
2454/2	03.82	Gaseous air pollution measurement; measurement of hydrogen sulphide concentration	Methylene blue Impinger method	0.3 $\mu g/m^3$ at 1 m^3 sample volume	± 0.5-0.7 $\mu g/m^3$ at 4.0-10.5 $\mu g/m^3$	
2455/1	08.70	Measurement of gaseous immissions; measurement of carbon monoxide concentration	Infrared absorption method (URAS 1 and 2)	1 ppm at measurement range of 0-100 ppm		
2455/2	10.70	Measurement of gaseous immissions; measurement of the carbon monoxide concentration	Infrared absorption method (UNOR 2)	1 ppm at measurement range of 0-100 ppm		

VDI No./Part	Edi-tion	Object	Method resp. Topic	Detection Limit	Standard Deviation	Remarks
2458/1	12.73	Gaseous air pollution measurement; measurement of chlorine concentration	Methylorange method	0.015 mg/m^3	± 0.05 mg/m^3 $S_{rel} \leq 8$ %	
2461/1	03.74	Gaseous air pollution measurement; measurement of ammonia gas concentration	Indophenol method	2.5 µg using impingers: DL_{rel}: 3.0 µg/m^3 at bottle:: DL_{rel} 20.0 µg/m^3	± 2.5 µg at approx. 50 µg/20 ml	
2461/2	05.76	Gaseous air pollution measurement; measurement of ammonia gas concentration	NESSLER's solution method	1.0 µg at Impingers: DL_{rel}: 2.5 µg/m^3 at bottle: DL_{rel} 50µg/m^3	± 0.6 µg at approx. 20 µg/50ml	
2463/1	11.99	Particulate matter measurement - Gravimetric determination of mass concentration of suspended particulate matter in ambient air	General principles			
2463/2 E	07.77	Particulate matter measurement; measurement of particulate matter in ambient air	High volume sampler HV 100	2.5 mg DL_{rel} 4 µg/m^3 (24h sampling)	uncertainty range ± 2.5 µg in the range 4-90 µg/m^3	
2463/3 E	12.76	Particulate matter measurement; Measurement of particulate matter in ambient air	TBF 50 f filter method	0.24 mg DL_{rel} 3.3 µg/m^3 (72 m^3 sampling)	uncertainty range ± 3.9 µg in the range 6.5-65 µg/m^3	
2463/4	12.76	Particulate matter measurement; Measurement of particulate matter in ambient air	LIB-filter method	absolute Membrane filter SM 11302: 3.6 mg Glass Fibre Filter GF9: 4.7 mg relative (360 m^3 sample) SM: 10µg/m^3 GP:13µg/m^3	S_D (with SM-Filter) = ± 3.0 µg/m^3 ($\overline{x}$ = 51-100) up to ± 13.7µg/m^3 ($\overline{x}$ = 251-510) S_D (with GF-Filter) = ± 2.6 µg/m^3 ($\overline{x}$ = 51-100) up to ± 21.1µg/m^3 ($\overline{x}$ = 501-950)	Uncertainty range (due to the concentration) SM: ± 6.4 - ± 33.6 µg/m^3 GF: ± 5.3 - ± 50 µg/m^3
2463/5	12.87	Particulate matter measurement; measurement of mass concentration in ambient air	Filter method; automated filter device FH 62 I		S_D = 1.4 µg/m^3 ($\overline{x}$ = 20-40) up to 13.3 µg/m^3 ($\overline{x}$ = 201-322)	Uncertainty range (3m^3/h) ± 2.9 - ± 34.3 µg/m^3
2463/6	11.87	Particulate matter measurement; measurement of mass concentration in ambient air	Filter method; automated filter device BETA-staubmeter F 703		S_D = 1.9 µg/m^3 ($\overline{x}$ = 15-40) up to 20.7 µg/m^3 ($\overline{x}$ = 201-259)	Uncertainty range ± 4.0 - ± 65.9 µg/m^3
2463/7	08.82	Particulate matter measurement; measurement of mass concentration in ambient air	Filter method; small filter device GS 050		S_D = 1.8 µg/m^3 ($\overline{x}$ = 30-80) up to 6.1 µg/m^3 ($\overline{x}$ = 231-350)	Uncertainty range ± 3.7 - ± 16.9 µg/m^3

<table>
<tr><th>VDI No./Part</th><th>Edi-tion</th><th>Object</th><th>Method resp. Topic</th><th>Detection Limit</th><th>Standard Deviation</th><th>Remarks</th></tr>
<tr><td>2463/8</td><td>08.82</td><td>Particulate matter measurement; measurement of mass concentration in ambient air</td><td>Standard method for the comparsion of nonfractionating methods</td><td></td><td>S_D = 1.7 µg/m^3 ($\overline{x}$ = 30-80)
up to 6.0 µg/m^3 ($\overline{x}$ = 231-350)</td><td>Uncertainty range
± 3.5 - ± 16.7 µg/m^3</td></tr>
<tr><td>2463/9</td><td>02.87</td><td>Particulate matter measurement; measurement of mass concentration in ambient air</td><td>Filter method; LIS/P filter device</td><td></td><td>S_D = 2.4 µg/m^3 ($\overline{x}$ = 50-80)
up to 8.1 µg/m^3 ($\overline{x}$ = 231-350)</td><td>Uncertainty range
± 5.7 - ± 25.8 µg/m^3</td></tr>
<tr><td>2463/10</td><td>09.96</td><td>Particulate matter measurement - Measurement of mass concentration in ambient air</td><td>Filter methods; AGS 050 and AGS 115 filter changer</td><td>concentration in the range :
0.01-0.25 mg/m^3</td><td>S_D = 0.001-0.0023 mg/m^3
($\overline{x}$ = 0.033-0.17 mg/m^3)</td><td>Due to device</td></tr>
<tr><td>2463/11</td><td>10.96</td><td>Particulate matter measurement - Measurement of mass concentration in ambient air</td><td>Filter method; Digitel DHA-80 filter changer</td><td>concentration in the range :
0.01-0.25 mg/m^3</td><td>S_D = 0.0008-0.0061 mg/m^3
($\overline{x}$ = 0.35-0.157 mg/m^3)</td><td>Due to device</td></tr>
<tr><td>2465/1</td><td>12.96</td><td>Measurement of soot (immission)</td><td>Chemical analysis of elemental carbon by extraction and thermal desorption of the organic carbon</td><td>absolute: 9 µg Carbon</td><td>S_D = 0.3-1.1 µg/m^3</td><td></td></tr>
<tr><td>2465/2</td><td>05.99</td><td>Measurement of soot (immission)</td><td>Thermographical determination of elemental carbon after thermal desorption of organic carbon</td><td>OC: DL_{abs} :1.78 µg
DL_{rel} :0.9 µg/m^3
EC: DL_{abs} :0.26 µg
DL_{rel} :0.13 µg/m^3</td><td>OC: S_D = 0.48-0.89 µg/m^3
$S_{rel.}$ = 8.2-12.8 %
EC: S_D = 0.21-0.33 µg/m^3
$S_{rel.}$ = 3.2-5.9 %</td><td>OC: Organic Carbon
EC: Elementary Carbon
due to laboratory</td></tr>
<tr><td>2467/1</td><td>08.91</td><td>Gaseous air pollution measurement; measurement of the concentration of primary and secondary amines by thin-layer chromatography</td><td>Visual and densitometric methods</td><td>0.01 µg using TLC plates;
0.001 µg for HPTLC-plates
DL_{rel} :0,02 µg/m^3</td><td>$S_{rel.}$ = ± 20 %</td><td></td></tr>
<tr><td>2467/2</td><td>08.91</td><td>Gaseous air pollution measurement; measurement of primary and secondary aliphatic amines</td><td>High performance liquid chromatography (HPLC)</td><td colspan="2"><table>
<tr><th>Amine</th><th>DL µg</th><th>DL_{rel} µg/m^3</th><th>S_{rel}%</th><th>S_{rel}%+</th></tr>
<tr><td>Methylamine</td><td>0.45</td><td>9</td><td>2.9</td><td>7.3</td></tr>
<tr><td>Dimethylamine</td><td>1.35</td><td>27</td><td>1.9</td><td>5.6</td></tr>
<tr><td>Ethylamine</td><td>0.5</td><td>10</td><td>6.3</td><td>6.3</td></tr>
<tr><td>Propylamine</td><td>0.45</td><td>9</td><td>2.1</td><td>2.9</td></tr>
<tr><td>Diethylamine</td><td>0.6</td><td>12</td><td>4.7</td><td>4.7</td></tr>
<tr><td>Butylamine-1</td><td>0.7</td><td>14</td><td>4.9</td><td>4.9</td></tr>
<tr><td>Pentylamine-1</td><td>0.55</td><td>11</td><td>5.1</td><td>5.1</td></tr>
</table></td><td>Without sample
S_{rel} + without elimination of the outlier</td></tr>
<tr><td>2468/4</td><td>05.78</td><td>Gaseous air pollution measurement; measurement of ozone concentrations</td><td>Chemiluminescence method; Bendix Ozone Monitor 8002</td><td>0.0015 ppm</td><td>S_D = ± 0.0003 ppm</td><td></td></tr>
</table>

VDI No./Part	Edi-tion	Object	Method resp. Topic	Detection Limit	Standard Deviation	Remarks
2468/5	10.78	Gaseous air pollution measurement; measurement of ozone concentration	Manual photometric method; indigo sulfonic acid method	DL_{rel} : 10 µg/m^3	S_{rel} = ± 3.5% (at 600 µg/m^3) S_{rel} = ± 6.5% (at 50 µg/m^3)	
2468/6	07.79	Gaseous air pollution measurement; measurement of ozone concentration	Direct UV-photometric method (Standard method)	0.01 ppm	S_D = ± 0.010 ppm	Only for purified or synthetic air for calibration of monitors
2468/7	06.85	Gaseous air pollution measurement	Measurement of peroxyacetyl nitrate (PAN)	0.1 – 0.18 ppm (depending on method)	S_{rel} = 0.4% (at 50 ppb) S_{rel}= up to 4% (at 0.5 ppb)	
2468/7 E	07.03	Gaseous air pollution measurement	Measurement of peroxyacetyl nitrate (PAN)	0.1 – 0.9 ppb (depending on method)	S_{rel} = 0.4 – 4.5% (depending on method)	
2468/8	06.85	Gaseous air pollution measurement; preparation of PAN calibration gas	Calibration of a PAN analyzer			
2468/8 E	07.03	Gaseous air pollution measurement; preparation of PAN calibration gas	Calibration of a PAN analyzer			
2468/9	09.95	Gaseous air pollution measurement - Measurement of hydrogen peroxide	Continuous fluorometric method	DL_{rel} :0.09 µg/m^3	S_{rel} = ± 2 %	
2468/10	07.95	Gaseous air pollution measurement	Preparation of hydrogen peroxide calibration - Gas mixtures			
3483/1	12.79	Gaseous air pollution measurement; determination of total organic compounds by use of a flame ionization detector (FID)	Fundamentals			
3483/2	11.81	Gaseous air pollution measurement; determination of total organic compounds less methane	Flame ionization detector (FID); Siemens U 100	measuring threshold in the range 0-2.5 mg/m^3: 0.026 mg/m^3	S_D = ±0.03 mg/m^3 ($\overline{x}$ =1.9)	
3483/4	11.81	Gaseous air pollution measurement; determination of total organic compounds and of methane	Flame ionization detector (FID); Bendix 8202	measuring threshold in the range 0-2.5 mg/m^3: 0.05 mg/m^3	S_D = ±0.03 mg/m^3 ($\overline{x}$ =1.9)	
3484/1	11.01	Gaseous ambient air measurements - Indoor-air pollution measurements	Test gases measurement; Measurement of the formaldehyde concentration with the sulfite pararosaniline method	DL_{abs} : 0.0003 mg DL_{rel} :0.004 mg/m^3	S_D = ±0.003 mg/m^3 ($\overline{x}$ = 0.04-0.1mg/m^3)	

VDI No./Part	Edi- tion	Object	Method resp. Topic	Detection Limit	Standard Deviation	Remarks
3484/2	11.01	Gaseous ambient air measurements - Indoor-air pollution measurements	Measurement of the formaldehyde concentration with the acatylacetone method	DL_{abs} : 0.0003 mg DL_{rel} :0.005 mg/m^3 (60l sampling volume) DL_{rel} :0.003 mg/m^3 (100l sampling volume)	S_D = ± 0.001-0.002mg/m^3 ($\overline{x}$ = 0.05-0.2 mg/m^3)	
3485/1	12.88	Ambient air measurement; measurement of gaseous phenoloc compounds	p-nitroaniline method	DL_{abs} : 0.0006 mg A:DL_{rel} :0.0008 mg/m^3 (800l sampling volume) B:DL_{rel} :0.012 mg/m^3 (50l sampling volume)	S_D = ± 0.006 mg/m^3 ($\overline{x}$ = 0.1-0.9 mg/m^3)	A:Impinger-method B:Muencke-method
3490/1	12.80	Measurement of gases; calibration gas mixtures	Terms and legends			
3490/2	12.80	Measurement of gases; calibration gas mixtures	Preparation methods; general			
3490/3	12.80	Measurement of gases; calibration gas mixtures	Specifications for transfer			Material , Building component, Linesystem
3490/4	12.80	Measurement of gases; calibration gas mixtures	Preparation by gravimetric methods			
3490/5	12.80	Measurement of gases; calibration gas mixtures	Determination of the composition by comparison methods			
3490/6	12.88	Measurement of gases; calibration gas mixtures	Dynamic preparation by gas-mixing pumps			Calibration
3490/7	12.80	Measurement of gases; calibration gas mixtures	Dynamic method of preparation by periodic injection			Examples
3490/8	01.81	Measurement of gases; calibration gas mixtures	Preparation by continuous injection method			Example
3490/9	12.80	Measurement of gases; calibration gas mixtures	Preparation by permeation procedures			
3490/10	01.81	Measurement of gases; calibration gas mixtures	Preparation of calibration gas mixtures using capillary device			
3490/11	12.80	Measurement of gases; calibration gas mixtures	Preparation of calibration gas mixtures using plastic bags			
3490/12	12.88	Measurement of gases; calibration gas mixtures	Preparation of calibration gas mixtures by manometric methods			Examples

VDI No./Part	Edi-tion	Object	Method resp. Topic	Detection Limit	Standard Deviation	Remarks
3490/13	02.92	Measurement of gases; calibration gas mixtures	Preparation of calibration gas mixtures by saturation methods			Examples
3490/14	11.94	Measurement of gases; calibration gas mixtures	Preparation of calibration gas mixtures by volumetric static method using glass vessels			
3490/15 E	11.85	Measurement of gases; calibration gas mixtures	Determination of the composition by gas density measuring technique; gas density balance			
3490/16	10.94	Measurement of gases; calibration gas mixtures	Dynamic preparation with critical orifice systems			
3490/17	08.98	Measurement of gases; calibration gas mixtures	Dynamic preparation with thermal mass flow controllers			
3491/1	09.80	Particulate matter measurement; test aerosols	Characteristics of suspended particulate matter in gases; terms and definitions			
3491/2	07.80	Particulate matter measurement; test aerosols	Production methods of test aerosols; foundations and synoptics			
3491/3	11.80	Particulate matter measurement; test aerosols	Generation of latex aerosols using nozzle atomizers			
3491/4	12.80	Particulate matter measurement; test aerosols	Generation of test aerosols; Sinclair-La Mer-generator			
3491/5	12.80	Particulate matter measurement; test aerosols	Generation of test aerosols by nebulization of dye-solutions with nozzle atomizers			
3491/6	12.80	Particulate matter measurement; test aerosols	Generation of test aerosols; platinum oxide generator			
3491/7	12.87	Particulate matter measurement; test aerosols	Generation of test aerosols; Rapaport-Weinstock generator			
3491/8	09.89	Particulate matter measurement; test aerosols	Generation of test aerosols from powders using a belt feed unit			
3491/9	09.89	Particulate matter measurement; test aerosols	Generation of test aerosols with a rotating brush generator			

VDI No./Part	Edi-tion	Object	Method resp. Topic	Detection Limit	Standard Deviation	Remarks
3491/10	01.90	Particulate matter measurement; test aerosols	Generation of test aerosols from fibrous powders using a vibrating bed aerosol generator			
3491/11	01.90	Particulate matter measurement; test aerosols	Generation of test aerosols using ultrasonic atomizers			
3491/12	01.90	Particulate matter measurement; test aerosols	Generation of test aerosols using centrifugal atomizers			
3491/13	06.96	Particulate matter measurement; test aerosols	Generation of test aerosols using a vibrating-orifice generator			
3491/14	11.95	Particulate matter measurement; test aerosols	Generation of test aerosols using a capillary wave generator			
3491/15	12.96	Particulate matter measurement; test aerosols	Generation of test aerosols - Dilution systems with continuous volumetric flow			
3491/16	11.96	Particulate matter measurement; test aerosols	Generation of carbon aerosols using a spark aerosol generator			
3492/1	08.91	Measurement of inorganic fibrous particles in ambient air	Scanning electron microscopy method		Uncertainty range due to sampling, sample preparation, analysis	Particulary critical: detection and analysis of thin fibres with $D < 0{,}2\ \mu m$
3492/2	06.94	Indoor air pollution measurement; measurement of inorganic fibrous particles;	Measurement planning and procedure; scanning electron microscopy method			
3492 E	12.02	Indoor air measurement; Ambient air measurement; Measurement of inorganic fibrous particles	Scanning electron microscopy method		Uncertainty range due to sampling, sample preparation, analysis	Particulary critical: detection and analysis of thin fibres with $D < 0{,}2\ \mu m$
3495/1	09.80	Gaseous air pollution measurement	Determination of organic carbon in ambient air adsorbed on silica gel	DL_{rel} :0.3 mg C/m^3	$S_D = \pm 0.11$ mg C/m^3 ($\overline{x}=1.0$)	

VDI No./Part	Edi-tion	Object	Method resp. Topic	Detection Limit	Standard Deviation	Remarks
3496/1	04.82	Gaseous air pollution measurement	Determination of basic nitrogen compounds by absorbtion in sulphuric acid	analytic 0.1 mg N photometric: 0.001 mg NH_3	S_{ana} = 5.8 mg/m^3($\bar{x}$ = 27-60) S_P = 7.7mg/m^3($\bar{x}$ = 30-64) S_P = 1.6mg/m^3($\bar{x}$ = 2,5-8)	analytic N photometric NH_3 photometric N by Kjedahl analysis
3497/1 E	12.87	Determination of particulate anions in ambient air	Loss-avoiding sampling of chloride, nitrate, and sulfate in the particle range up to a mean aerodynamic diameter of 5µm			
3497/2	09.91	Determination of particulate anions in ambient air	Isotope dilution analysis for sulphate on filters	0.14 µg Sulfate 0.1 µg/m^3	S_D = ± 0.18 µg Sulfate at $\bar{x}$ = 1.5 µg Sulfate	S_D = 9 % at $\bar{x}$ = 3 µg/m^3
3497/3	07.88	Determination of particulate anions in ambient air; analysis of chloride, nitrate, and sulfate	Ion chromatography using suppressor technique after aerosol sampling on PTFE-filters	Substance: (at 5 m^3) Chloride 93 ng/m^3 Nitrate 10 ng/m^3 Sulphate 17 ng/m^3	Substance: Chloride S_D = 10 % ($\bar{x}$ =1.5 µg/m^3) Nitrat S_D = 5 % ($\bar{x}$ = 8 µg/m^3) Sulphate S_D = 5 % ($\bar{x}$ =10 µg/m^3)	
3497/4	09.91	Determination of particulate anions in ambient air; analysis of chloride, nitrate, and sulphate	Ion chromatography using single-column-technique after aerosol sampling on PTFE-filters	Substance: (at 5 m^3) Chloride 78 ng/m^3 Nitrate 9 ng/m^3 Sulphate 18.6 ng/m^3	Substance: Chloride S_D = 8 % ($\bar{x}$ = 2.3 µg/m^3) Nitrate S_D = 8 % ($\bar{x}$ = 8.6 µg/m^3) Sulphate S_D = 8 % ($\bar{x}$ =10 µg/m^3)	

VDI No./Part	Edition	Object	Method resp. Topic	Detection Limit		Standard Deviation		Remarks
3498/1	07.02	ion chromatography using single-column-technique after aerosol sampling on PTFE-filters dibenzo-p-dioxins and dibenzofurans;	large filtering method	**PCDD**	**DL_{rel} fg/m^3**	**Concentration fg/m^3**	**s_{rel} %**	
				2,3,7,8-TCDD	0.5	4-7	7	
				1,2,3,7,8-PeCDD	1.6	19-38	10	
				1,2,3,6,7,8-HxCDD	3.4	32-66	7	
				1,2,3,4,6,7,8-HpCDD	1.8	295-554	11	
				OCDD	3.0	620-965	6	
				PCDF	**DL_{rel} fg/m^3**	**Concentration fg/m^3**	**s_{rel} %**	
				2,3,7,8-TCDF	0.3	62-113	7	
				1,2,3,7,8-PeCDF	1.2	61-186	9	
				1,2,3,4,7,8-HxCDF 2,3,4,6,7,8-HxCDF	1.1/ 0.7	56-133 36-87	7 7	
				1,2,3,4,6,7,8-HpCDF	1.3	170-434	5	
				OCDF	2.4	139-291	10	
3498/2	07.02	Ambient air measurement; indoor air measurement - Measurement of polychlorinated dibenzo-p-dioxins and dibenzofurans	small filtering method	**PCDD**	**DL_{rel} fg/m^3**	**Concentration fg/m^3**	**s_{rel} %**	
				2,3,7,8-TCDD	< 1.0	2.1-2.6	9.6	
				1,2,3,7,8-PeCDD	< 1.5	8-9	5.0	
				1,2,3,6,7,8-HxCDD	< 2.0	10-13	8.9	
				1,2,3,4,6,7,8-HpCDD	<3.0	243-287	6.6	
				OCDD	<3.5	615-643	1.7	
				PCDF	**DL_{rel} fg/m^3**	**Concentration fg/m^3**	**s_{rel} %**	
				2,3,7,8-TCDF	< 1.0	23-27	6.2	
				1,2,3,7,8-PeCDF	< 1.0	30-36	6.2	
				1,2,3,4,7,8-HxCDF 2,3,4,6,7,8-HxCDF	< 1.5	22-28	8.0	
				1,2,3,4,6,7,8-HpCDF	< 3.0	6-8	11.2	
				OCDF	< 3.0	55-58	5.4	

VDI No./Part	Edi-tion	Object	Method resp. Topic	Detection Limit	Standard Deviation	Remarks
3792/5	06.91	Response dose determination	standardization of sampling of leaves and needles from trees at their natural site			
3794/1	11.82	Determination of immission rates	determination of the immission rate by means of the IRMA-method	Substance: mg/m^2d SO_2 2.0 F^- 0.29 Cl^- 1.0	Substance: x $[mg/m^2d]$ S_{drel} [%] SO_2 15-200 10 F^- 0.1-2.2 30 Cl^- 1-16 13.3	
3794/2	01.03	Determination of immission rates	determination of the immission rate of ammonia and ammonia compounds by means of the IRMA-method	baseline value 180 µg NH_4^+ 0.7 mg/m^2d	± 0.1 mg/m^2d	Detected value near to a Fattening Farm: 3.7-94.9 mg/m^2d
3795/1	06.78	Determination of air pollution components in biological material	determination of fluorides in biological material and IRMA-solutions; photometric analysis	0.8 mg F/ kg	S_{rel} = 3.3-4.6 %	
3795/2	04.81	Determination of air pollution components in biological material	determination of fluorides in biological material and IRMA-solutions; electrometric analysis	2.4 µg/g	S_{rel} = 2.2-3.1 at = 10 - >100	
3796/1	09.96	Determination of thallium in soil and plants	basics, sample treatment			
3869/1	09.91	Measurement of acids and bases in ambient air; measurement of sulphuric acid aerosols	precipitation by thermal diffusion	0.01 $µg/m^3$ (at 24h sampling)	S_D = 15 % ($\overline{x}$ = 1.2 ng/m^3)	
3869/2 E	05.96	Measurement of acids and bases in ambient air - Measurement of gaseous hydrochloric and nitric acid	sampling by diffusion on separators coated with sodium fluoride - Determination by ion chromatography	0.10 $µg/m^3$ HCL 0.08 $µg/m^3$ HNO_3	S_D = 20 % In average range 1.0 $µg/m^3$	
3869/3 E	05.96	Measurement of acids and bases in ambient air - Measurement of ammonia	sampling in diffusion separators coated with phosphoric acid - Determination by flow injection analysis	0.1 $µg/m^3$	S_D = 10 % In average range 2.9 $µg/m^3$	

VDI No./Part	Edi-tion	Object	Method resp. Topic	Detection Limit	Standard Deviation	Remarks
3869/4 E	05.96	Measurement of acids and bases in ambient air - Measurement of ammonia	sampling in diffusion separators coated with citric acid - Determination by indophenol method	0.1 µg/m^3	S_D = 10 % In average range 2.9 µg/m^3	
3869/5 E	07.97	Measurement of acids and bases in ambient air - Measurement of lower carboxylic acids	sampling in diffusion separators; determination by ion chromatography	Substance: mg/m^3 Formic acid 0.09 Acetic acid 0.10 Propionic acid 0.16	Substance: mg/m^3 S_{rel} Formic acid 1.8 8.6% Acetic acid 3.2 8.9% Propionic acid 3.6 10.1%	
3870/1 E	07.85	Analysis of rain water	criteria for design, siting and operation of rain samplers			
3870/2	12.97	Analysis of rain water	sampling of rain water - Sampler type ARS 721	Precipation depth of 0.1 mm/h for a 75 % ratio of all events		
3870/10	12.94	Analysis of rain water	determination of the pH value of rainwater		S_w = 0.01 pH units	Up to 0.05 pH units result from interferences
3870/11	12.96	Analysis of rain water	determination of free acidity	20 µmol/l	$S_w < 2\%$	
3870/13	12.96	Analysis of rain water	determination of chloride, nitrate and sulfate in rainwater by ion chromatography using the suppressor technique	Substance: mg/l n=6 Chloride 0.001 Nitrate 0.004 Sulphate 0.005	Substance: Chloride S_{Wrel} = 31 % ($\overline{x}$ = 0.22-2.46 mg/l) Nitrate S_{Wrel} = 11 % ($\overline{x}$ = 0.63-4.05 mg/l) Sulphate S_{Wrel} = 14 % ($\overline{x}$ = 1.31-7.62 mg/l)	

<table>
<tr><th>VDI No./Part</th><th>Edi-tion</th><th>Object</th><th>Method resp. Topic</th><th>Detection Limit</th><th>Standard Deviation</th><th>Remarks</th></tr>
<tr><td>3875/1</td><td>12.96</td><td>Outdoor-air pollution measurement - Indoor-air pollution measurement</td><td>measurement of polycyclic aromatic hydrocarbons (PAHs) – Gas chromatographic determination</td><td>5.7 pg/m^3
double determination in 2 measuring series</td><td colspan="2"><table>
<tr><th>PAHs</th><th>S_D (%)</th><th>$\overline{x}$ (ng/m^3)</th></tr>
<tr><td>Benzo(b)naphtho (2,1-d) thiophene</td><td>13.20 / 11.20</td><td>0.99 / 0.78</td></tr>
<tr><td>Benzo(ghi)fluoranthene und Ben2o(c)phenanthrene</td><td>8.40 / 6.15</td><td>3.90 / 2.92</td></tr>
<tr><td>Cyclopenta(cd)pyrene</td><td>16.56 / 10.82</td><td>4.62 / 3.03</td></tr>
<tr><td>Benz(a)anthracene</td><td>9.15 / 5.14</td><td>3.19 / 2.66</td></tr>
<tr><td>Chrysene und Triphenylene</td><td>6.53 / 4.99</td><td>5.51 / 4.55</td></tr>
<tr><td>Benzofluoranthenes (b+j+k)</td><td>5.33 / 3.45</td><td>8.13 / 6.48</td></tr>
<tr><td>Benzo(e)pyrene</td><td>6.0 / 4.84</td><td>3.40 / 2.63</td></tr>
<tr><td>Benzo(a)pyrene</td><td>7.69 / 5.93</td><td>3.13 / 2.52</td></tr>
<tr><td>lndeno(1.2.3-cd)pyrene</td><td>4.94 / 3.35</td><td>3.34 / 2.66</td></tr>
<tr><td>Dibenz(a,c)anthracene und Dibenz(a,n)anthanthrene</td><td>9.62 / 9.59</td><td>0.40 / 0.31</td></tr>
<tr><td>Benzo(ghi)perylene</td><td>6.13 / 3.26</td><td>6.22 / 4.84</td></tr>
<tr><td>Anthanthrene</td><td>13.14 / 11.13</td><td>0.93 / 0.70</td></tr>
<tr><td>Coronene</td><td>6.45 / 6.24</td><td>4.80/3.64</td></tr>
</table></td></tr>
<tr><td>3956/1</td><td>12.97</td><td>Objective, importance, and fundamentals of the guidelines for soil protection</td><td>establishment of maximum immission values</td><td colspan="3"></td></tr>
<tr><td>3956/2</td><td>04.02</td><td>Establishment of maximum immission values for soil protection</td><td>deposition values for Cadmium</td><td colspan="2"><table>
<tr><td>Children´s playing areas</td><td>3.4 µg Cd /(m^2 day)</td></tr>
<tr><td>Arable soils</td><td>2.5 µg Cd /(m^2 day)</td></tr>
<tr><td>Grass</td><td>32 µg Cd /(m^2 day)</td></tr>
<tr><td>Forest soils</td><td>2 µg Cd /(m^2 day)</td></tr>
</table></td><td>establishment of maximum immission values for soil protection</td></tr>
<tr><td>3956/3 E</td><td>11.03</td><td>Establishment of maximum immission values for the protection of soils</td><td>maximum Immission Rates (MIR) Deposition values for nickel</td><td colspan="3"></td></tr>
<tr><td>3957/1</td><td>05.99</td><td>Biological measuring techniques for the determination und evaluation of effects of air pollutants on plants</td><td>fundamentals and aims</td><td colspan="3"></td></tr>
<tr><td>3957/2 E</td><td>01.01</td><td>Biological measuring techniques for the determination and evaluation of effects of air pollutants on plants (bioindication)</td><td>method of standardised grass exposure</td><td colspan="3">General description of proceeding to determinate relevant performance characteristics and of data handling, presentation, and evaluation</td></tr>
<tr><td>3957/3</td><td>12.00</td><td>Biological measuring techniques for the determination and evaluation of effects of air pollutants on plants</td><td>standardised exposure of green cabbage</td><td colspan="3">General description of proceeding to determinate relevant performance characteristics and of data handling, presentation, and evaluation</td></tr>
</table>

VDI No./Part	Edi-tion	Object	Method resp. Topic	Detection Limit	Standard Deviation	Remarks
3957/5	12.01	Biological measuring techniques for the determination and evaluation of effects of air pollutants on plants (bioindication)	standardised exposure of spruce	General description of proceeding to determinate relevant performance characteristics and of data handling, presentation, and evaluation		
3957/6 E	11.00	Biological measuring techniques for the determination und evaluation of effects of air pollutants on plants (bioindication)	determination of the phytotoxic effects of ozone and other photooxidants - Standardised exposure of tabacco	General description of proceeding to determinate relevant performance characteristics and of data handling, presentaion, and evaluation; optical evaluation of bioindication		
3957/8 E	01.02	Determination of the growth rate of epiphytic lichens of ecological long-term monitoring		General description of proceeding to determinate relevant performance characteristics and of data handling, presentation, and evaluation		
3957/10	11.02	Biological measuring techniques for the determination and evaluation of effects of air pollutants on plants (bioindication)	source-related measurements of ambient air quality using bioindicators			
4210/1	06.99	Remote sensing - Atmospheric measurements with LIDAR	measuring gaseous air pollution with DAS LIDAR			
4211/1	12.00	Remote sensing - Atmospheric measurements near ground wit FTIR spectroscopy	measurement of gaseous emissions and immissions; Fundamentals			
4280/1	11.96	Planning of ambient air quality measurements	general rules			
4280/2	12.00	Planning of ambient air quality measurements	rules for planning investigations of traffic related air pollutants in key pollution areas			
4280/3	06.03	Planning of ambient air quality measurements	measurement strategies for the determination of air quality characteristics in the vicinity of stationary emission sources			
4300/1	12.95	Indoor-air pollution measurement	general aspects of measurement strategy			
4300/2	12.97	Indoor-air pollution measurement	measurement strategy for polycyclic aromatic hydrocarbons (PAHs), polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs) and polychlorinated bibhenyle (PCBs)			

<table>
<tr><th>VDI No./Part</th><th>Edition</th><th>Object</th><th>Method resp. Topic</th><th>Detection Limit</th><th colspan="4">Standard Deviation</th><th colspan="4">Remarks</th></tr>
<tr><td>4300/3</td><td>12.97</td><td>Measurement of indoor air pollutants</td><td>measurement strategy for formaldehyde</td><td colspan="9"></td></tr>
<tr><td>4300/4</td><td>08.97</td><td>Measurement of indoor air pollutants</td><td>measurement strategy for pentachlorophenol (PCP) and γ -hexachlorocyclohexane (lindane) in indoor air</td><td colspan="9"></td></tr>
<tr><td>4300/5</td><td>06.02</td><td>Measurement of indoor air pollutants</td><td>measurement strategy for nitrogen dioxide (NO_2)</td><td colspan="9"></td></tr>
<tr><td>4300/6</td><td>12.00</td><td>Measurement of indoor air pollutants</td><td>measurement strategy for volatile organic compounds (VOC)</td><td colspan="9"></td></tr>
<tr><td>4300/7</td><td>07.01</td><td>Measurement of indoor air pollutants</td><td>measurement of indoor air change rate</td><td colspan="9"></td></tr>
<tr><td>4300/8</td><td>06.01</td><td>Measurement of indoor air pollutants</td><td>sampling of house dust</td><td colspan="9"></td></tr>
<tr><td>4300/9</td><td>05.03</td><td>Measurement of indoor air pollutants</td><td>measurement strategy for carbon dioxide (CO_2)</td><td colspan="9"></td></tr>
<tr><td>4301/1</td><td>12.97</td><td>Measurement of indoor air pollution</td><td>determination of the concentration of nitrogen dioxide - Manual photometric method (Saltzman)</td><td>DL: 3-15 µg/m^3
due to device</td><td colspan="4">S_{rel} = 1- 3 %
at 10 – 750 µg/m^3</td><td colspan="4"></td></tr>
<tr><td rowspan="5">4301/2</td><td rowspan="5">06.00</td><td rowspan="5">Measurement of indoor air pollution</td><td rowspan="5">measurement of pentaclorphenol (PCP) and -hexachlorcyclohexane (lindane)- GC/MS-method</td><td rowspan="5">0.01 µg/m^3

left PCP
right γ-HCH</td><td>$C_{L\,PCP}$ µg/m^3</td><td>S_l µg/m^3</td><td>VK %</td><td>n</td><td>C_L µg/m^3</td><td>S_l µg/m^3</td><td>VK %</td><td>n</td></tr>
<tr><td>1.6</td><td>0.133</td><td>8</td><td>20</td><td>0.41</td><td>0.040</td><td>10</td><td>20</td></tr>
<tr><td>0.29</td><td>0.025</td><td>9</td><td>16</td><td>0.31</td><td>0.018</td><td>6</td><td>20</td></tr>
<tr><td>0.21</td><td>0.023</td><td>11</td><td>14</td><td>0.30</td><td>0.025</td><td>8</td><td>15</td></tr>
<tr><td>0.14</td><td>0.030</td><td>21</td><td>20</td><td>0.21</td><td>0.023</td><td>11</td><td>17</td></tr>
<tr><td>4301/3</td><td>06.03</td><td>Measurement of indoor air pollution</td><td>measurement pentaclorophenol (PCP) and hexachlorcyclohexane (lindane) - GC/ECD method</td><td>20 ng/m^3</td><td colspan="4"></td><td colspan="4"></td></tr>
</table>

Classification DIN-EN-ISO	**Edition**	**Title**
DIN ISO 4219	1990-05	Air quality; determination of gaseous sulfur compounds in ambient air; sampling equipment
DIN ISO 4220	1990-05	Ambient air; determination of a gaseous acid air pollution index; titrimetric method with indicator or potentiometric end-point detection
DIN ISO 4221	1990-05	Air quality; determination of mass concentration of sulfur dioxide in ambient air; thorin spectrophotometric method
DIN ISO 4225	1996-08	Air quality - General aspects - Vocabulary
DIN ISO 4226	1996-02	Air quality - General aspects - Units of measurement
DIN ISO 6879	1996-12	Air quality - Performance characteristics and related concepts for air quality measuring methods
DIN ISO 7168-1	1999-12	Air quality - Exchange of data - Part 1: General data format
DIN ISO 7168-2	1999-12	Air quality - Exchange of data - Part 2: Condensed data format
DIN ISO 7708	1996-01	Air quality - Particle size fraction definitions for health-related sampling
DIN ISO 7996	1990-02	Ambient air; determination of the mass concentration of nitrogen oxides; chemiluminescence method
DIN ISO 9169	1996-08	Air quality - Determination of performance characteristics of measurement methods
E DIN ISO 10473	2001-11	Ambient air - Measurement of the mass of particulate matter on a filter medium - Beta-ray absorption method
DIN ISO 11222	2002-12	Air quality - Determination of the uncertainty of the time average of air quality measurements
DIN ISO 12884	2000-12	Ambient air - Determination of total (gas and particle phase) polycyclic aromatic hydrocarbons - Collection on sorbent-backed filters with gas chromatographic/mass spectrometric analysis
DIN ISO 13752	1999-01	Air quality - Assessment of the uncertainty of a measurement method under field conditions using a second method as reference
DIN ISO 13964	1999-12	Air quality - Determination of ozone in ambient air - Ultraviolet photometric method
DIN ISO 16362	2002-12	Ambient air - Determination of particle-phase polycyclic aromatic hydrocarbons by high performance liquid chromatographic analysis
DIN EN 12341	1999-03	Air quality - Determination of the PM10 fraction of suspended particulate matter - Reference method and field test procedure to demonstrate reference equivalence of measurement methods

Classification DIN-EN-ISO	Edition	Title
E DIN EN 13528-1	1999-07	Ambient air quality - Diffusive samplers for the determination of concentrations of gases and vapours; Requirements and test methods - Part 1: General requirements
DIN EN 13528-2	2002-12	Ambient air quality - Diffusive samplers for the determination of concentrations of gases and vapours; Requirements and test methods - Part 2: Specific requirements and test methods
DIN EN 13528-3	2002-12	Ambient air quality - Diffusive samplers for the determination of concentrations of gases and vapours - Part 3: Guide to selection, use and maintenance
DIN EN 13725	2003-07	Air quality - Determination of odour concentration by dynamic olfactometry
E DIN EN 14211	2003-05	Ambient air quality - Measurement method for the determination of the concentration of nitrogen dioxide and nitrogen monoxid by chemiluminescence
E DIN EN 14212	2003-05	Ambient air quality - Measurement method for the determination of the concentration of sulphur dioxide by ultraviolet fluorescence
E DIN EN 14625	2003-06	Ambient air quality - Measurement method for the determination of ozone in ambient air by means of ultraviolet photometric method
E DIN EN 14626	2003-06	Ambient air quality - Measurement method for the determination of carbon monoxide in ambient air by means of the non-dispersive infrared method
E DIN EN 14662-1	2003-08	Ambient air quality - Standard method for the measurement of benzene concentration - Part 1: Pumped sampling followed by thermal desorption and gas chromatography method
E DIN EN 14662-2	2003-08	Ambient air quality - Standard method for measurement of benzene concentration - Part 2: Pumped sampling followed by solvent desorption and gas chromatography
E DIN EN 14662-3	2003-08	Ambient air quality - Standard method for the measurement of benzene concentration - Part 3: Automated pumped sampling with in situ gas chromatographic analysis
E DIN EN 14662-4	2003-08	Ambient air quality - Standard method for measurement of benzene concentrations - Part 4: Diffusive sampling followed by thermal desorption and gas chromatography

Classification DIN-EN-ISO	Edition	Title
E DIN EN 14662-5	2003-08	Ambient air quality - Standard method for measurement of benzene concentrations - Part 5: Diffusive sampling followed by solvent desorption and gas chromatography
DIN 19739-1	2002-03	Air and soil quality - Measurement of atmospheric deposition of organic trace substances; Funnel adsorber method - Part 1: Sampling devices; Requirements, installation, application
DIN 19739-2	2003-03	Air and soil quality - Measurement of atmospheric deposition of organic trace substances; Funnel adsorber method - Part 2: Determination of polynuclear aromatic hydrocarbons
DIN 33963-1	1997-02	Measurement of organic compounds in ambient air - Part 1: Requirements and testing instructions for automated single cycle measuring instruments for organic components in air
DIN 33963-2	1997-02	Measurement of organic compounds in ambient air - Part 2: Requirements and testing instructions for automated single cycle measuring instruments for benzene in air with concentrating sampling followed by gas chromatographic separation
DIN EN ISO 14956	2003-01	Air quality - Evaluation of the suitability of a measurement procedure by comparison with a required measurement uncertainty
DIN EN ISO 16017-1	1999-10	Indoor, ambient and workplace air - Sampling and analysis of volatile organic compounds by sorbent tube/thermal desorption/capillary gas chromatography - Part 1: Pumped sampling
DIN EN ISO 16017-2	1999-03	Indoor, ambient and workplace air - Sampling and analysis of volatile organic compounds by sorbent tube/thermal desorption/capillary gas chromatography - Part 2: Diffusive sampling

E: Entwurf (draft)

APPENDIX 3

SUITABILITY TESTED AMBIENT AIR MEASUREMENT DEVICES

Suitability Tested Continuously Operating Devices for Measurement of Ambient Air Pollutants (Status: September 2003)

Substance	Measurement Principle	Model	Manufacturer (Retailer)1)	Testing Institute2)	Announcement in the GMBl3)
SULPHUR DIOXIDE	Conductometry	Ultragas U3 ES*)	H. Wösthoff, Bochum	RW TÜV	1985, 22, 455
		Picoflux 4*)	Hartmann & Braun, Frankfurt	RW TÜV	1985, 22, 455
		Ultragas U3 EK	H. Wösthoff, Bochum	RW TÜV	1990, 12, 242
		Ultragas U3 RK	H. Wösthoff, Bochum	UBA	1995, 33, 703
	UV Fluorescence	Modell 43*)	Thermo ESM Andersen, Erlangen	UBA	1990, 12, 242
		ML 8850*)	Monitor Labs, Englewood, CO (USA) (MS4-Analysentechnik, Rockenberg)	UBA	1990, 12, 242
		ML 8850 S*)	Monitor Labs, Englewood, CO (USA) (MS4-Analysentechnik, Rockenberg	UBA	1992, 32, 796
		APSA 350 E*)	Horiba Europe, Leichlingen	TÜV Rheinland	1990, 12, 243
		Modell 43a+)*)	Thermo Instruments, Dortmund	UBA	1990, 12, 243
		AF 21M	Environnement S.A. (Ansyco, Karlsruhe)	UBA	1992, 45, 1143
		ML 9850	Monitor Labs, Englewood, CO (USA) (MS4-Analysentechnik, Rockenberg)	RW TÜV	1996, 8, 189
		APSA 360	Horiba Europe, Leichlingen	TÜV Rheinland	1996, 28, 594
		API Modell 100 A (MLU 100A)	Advanced Pollution Instrumentation, San Diego (USA) (MLU, Essen)	RW TÜV	1997, 29, 466
		Modell 43 C	Thermo ESM Andersen, Erlangen	UBA	1997, 29, 466
	DOAS	Mehrkomponentenmessgerät AR 500 mit Kalibriereinheit CB 100	Opsis AB, Furuland (Schweden)	UMEG	1993, 26, 471
NITROGEN OXIDES	Chemiluminescence	ML 8440*)	Monitor Labs (Rohde & Schwarz, Köln)	UBA	1990, 12, 243
		Modell 14 D/E*)	Thermo Instruments, Dortmund	LfU B.-W.	1985, 22, 455
		ML 8840*)	Monitor Labs (Rohde & Schwarz, Köln)	UBA	1990, 12, 243
		CSI 1600**)	Columbia Scientific Ind. Corp. (Bestobell Mobrey, Düsseldorf)	RW TÜV	1990, 12, 243
		Modell 8101-CTM*)	UPM, Langgöns	LfU B.-W.	1990, 12, 243
		APNA 300 E*)	Horiba Europe, Leichlingen	TÜV Rheinland	1990, 12, 243
		APNA 350 E*)	Horiba Europe, Leichlingen	UBA	1992, 32, 796
		AC 30 M*)	Environnement S.A. (Ansyco, Karlsruhe)	UBA	1990, 12, 243
		Modell CLD 502*)	TECAN, Hombrechtikon (Schweiz)	TÜV Bayern	1990, 12, 243
		CLD 700 AL	Eco Physics, Dürnten (Schweiz) Ergänzungsprüfung von 1996	UMEG	1991, 37, 1046 1996, 42, 884
		Modell TE 42*)	Thermo ESM Andersen, Erlangen	UBA	1994, 28, 871
		Modell 8841*)	Monitor Labs, Englewood, CO (USA) (Rohde & Schwarz, Köln)	UBA	1995, 7, 132

Substance	**Measurement Principle**	**Model**	**Manufacturer (Retailer)1)**	**Testing Institute2)**	**Announcement in the GMBl3)**
NITROGEN OXIDES	Chemiluminescence	ML 9841	Monitor Labs, Englewood, CO (USA) (Rohde & Schwarz, Köln)	UBA	1996, 8, 189
		APNA 360 E	Horiba Europe, Leichlingen	UBA	1996, 28, 594
		AC 31 M	Environnement S.A. (Ansyco, Karlsruhe)	UBA	1996, 28, 594
		API Modell 200A (MLU 200A)	Advanced Pollution Instrumentation, San Diego (USA) (MLU, Essen)	RW TÜV	1996, 42, 884
		Modell TE 42 C	Thermo ESM Andersen, Erlangen	UBA	2003, 7, 139
	DOAS	AR 500 mit CB 100	Opsis, Furuland (Schweden)	TÜV Rheinland	2000, 22, 445
CARBON MONOXIDE	Conductometry	Ultragas U3 D-CO	H. Wösthoff, Bochum	RW TÜV	1990, 12, 243
		Ultragas U3 ED-CO	H. Wösthoff, Bochum	RW TÜV	1990, 12, 243
	Non-dispersive IR-Absorption	Ultramat 3*)	Siemens, Karlsruhe	RW TÜV	1985, 22, 455
		URAS 2 T*)	Hartmann & Braun, Frankfurt	RW TÜV	1985, 22, 456
		URAS 4 N*)	Maihak, Hamburg	RW TÜV	1990, 12, 243
		UNOR 5 N*)	Maihak, Hamburg	RW TÜV	1985, 22, 456
		APMA 300 E*)	Horiba Europe, Leichlingen	LfU B.-W.	1990, 12, 244
		APMA 350 E*)	Horiba Europe, Leichlingen	UBA	1991, 20, 526
		APMA 360 CE	Horiba Europe, Leichlingen	UBA	1996, 42, 884
	Gas-Filter-Correlation	Modell 48+)*)	Thermo ESM Andersen, Erlangen	UBA	1990, 12, 244
		CO 10 M*)	Environnement S.A. (Ansyco, Karlsruhe)	UBA	1990, 12, 244
		CO 11 M	Environnement S.A. (Ansyco, Karlsruhe)	UBA	1995, 33, 704
		ML 8830*)	Monitor Labs (Rohde & Schwarz, Köln)	RW TÜV	1991, 37, 1046
		ML 9830	Monitor Labs / Englewood, CO (USA) (Rohde & Schwarz, Köln)	RW TÜV	1995, 33, 704
		API Modell 300 (MLU 300)	Advanced Pollution Intrumentation, San Diego (USA) (MLU Essen)	RW TÜV	1996, 28, 594
SUM OF ORGANIC-GASES (WITHOUT METHANE)	Gas-Chromatography/ Flamme Ionisation	U 100*)	Siemens, Karlsruhe	UBA	1985, 22, 456
		APHA 300 E*)	Horiba Europe, Leichlingen	TÜV Rheinland	1990, 12, 244
		APHA 350 E*)	Horiba Europe, Leichlingen	TÜV Rheinland	1991, 20, 526
		APHA 360	Horiba Europe, Leichlingen	UBA	1998, 1, 10
BENZENE	Gas Chromatography	Umwelt-Gas-Chromatograph U 102 BTX***)	Siemens, Karlsruhe	UMEG	1995, 33, 704
		Airmo BTX 1000	Airmotec, Illnau (Schweiz) (Airmotec, Essen)	RW TÜV	1996, 28, 595
		CP-7001 BTX Monitor*)	Chrompack, Frankfurt	TÜV Bayern	1996, 28, 595
		GC 855 Serie 600	Umwelttechnik MCZ, Ober-Mörlen	UBA	1998, 20, 419
	DOAS	AR 502 mit FC 150	Opsis, Furuland (Schweden)	UBA	2001, 19, 388

Substance	Measurement Principle	Model	Manufacturer (Retailer)1)	Testing Institute2)	Announce-ment in the GMBl3)
MULTIPLE COMPONENT MEASURING DEVICE	Gas-Chromatography	airmo BTX 1000 für Toluol, Ethylbenzol, m-, p-Xylol und o-Xylol	Airmotec, Illnau (Schweiz) (Airmotec, Essen)	RW TÜV	1996, 28, 595
OZONE	UV Absorption	1008 AH*)	Dasibi (Bionics Instruments, Wuppertal)	LIS	1990, 12, 244 1992, 32, 796
		Modell 3100**)	Columbia Scientific Inc. Corp. (Bestobell Mobrey, Düsseldorf)	RW TÜV	1990, 12, 244
		APOA 300 E*)	Horiba Europe, Leichlingen	TÜV Rheinland	1990, 12, 244
		ML 8810*)	Monitor Labs, Englewood, CO (USA) (Rohde & Schwarz, Köln)	UBA	1990, 12, 244
		APOA 350 E*)	Horiba Europe, Leichlingen	TÜV Rheinland	1990, 34, 861
		Modell 49+)*)	Thermo ESM Andersen, Erlangen	UBA	1991, 37, 1046
		Modell 0_3 41 M	Environnement S.S. (Ansyco, Karlsruhe)	LIS	1993, 43, 865
		ML 9810	Monitor Labs, Englewood, CO (USA) (Rohde & Schwarz, Köln)	UMEG	1995, 7, 132
		ML 9811/12****)	Monitor Labs, Englewood, CO (USA) (Rohde & Schwarz, Köln)	UMEG	1995, 33, 704
		API Modell 400 (MLU 400)	Advanced Pollution Instrumentation, San Diego (USA) (MLU Messtechnik für Luft und Umwelt, Essen)	RW TÜV	1995, 33, 704
		APOA 360	Horiba Europe, Leichlingen	TÜV Rheinland	1996, 28, 595
		TE 49 C	Thermo ESM Andersen, Erlangen	RW TÜV	1999, 22, 448
	DOAS	AR 500 mit CB 100 und OC 500	Opsis, Furuland (Schweden)	TÜV Rheinland	1999, 22, 448
	Chemiluminescence	Modell 8002*)	UPM, Langgöns	UBA	1990, 12, 244
SOOT	Thermal CO_2-Method	rp 5400	Rupprecht & Patashnick, Albany, N.Y. (USA) (MLU Essen)	RW TÜV	1997, 29, 466
SUSPENDED PARTICULATE MATTER	Beta-Ray-Absorption	FH 62 I	Thermo ESM Andersen, Erlangen	LIS	1990, 12, 242
		FH 62 I (3 m^3/h)	Thermo ESM Andersen, Erlangen	LIS	1990, 12, 242
		F 703 *)-)	VEREWA, Mülheim (Ruhr)	BGA	1990, 12, 242
		FH 62 I-N	Thermo ESM Andersen, Erlangen	LIS	1992, 45, 1142
		FH 62-IR, PM 10 nach DIN EN 12341	Thermo ESM Andersen, Erlangen	TÜV Bayern TÜV Süddeutschland	1995, 33, 703 2000, 60, 1195
	Oscillating Microbalance	TEOM Modell 1400*)	Rupprecht & Patashnick, Albany, N.Y. (USA) (MLU, Essen)	RW TÜV	1992, 32, 796
		TEOM Modell 1400a	Rupprecht & Patashnick, Albany, N.Y. (USA) (MLU Essen)	RW TÜV	1995, 7, 132 1996, 8, 190

Substance	**Measurement Principle**	**Model**	**Manufacturer (Retailer)1)**	**Testing Institute2)**	**Announce-ment in the GMBl3)**
SUSPENDED PARTICULATE MATTER/PM10	Oscillating Microbalance	TEOM Modell 1400a Revision B	Rupprecht & Patashnick, Albany, N.Y. (USA) (MLU, Essen)	RW TÜV	1996, 42, 884 1999, 22, 448
PM 10	Beta-Ray-Absorption	SM 200	Opsis, Furuland (Schweden)	TÜV Rheinland	15.05.2003 4)

*) The device is no longer included in the production range of the manufacturer. The last retailer is named above

**) Manufacturer does not exist any more

***) Device not available at present

****) The device 9812 is supplied as 9810 with IZS-Model

-) For the following device F-701, a suitability test is prepared

+) The announcement of suitability was conferred upon the Phillips K 50206/00 (SO_2), K 50109/00 (CO) and K 50110/00 (O_3) which are structurally equal (GMBl 1992, 32, 796)

1) In some cases, the retailer changed after the suitability test. The current retailer is named above

2) BGA = Bundesgesundheitsamt, Institut für Wasser-, Boden- und Lufthygiene, Berlin;

LfU B.-W. = Landesanstalt für Umweltschutz Baden-Württemberg, Karlsruhe (now: UMEG);

LIS = Landesanstalt für Immissionsschutz (now: Landesumweltamt) des Landes Nordrhein-Westfalen, Essen;

RW TÜV = Rheinisch-Westfälischer Technischer Überwachungs-Verein, Essen;

TÜV Bayern, München;

TÜV Rheinland, Köln;

TÜV Süddeutschland, München

UBA = Umweltbundesamt, Pilotstation Frankfurt, Offenbach;

UMEG = Gesellschaft für Umweltmessungen und Umwelterhebungen, Karlsruhe

3) GMBl = Gemeinsames Ministerialblatt Jahr, No., pp

4) Change of Announcement: Bundesanzeiger 15.05.2003 Nr. 90 10742ff

Overview of the Suitability Tested Measuring Devices described in Appendix 3

	Substance								
Manufacturer/Retailer	**Sulphur dioxide**	**Nitrogen oxides**	**Carbon monoxide**	**Ozone**	**Hydrocarbons**	**Soot**	**Benzene**	**Organic Multicompounds**	**TSP / PM$_{10}$**
Airmotec							**BTX 1000**	**BTX 1000**	
Ansyco	**AF 21M**	**AC 31M**	**CO 11M**	**O$_3$ 41M**					
ECO Physics		**CLD 700 AL**							
HORIBA	**APSA-360**	**APNA-360**	**APMA-360**	**APOA-360**	**APHA-360**				
MCZ Umwelttechnik							**GC 855 Series 600**		
MLU	**MLU 100A**	**MLU 200A**	**MLU 300**	**MLU 400**		**rp 5400**			**TEOM 1400a**
MS4-Analysentechnik	**ML 9850**	**ML 9841**	**ML 9830**	**ML 9810** **ML 9811**					
Opsis	**AR 500**	**AR 500**		**AR 500**			**AR 502Z**		**SM 200**
Thermo ESM Andersen	**TE 43 C**	**TE 42 C**		**TE 49 C**					**FH 62-I-N** **FH 62-I-R**

Register of described devices

The following descriptions of suitability-tested ambient air quality measuring devices are normally based on details provided by the manufacturer or sales-agent, and on information, figures and sketches made available by them. Hence the descriptions differ slightly from each other. In some cases, and at any rate for the compilation of "Technical data", use was made of the test reports on the suitability test, which are elaborated ed by the testing institutes. Some results of the suitability tests refer to IW 1 and IW 2 values from TA Luft 86 /51/ (revised version TA Luft 02 /24/).

Devices no longer contained in the manufacturer´s range or seldom in use are not listed here. A new version is described even if the former model has been suitability-tested. Generally, it is assumed that new developments will substitute suitability tested older devices.

Airmotec GmbH

airmo BTX 1000 for Benzene and
airmo BTX 1000 for Toluene, Ethylbenzene, m, p-Xylene und o-Xylene 168

Ansyco GmbH

SO_2 Analyzer Model AF 21M 171
NO/NO_x Analyzer Model AC 31M 174
CO Analyzer Model CO 11M 177
Ozone Analyzer Model O_3 43M 180

ECO PHYSICS AG

NO/NO_2/Nox Analyzer CLD 700 AL 183

Horiba Europe GmbH

SO_2 Analyzer APSA-360 186
NO_x Analyzer APNA-360 188
CO Analyzer APMA-360 191
O_3 Analyzer APOA-360 194
HC Analyzer APHA-360 196

MCZ Umwelttechnik GmbH

Benzene Analyzer GC 855 199

Register of described devices (continued)

MLU Messtechnik für Luft und Umwelt GmbH

Model 100A SO_2 Analyzer 201

Model 200A $NO/NO_2/NO_x$ Analyzer 203

Model 300 CO Analyzer 206

Model 400 Ozone Analyzer 209

Ambient Particulate Monitor TEOM 1400a 212

Ambient Carbon Particulate Monitor Model rp 5400 214

MS4-Analysentechnik GmbH

SO_2 Analyzer ML 9850 216

$NO/NO_2/NO_x$ Analyzer ML 9841 219

CO Analyzer ML 9830 222

Ozone Analyzer ML 9810 225

Ozone Analyzer ML 9811 228

Opsis Umweltmesssysteme GmbH

Air Quality Monitoring System AR 500 230

Air Quality Monitoring System AR 502 Z 233

Ambient Particulate Monitor SM200 235

Thermo ESM Andersen

SO_2 Analyzer Modell TE 43C 237

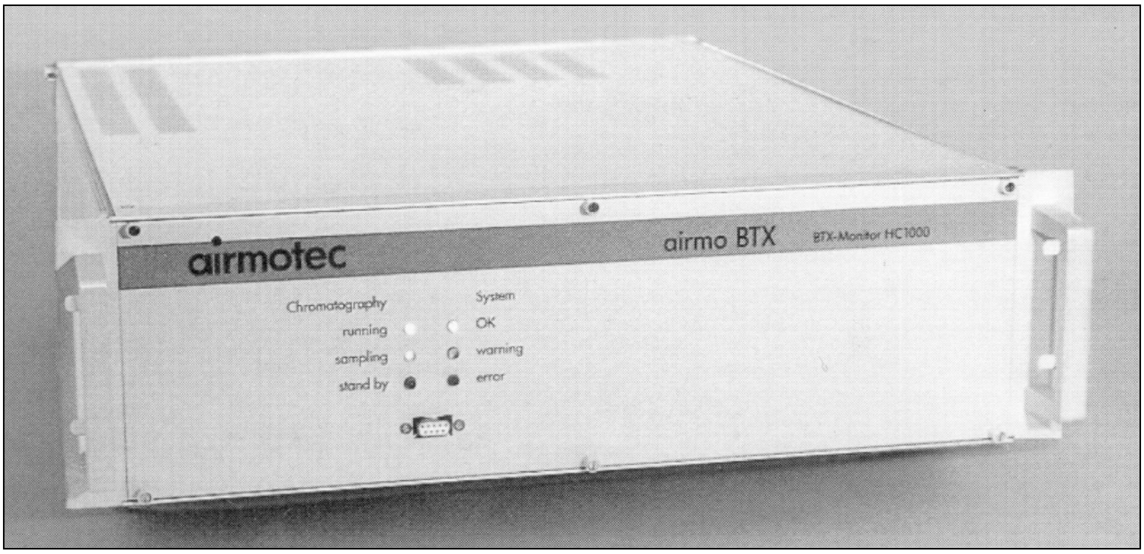
$NO/NO_2/NO_x$ Analyzer Modell TE 42C 239

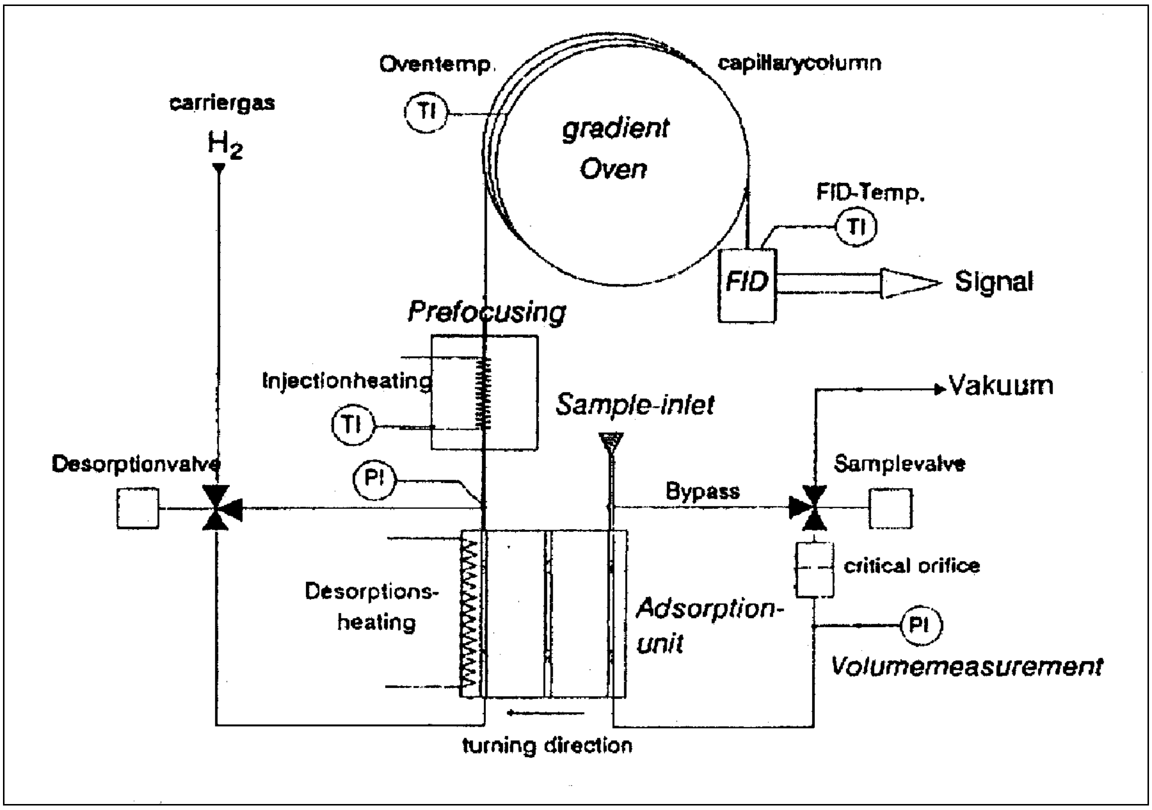
Ozone Analyzer Modell 49C 241

Particulate Monitoring Instrument 62 I-N 243

Particulate Monitoring Instrument 62 I-R 246

airmo BTX 1000 for Benzene
airmo BTX 1000 for Toluene, Ethylbenzene and o, m, p-Xylene





1. Field of Application

Automatic and continuous measurement of benzene and other volatile hydrocarbons (toluene, ethylbenzene, xylenes) in ambient air (and in indoor air).

The suitability of the device has been tested by Rheinisch-Westfälischer Technischer Überwachungs-Verein - Anlagentechnik GmbH, Essen, for the measurement of benzene, Report No. 3.5.1/1169/92 - 474267/02, 01.03.1996.

Suitability test for the measurement of toluene, ethylbenzene m-, p-xylene and o-xylene by RWTÜV, Essen, Report No. 3.5.1/1169/69 - 474267/01, 01.03.1996.

2. Set-up and Mode of Operation

The airmo BTX 1000 is a dedicated automated purge&trap capillary gas chromatograph for the specific analysis of BTX in ambient air. The gas sample is drawn through a revolving sampling drum with 3 adsorbent tubes. Since sampling and thermal desorption are executed simultaneously, close to 100% sampling time coverage is achieved. The desorbed and prefocused sample is injected into the fused silica capillary for separation. A controlled temperature gradient oven allows the precise separation of the analytes in a few minutes only. Detection is achieved by a flame ionization detector (FID). The identification of the compounds is based on their retention time of elution from the capillary.

The unique feature of the airmo BTX 1000 is the fully automatic, unattended execution of quantitative VOC-analysis of high quality, as a stationary monitor or as a mobile unit.

3. Technical Data

3.1 Results of Suitability Test

Calibration function	linear
Lower detection limit	< 0.16 µg/m^3 (1) 0.58 µg/m^3 (2)
Rating	300 µg/m^3 Benzene 300 µg/m^3 Toluene 250 µg/m^3 m ,p-Xylene 420 µg/m^3 Ethylbenzene 130 µg/m^3 o-Xylene
Reproducibility	> 19.4 (1) > 18.7 (2)
Temperature dependence Of the zero point (ambient temperature)	< - 1.2% (1) < + 1.285% (2)
Temperature dependence of the sensitivity (ambient temperature)	< -3.365% (1) < - 3.485% (2)
Drift of the zero point	0%
Drift of the sensitivity	
within 24h	< 0.41% (1) < 0.51% (2)
within 14 d	< 5.8% (1) < 7.1 % (2)
Voltage dependence of the measured signal 220-245V	< +1.36% (1) < - 1.97% (2)
Availability	> 99%
Warm-up-time	<< 15 min
Useful life of all consumables	> 6 weeks
Life of all replaceable parts	> 6 month
Interference error (Response to stated levels of interfering substances present in the samples. Test gas mixtures of O_3, H_2O, CCl_4, C_2HCl and 8 hydrocarbons(1))	max. –8.02%

(1) Benzene
(2) Toluene, Ethylbenzene, o-, m- und p-Xylene

3.2 Further Technical Data

Space requirements	19“, 3 HU
Weight	18 kg
Power supply	230V / 50-60Hz 130VA
Signal output	0...1V analog (FID signal) RS 232
Mean power requirement	130VA

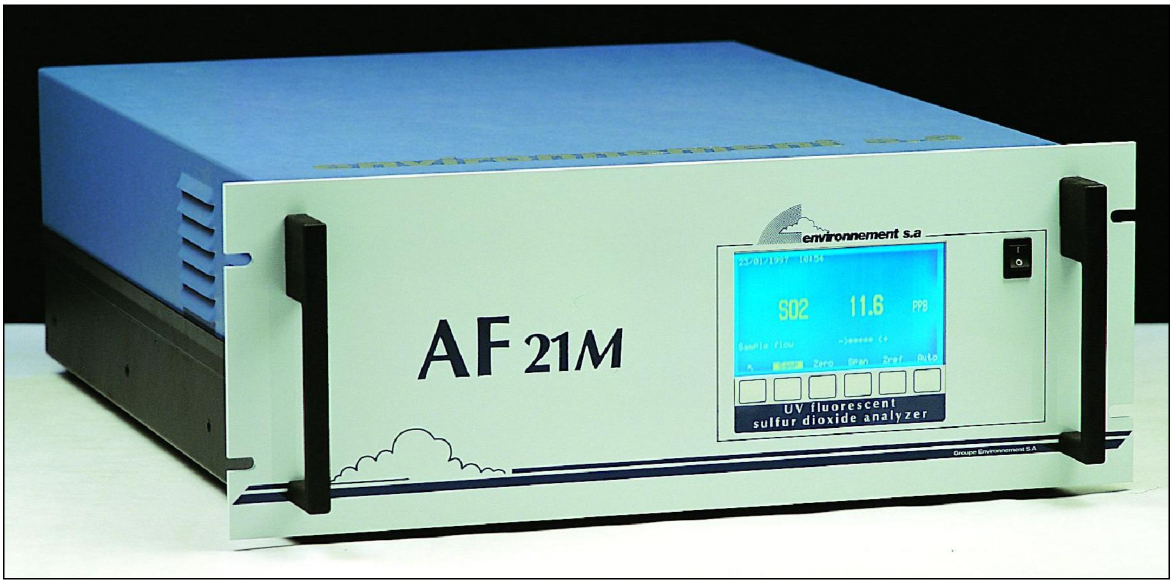
Manufacturer Airmotec, Illnau
(Switzerland)

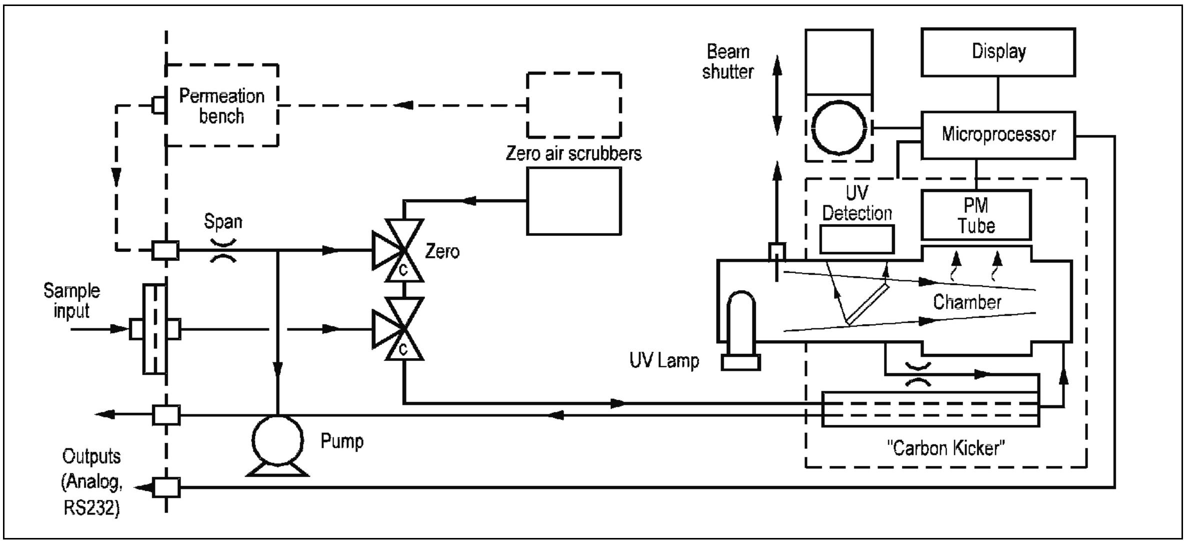
Agency
in Germany
Airmotec GmbH
Kurfürstenstraße 19
D-45138 Essen

Phone +49 201 280 280
Fax +49 201 280 2899
Email
airmotec-gmbh@t-online.de
Internet www.airmotec.com

ansyco
analytische Systeme und
Componenten GmbH

SO_2 Analyzer Model AF 21M





1. Field of Application

Automatic and continuous measurement of sulphur dioxide in ambient air.

The suitability of the device has benn tested by Umweltbundesamt, Pilotstation Frankfurt, Offenbach, Test report No. 16, August 1992.

A converter unit enables the continuous measurement of hydrogen sulphide, oxidizing H_2S to SO_2 before analyzing.

2. Set-up and Mode of Operation

The gas sample, continuously collected by a pump placed at the end of the circuit, passes through a teflon particulate filter and is introduced into an optical chamber, which is subjected to a UV beam at a given wavelength (zinc ray lamp with a life time of more than 2 years, stabilized HF power-supply, and continuous detection of any possible energy fluctuation).

A high sensitivity PM tube detects fluorescent energy, the signal is then processed by the microprocessor and the SO_2 value is displayed in ppm or µg/m^3.

The measurement cannot be affected by interference from water vapour or hydrocarbons because of the selection of the UV wavelength and the use of an aromatic hydrocarbon filter "type permeation kicker".

Zero control (manual or automatic by programming) is carried out by internal zero filter, and calibration control can be carried out automatically using an optional new permeation bench (high performance electronic temperature regulation).

This instrument has been designed keeping in mind total accessibility of the different modules and simple and rapid disassembly (a few minutes).

The user is provided with a real aid to maintenance through the microprocessor with keyboard and alphanumeric display (control of all parameters, possible variations compared to original values, test programs, drawing of one of the parameters, remote control...).

The processor electronics provides output of instantaneous data and average values (internal Datalogger for up to 10.000 average values).

3. Technical Data

3.1 Results of Suitability Test

Calibration function	linear
Lower detection limit	≤ 11.5 µg/m^3
Range	0 - 1144 µg/m^3
Reproducibility (R)	143 µg/m^3: 21 429 µg/m^3: 52 858 µg/m^3: 80
Temperature dependence of the zero point (ambient temperature)	5°C - 40°C: ≤ 2%
Temperature dependence of the sensitivity (ambient temperature)	5°C - 40°C: ≤ 2%
Drift of the zero point	
within 24 h	≤ 2% (mostly)
within period of unattended operation	≤ 10%
Drift of the sensitivity	
within 24 h	≤ 2%
within period of unattended operation	≤ 10
Voltage dependence of the measured signal	no dependence
Availability	> 95%
Calibration time	≤ 2%
Preparation time	approx. 1 h
Response time	≤ 120 s
Calibration time	≤ 2% of the measuring time
Period of unattended operation	approx. 4 months
Interference error; Response to stated levels of interfering substances present in the sample CO_2, CO, H_2S, NH_3, CH_4, C_6H_6, C_2H_4, NO, NO_2, H_2O	≤ 2% per substance H_2O: ≤ 3.5% (80% r.h.)

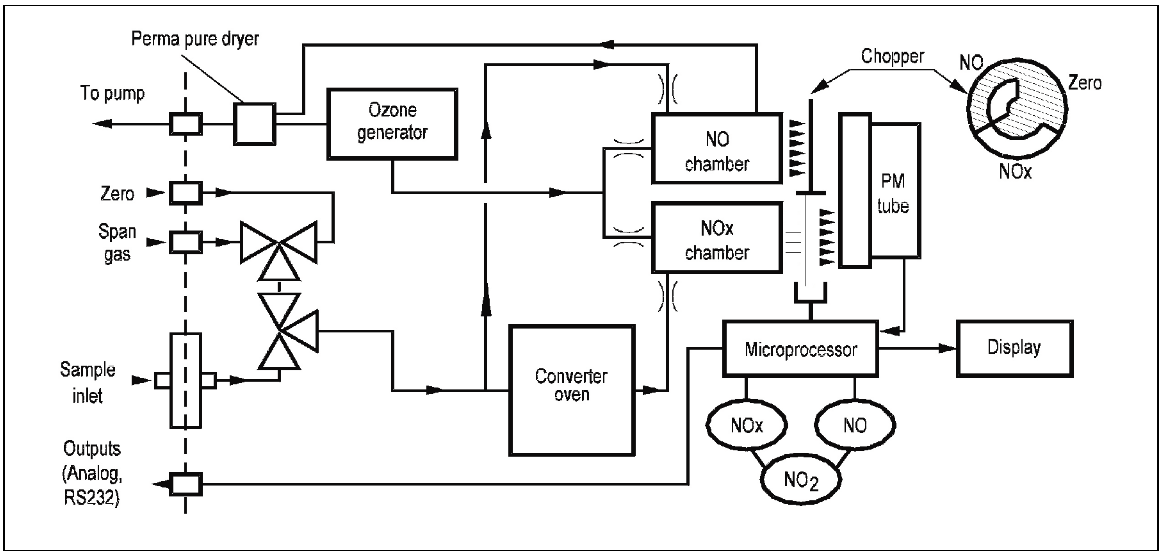
3.2 Further Technical Data

Space requirements	19“, 4 HU, 650 mm depth
Weight	approx. 15 kg
Power supply	220V / 50Hz, approx. 70VA
Signal output	0 – 1…10V or 0 – 4…20mA RS232/RS422 (Bayern-Hessen-Protocol))

Manufacturer	Environnement s.a., France
Agency in Germany	Ansyco GmbH Ostring 4 D-76351 Karlsruhe

Phone	+49 721 626560
Fax	+49 721 621332
E-Mail	info@ansynco.de
Internet	www.ansyco.de

NO/NOx Analyzer Model AC 31M



1. Field of Application

Automatic and continuous measurement of nitrogen oxides in ambient air.

The suitability of the device has been tested by Umweltbundesamt, Pilotstation Frankfurt, Offenbach, Testbericht (Test report) No. 23, March 1996.

The instrument is a further development of the Model AC 30 M, the suitability of which was also successfully tested.

A converter unit enables the continuous measurement of ammonia, oxidizing NH_3 to NO before analyzing.

2. Set-up and Mode of Operation

Continuous measurement of NO and NO_x by chemiluminescence - measurement of NO by detection of the light emitted when NO is oxidized to activated NO_2 in the presence of ozone produced from ambient air:

$$NO + O_3 \rightarrow NO_2 + O_2 + h\nu.$$

Measurement of NO_x by previously passing the sample gas through a molybdenum $NO_2 \rightarrow NO$ converter. The performance of this converter oven has been improved: efficiency, lifetime of more than 2 years at 100 ppb, temperature regulation,...

Elimination of any interference from ammonia and hydrocarbons.

Modular design with thermoregulated dust-tight optical block composed of two heated chambers, viewed by a single colled highly sensitive photomultiplier (PM) tube.

Permanent electrical zero carried out by the microprocessor and span control with integrated electrovalve for calibration with bottles of span gas. An optical remote controlled bench, for control of span by permeation (large capacity NO_2 tube) can be incorporated into the analyzer. Automatic change of range during the calibration procedure.

The processor electronics provides output of instantaneous data and average values (internal Datalogger for up to 10.000 average values).

3. Technical Data

3.1 Results of Suitability Test

Calibration function	linear
Lower detection limit	NO, NO_x : $< 8\ \mu g/m^3$ NO_2 : $3.7\ \mu g/m^3$
Range	0 - 1340 resp. 2040 $\mu g/m^3$
Reproducibility	NO 26 - 57 NO_x 69 - 90 NO_2 34.7 - 355
Temperature dependence of the zero point (ambient temperature)	5 - 40°C: ≤ 0.5%
Temperature dependence of the sensitivity (ambient temperature)	0 - 30°C: ≤ 2% > 30°C : > 2%
Drift of the zero point	
within 24 h	≤ ±2%
within period of unattended operation	≤ ±10%
Drift of the sensitivity	
within 24 h	≤ ±2%
within period of unattended operation	≤ ±10%
Voltage dependence of the measured signal	no dependence
Availability	100%
Preparation time + Warm-up time	approx. 1 h
Response time	< 70 s
Period of unattended operation	approx. 1 month
Interference error; Response to stated levels of interfering substances present in the sample CO_2, SO_2, H_2S, NH_3, CO, CH_4, C_2H_4, C_6H_6 H_2O	NO : ≤ 0.1% per substance NO_x : ≤ 1% sum of substances NO_2 : H_2O ≤ 1% (85% r.h.)

3.2 Further Technical Data

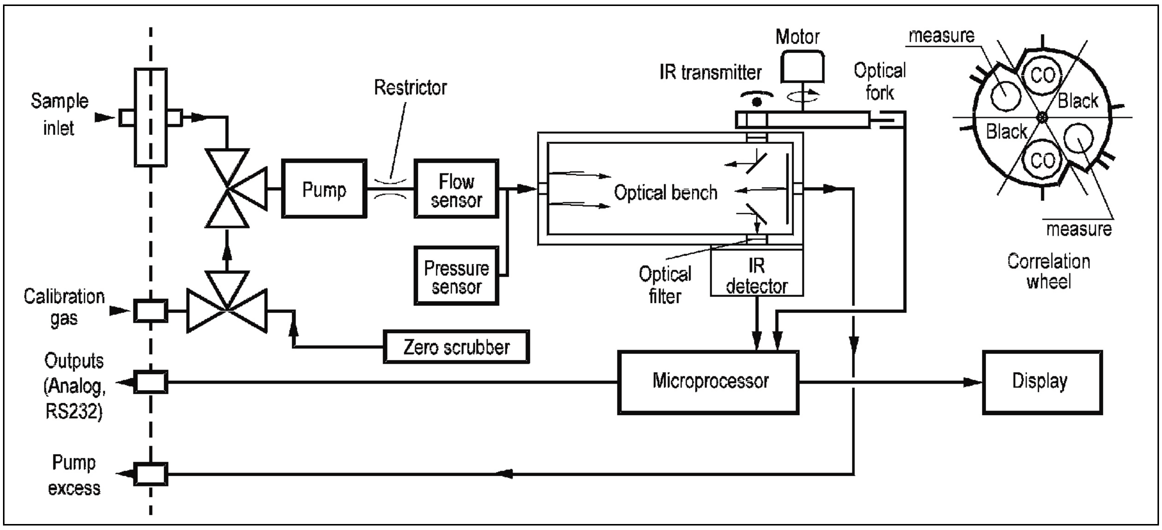
Space requirements	19", 4 HU, 650 mm depth
Weight	approx. 25 kg
Power supply	220V / 50Hz, approx. 300VA (heating phase), 150VA (steady load)
Signal output	0 – 1…10V or 0 – 4…20mA RS232/RS422 (Bayern/Hessen-Protocol)

Manufacturer	Environnement s.a., France
Agency in Germany	Ansyco GmbH Ostring 4 D-76351 Karlsruhe

Phone	+49 721 626560
Fax	+49 721 621332
E-Mail	info@ansynco.de
Internet	www.ansyco.de

ansyco
analytische Systeme und
Componenten GmbH

CO Analyzer Model CO 11M



1. Field of Application

Automatic and continuous measurement of carbon monoxide in ambient air.

The suitability of the device has been tested by Umweltbundesamt, Pilotstation Frankfurt, Offenbach, Testbericht (test report) No.20, March 1986.

The instrument is a further development of the Model CO 10 M, the suitability of which was also successfully tested.

2. Set-up and Mode of Operation

The principle of measurement is the selective absorption in the infra-red associated with gas filter correlation. The measurement carried out is specific.

The gas sample - drawn by an internal pump placed at the head of the fluid circuit - passes through a teflon dust filter and is introduced into a measurement chamber with a long optical path (5.60 m) (multireflexion chamber).

The beam emitted by the infra-red source alternately passes through the cell of the correlation wheel filled with CO and the empty cell, then through the measurement chamber and an interferential optical filter placed in front of the detector (semi-conductor).

When the infra-red beam passes through the CO cell, all the lines specific to CO are absorbed. The beam which cannot be affected by additional absorption by CO contained in the sample, then serves as a reference.

On the other hand, when the infrared beam passes through the empty cell and therefore remains unchanged, the lines specific to CO are only partially absorbed in the measurement chamber according to the CO content of the sample.

The highly sensitive infrared detector measures the energy levels, and the microprocessor differentially calculates the concentration of CO in ppm or mg/m^3 according to Beer Lambert's Law.

If interfering gases are present in the sample, in both cases, the infrared absorptions will be identical and will cancel each other out.

Zero check (manual or automatic as programmed) is carried out on an internal zero filter; span check is carried out on an external span gas inlet (CO bottle).

The processor electronics provides output of instantaneous data and average values (internal Datalogger for up to 10.000 average values).

3. Technical Data

3.1 Results of Suitability Test

Calibration function	linear
Lower detection limit	≤ 0.032 mg/m^3
Range	0 - 120 mg/m^3
Reproducibility (R)	IW 1 : 19.2 IW 2 : 57.9 2 · IW 2 : 119.1
Temperature dependence of the zero point (ambient temperature)	5 - 40°C : ≤ 2%
Temperature dependence of the sensitivity (ambient temperature)	5 - 35°C : ≤ 2% 35 - 40°C : ≤ 3%
Drift of the zero point	
within 24 h	≤ 2%
within period of unattended operation	≤ 10%
Drift of the sensitivity	
within 24 h	≤ 2%
within period of unattended operation	≤ 10%
Voltage dependence of the measured signal	no dependence
Availability	> 95%
Preparation time	approx. 1 h
Response time	≤ 70 s
Calibration time	< 2% of the measuring time
Period of unattended operation	approx. 1 month
Interference error; Response to stated levels of interfering substances present in the sample CO_2, SO_2, H_2S, NH_3, NO_2, NO, CH_4, C_2H_4, C_6H_6, H_2S	≤ 2% per substance

3.2 Further Technical Data

Space requirements	19", 4 HU, 650 mm depth
Weight	approx. 18 kg
Power supply	220V / 50Hz, approx. 90VA (mean steady load)
Signal output	0 – 1…10V or 0 – 4…20mA RS232/RS422 (Bayern-Hessen-Protocol)

Manufacturer	Environnement s.a., France
Agency in Germany	Ansyco GmbH Ostring 4 D-76351 Karlsruhe

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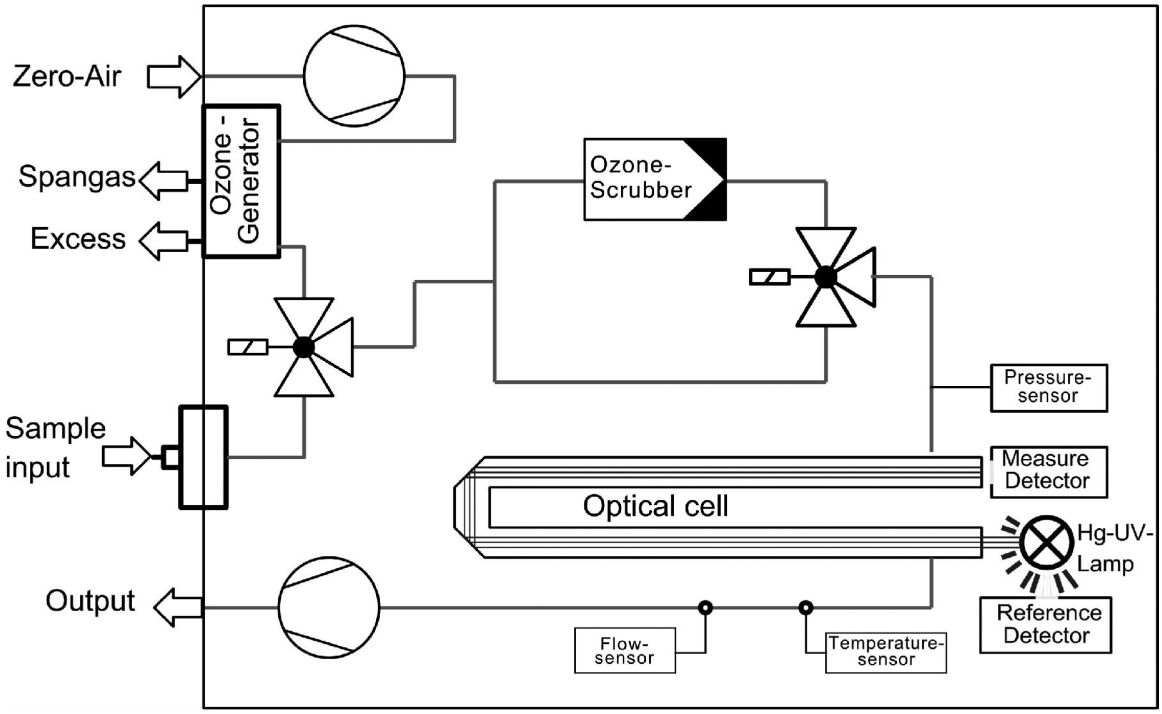
ansyco
analytische Systeme und
Componenten GmbH

Ozone Analyzer Model O_3 41M



1. Field of Application

Automatic and continuous measurement of ozone in atmospheric air.

The suitability of the device has been tested by Landesanstalt für Immissionsschutz (today: Landesumweltamt) des Landes Nordrhein-Westfalen, Essen, LIS Report 111/1993.

2. Set-up and Mode of Operation

The air sample, taken continuously by a pump placed at the end of the circuit, passes first through a teflon dust filter, then flows to the optical chamber either directly or through an ozone selective filter (commutation every 5 seconds).

In the optical chamber, where ozone molecules selectively absorb 253.7 nm UV radiation, ozone concentration measurement is carried out by difference between UV absorption due to the gas sample and UV absorption due to the ozone free sample. Therefore, any interference from dust or any other gas is eliminated aside.

The signal is treated numerically and the microprocessor also monitors the flow rate, the automatic compensation for temperature and altitude, and the continuous compensation of UV energy as well as all operating parameters.

Especially designed for the user (data transmission, remote test...), the analyzer also offers extremely simplified maintenance.

As an option, an internal ozone generator joined to an independent pump, allows:

- Execution of a proper functioning check directly on the analyzer. This control can be manual or automatically managed by a built-in real time clock or by remote control at the frequency programmed by the user.
- Use of the instrument as a transfer standard to check and calibrate an ozone analyzer, the generator supplies at the same time the analyzer being checked and the instrument which displays the concentration of ozone generated.

The processor electronics provides output of instantaneous data and average values (internal Datalogger for up to 10.000 average values).

3. Technical Data

3.1 Results of Suitability Test

Calibration function	x = by + a
Lower detection limit	1 ppb
Range	0 – 200 ppb
Reproducibility (R)	48
Temperature dependence of the zero point (ambient temperature)	0.4%
Temperature dependence of the sensitivity (ambient temperature)	1%
Drift of the zero point	
within 24 h	< 0.1%
within period of unattended operation	0.2%
Drift of the sensitivity	
within 24 h	0.1%
within period of unattended operation	1.5%
Voltage dependence of the measured signal	0.4%
Availability	≤ 80%
Response time	≤ 180 s
Period of unattended operation	30 d
Interference error; Response to stated levels of interfering substances present in the sample SO_2, CO_2, CO, NO, NO_2, Benzene, H_2O, NH_3, H_2S, Ethene, iso-Butene, Methane, Ethane	< 6%

3.2 Further Technical Data

Space requirements	19", 4 HU, 650 mm depth
Weight	approx. 15 kg
Power supply	220V / 50Hz, approx. 50VA
Signal output	0 – 1…10V or 0 – 4…20mA RS232/RS422 (Bayern-Hessen-Protocol))

Manufacturerer Environnement s.a.,
France

Agency
in Germany
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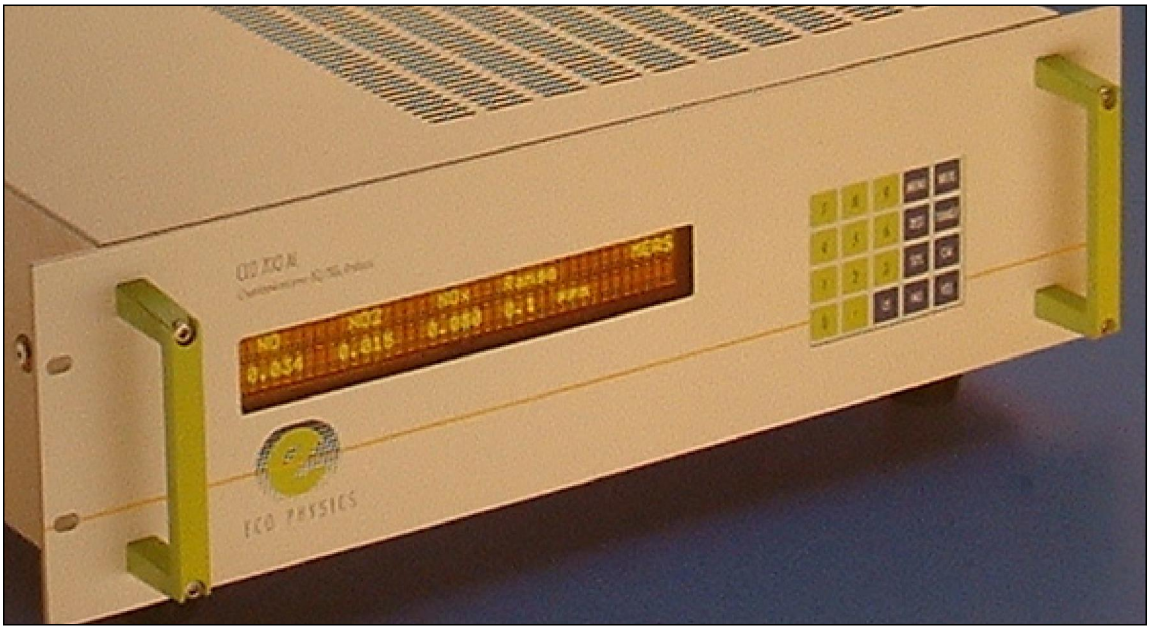
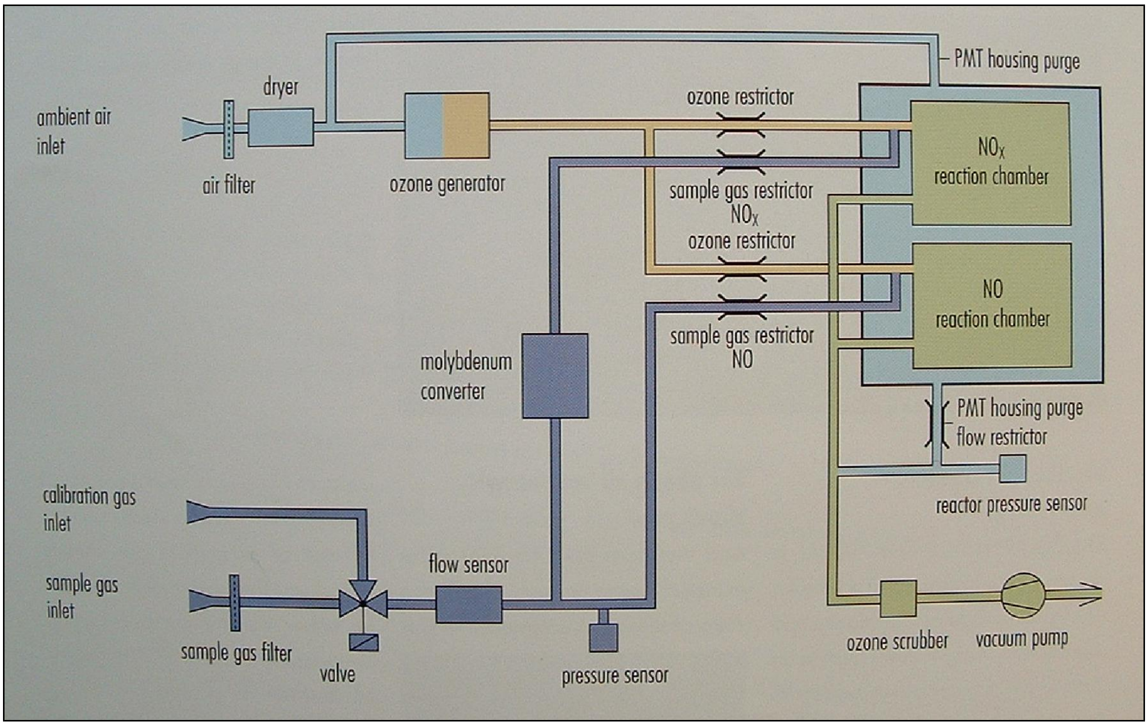
NO/NO$_2$/NO$_x$ Analyzer CLD 700 AL



Flow Diagram CLD 700 AL



1. Field of Application

Simultaneous automatic, continuous monitoring of NO, NO_2, and NO_x in ambient air.

The suitability of the device has been tested by Gesellschaft für Umweltmessungen und Umwelterhebungen mbH, Karlsruhe, UMEG-Bericht (Report) No.33-19/91, August 1991.

Supplementary test; UMEG - Bericht No. 33-07/96, August 1996.

2. Set-up and Mode of Operation

Model CLD 700 AL is a two-channel chemiluminescence measuring device featuring a photomultiplier (see figure). The measurement principle is based on the chemiluminescence reaction of nitrogen monoxide and ozone. Providing the availability of a constant and abundant amount of ozone, chemiluminescence radiation will be proportional to the NO concentration contained in the sample air. In a molybdenum converter (working temperature 325°C) situated in front of the second reaction chamber, any nitrogen dioxide present in the sample is reduced to nitrogen monoxide and also measured as NO. The amount of NO_2 in ambient air is determined in a subtraction calculation.

The reaction light of the two reaction chambers, held at a constant temperature of 55°C, is separated by a diversion mirror operated by a stepper motor.

Ozone is generated by a principle of a so-called still electric current. For this, dry ambient air is led via a dry cartridge (filled with silicagel) through a dust filter and through an electric AC field. In an ionisation reaction, oxygen contained in the air is converted into ozone.

The dependence of the measuring signal on the mass flow in the reaction chamber is minimized by keeping the flow constant. This is achieved by employing high-grade steel capillaries in both the ozone and sample gas flow lines, and integrating a vacuum pump generating up to 40 mbar below atmospheric pressure.

A small part flow of dry air is used to clean the case of the photomultiplier.

The pressure in the reaction chamber and the initial pressure of the sample gas on entering the system are measured and taken into account for correction of the measuring signal and for the monitoring of the device.

A thermic ozone destructor is situated at the vent of the vacuum membrane pump. A thermal exchanger cools down the waste gas to pump temperature. The temperature is monitored and the pump will only start working after the ozone destructor has reached a working temperature of 700°C.

The supplementary (1996) tested device differs from the 1991 tested model in the following modifications:

- substitution of the capillaries for keeping the volume flows constant for critical orifices;
- substitution of the former dry cartridge to dry the supply air of the ozone generator for a permeation dryer;
- smaller and therefore a changed structure of the assembly groups in the analyzer;
- changed software with compensation of the influence of ambient air.

3. Technical Data

3.1 Results of Suitability Test

Calibration function	linear
Lower detection limit (2 devices)	NO 0.55 / 0.49 ppm NO_x 0.63 / 0.74 ppm
Range	0 - 1000 ppb (at the test)

Reproducibility (R)

ppb	NO	NO_x
58.3	81	31
290.2	26	20
436.9	16	27
861.1	13	11

Temperature dependence of the zero point (ambient temperature)	NO max. 0.1% NO_x max. 0.7% (at 30 / 40°C: -4.8%)
Temperature dependence of the sensitivity (ambient temperature)	NO max. 5.3% NO_x max. 5.0%
Drift of the zero point	
within 24 h	0%
within period of unattended operation	max. 0.2%
Drift of the sensitivity	
within 24 h	max. 0.4%
within period of unattended operation	max. 5.6%
Voltage dependence of the measured signal	no influence
Availability	> 99%
Preparation time	0.5 h
Warm-up time	approx. 2 h

Response time	60 s
Period of unattended operation	14 d

Interference error;
Response to stated levels of interfering substances present in the sample (at 428 ppb)

		NO	**NO_x**
SO_2, SF_6, CO, CO_2, CH_4, Ethene, Propane		0	0
H_2S	1 ppm	2.8%	0
Benzene	0.1 ppb	2.4%	2.4%
NH_3	5 ppb	max. 1.6%	max. 1.9%
H_2O	50%	-2.9%	-2.4%
H_2O	93%	-6.2%	-5.1%

3.2 Further Technical Data

Space requirements	w x h x d 482 x 133 x 546 mm
Weight	34 kg
Power supply	220V / 50Hz, 110V / 60Hz (±10%)
Signal output	selectable 1V / 10V, 20mA RS 232

Manufacturer

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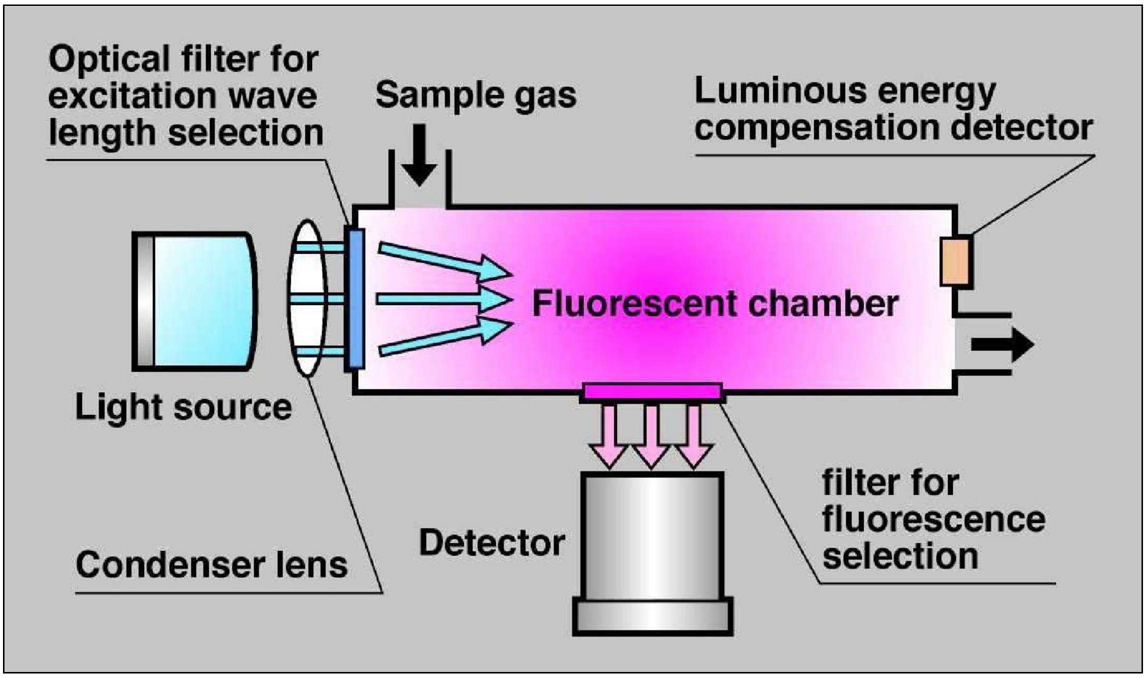
HORIBA

SO_2 Analyzer, HORIBA Model APSA-360

Flow-Diagram:
UV Fluorescence



1. Field of Application

Continuous and automatic monitoring of sulphur dioxide in ambient air.

The suitability of the device has been tested by Technischer Überwachungs-Verein (TÜV) Rheinland, Institut für Umweltschutz und Energietechnik, Köln, TÜV Report 936/805008/SO_2, 29.02.1996.

The Monitor is a further development of the Model APSA-350 E, the suitability of which was also successfully tested.

2. Set-up and Mode of Operation

The monitor APSA-360 uses the UV fluorescence measurement. This method operates on the principle that when the SO_2 molecules contained in the sample gas are exited by ultraviolet radiation they emit a characteristic fluorescence in the range of 220-240 nm. This fluorescence is measured and the SO_2 concentration is obtained from changes in the intensity of the fluorescence.

The APSA-360 uses a Xe lamp as light source, and the fluorescent chamber design minimizes scattered light. The optical system has been carefully designed with low background, making it possible to take measurements with a highly stable zero-point. In addition, a reference detector monitors any fluctuation in the intensity of the light source. This allows the unit to calibrate itself automatically for sensitivity, resulting in greater span stability.

The monitor has a built-in aromatic hydrocarbon cutter with a selective transmission membrane.

3. Technical Data

3.1 Results of Suitability Test

Calibration function	linear
Lower detection limit	1.7 ppb
Range in the suitability test	0 – 100 ppb (0 – 286 µg/m³) 0 – 500 ppb (0 – 1430 µg/m³)
Reproducibility (R)	Laboratory : 271 Field : 70
Temperature dependence of the zero point (ambient temperature) 5 - 40°C	max. ±0.2%
Temperature dependence of the sensitivity (ambient temperature) 5 - 40°C	max. -0.2%
Drift of the zero point	
within 24 h	0.00%
within period of unattended operation	0.02%
Drift of the sensitivity	
within 24 h	0.00%
within period of unattended operation	-0.06%
Voltage dependence of the measured signal	no dependence
Availability	99%
Preparation time	approx. 15 min
Response time	130 s
Warm-up time	approx. 60 min
Calibration time	< 5% of measuring time
Period of unattended operation	3 weeks
Interference error; response to stated levels of interfering substances present in the sample CH_4, C_2H_4, C_6H_6, CO, CO_2, H_2S, O_3, NO, NO_2, N_2O, NH_3, H_2O	< 8.4 ppb (< 6% of ambient air quality limit value IW 2)

3.2 Further Technical Data

Space requirements	w x h x d 430 x 221 x 550 mm
Weight	approx. 20 kg
Power supply	220V AC, 50Hz, approx. 120VA
Signal output	RS 232 C or 0 - 1V, 0 - 10V and 4 - 20mA DC

Manufacturer (resp. Agency in Germany)	Horiba Europe GmbH Julius-Kronenberg-Str. 9 D-42799 Leichlingen
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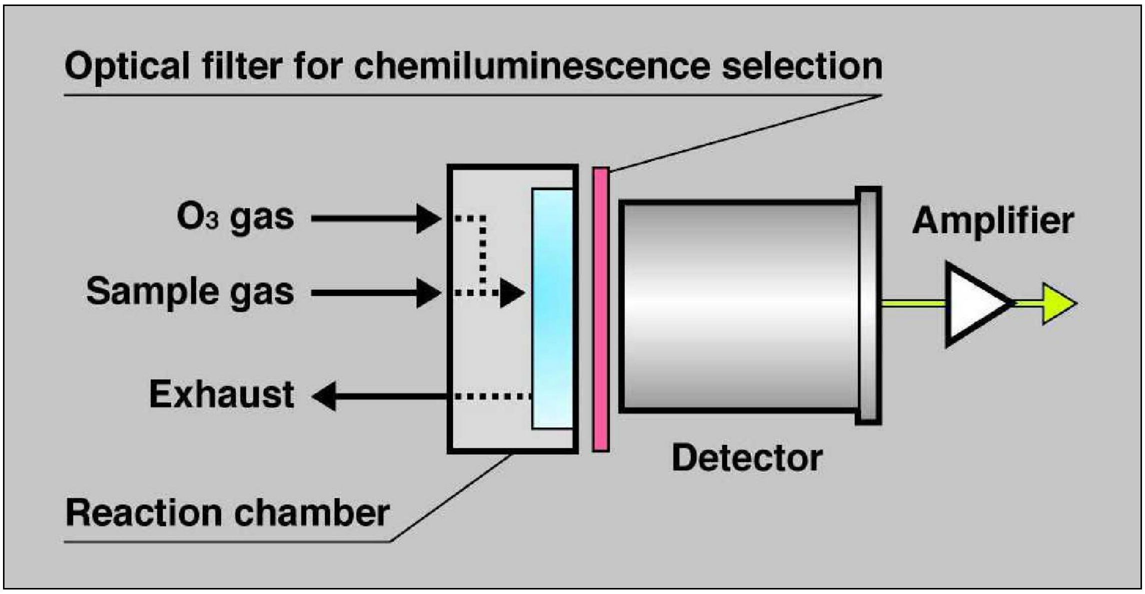
HORIBA

NO/NO_2/NO_x Analyzer, HORIBA Model APNA-360

Flow Diagram:
Chemiluminescence



1. Field of Application

Continuous and automatic measurement of nitrogen oxides in ambient air.

The suitability of the device has been tested by Umweltbundesamt, Pilotstation Frankfurt, Offenbach, Testbericht (Test report) No. 24, March 1996.

The monitor is a further development of the Model APNA-350 E, the suitability of which was also successfully tested.

A converter unit enables the continuous measurement of ammonia, oxidizing NH_3 to NO before monitoring.

2. Set-up and Mode of Operation

The monitor APNA-360 uses a combination of the dual cross flow modulation type chemiluminescence principle and the referencial calculation method.

Standard equipment includes a drier unit with an automatic recycle function to provide dry ambient air as the ozone source. This makes long-run continuous measurements possible.

The detector uses a semiconductor sensor for compactness and long working life.

All the necessary features are built right into a single rack-sized unit, including a reference-gas generator, an ozone-source drier unit, an ozone decomposer, and a sampling pump. No supplemental gas is required.

The chemiluminescence method uses the reaction of NO with O_3

$$\begin{aligned} NO + O_3 &\rightarrow NO_2 + O_2 \\ NO + O_3 &\rightarrow NO_2^* + O_2 \\ NO_2^* &\rightarrow NO_2 + h\nu \end{aligned}$$

A portion of the NO_2 generated as the result of this reaction becomes NO_2^*. As these excited molecules return to the ground state, chemiluminescence is generated in the range of 600 nm - 3,000 nm. The light intensity is in proportion to the concentration of NO molecules and by measuring it we obtain the NO concentration of the sample. A deoxidation converter changes the NO_2 to NO, which is measured. In other words, the NO_2 concentration can be obtained by the difference between the NO_x concentration measured when the sample gas is directed through a converter and the NO concentration measured when the gas is not run through the converter.

3. Technical Data

3.1 Results of Suitability Test

Calibration function	linear
Lower detection limit	NO, NOx : < 3 μg/m^3 NO_2 : < 2.6μg/m^3
Range at suitability test	NO : 0 - 1340 μg/m^3 (1000 ppb) NO_2 : 0 - 2050 μg/m^3 (1000 ppb)

Reproducibility (R)

NO	NO_x	NO_2
53 - 55	125 - 138	47 - 281
(depending on concentration)		

Temperature dependence of the zero point (ambient temperature) 5 - 40°C	≤ 1%
Temperature dependence of the sensitivity (ambient temperature) 5 - 40°C	≤ 2%
Drift of the zero point	
within 24 h	≤ ±2%
within period of unattended operation	≤ ±10%
Drift of the sensitivity	
within 24 h	≤ ±2%
within period of unattended operation	≤ ±10%
Voltage dependence of the measured signal 200 - 240V	no dependence
Availability	> 95%
Preparation time and warm-up time	approx. 1 h
Response time	≤ 70 s
Calibration time	≤ 2% of measuring time
Period of unattended operation	approx. 1 month
Interference error; response to stated levels of interfering substances present in the sample	Only short-test. Reference to tested Model APNA 350 E

3.2 Further Technical Data

Space requirements	w x h x d 430 x 221 x 550 mm
Weight	approx. 30 kg
Power supply	220V AC, 50Hz, approx. 300VA
Signal output	RS 232 C or 0 - 1V, 0 - 10V and 4 - 20mA DC

Manufacturer (resp. Agency in Germany)

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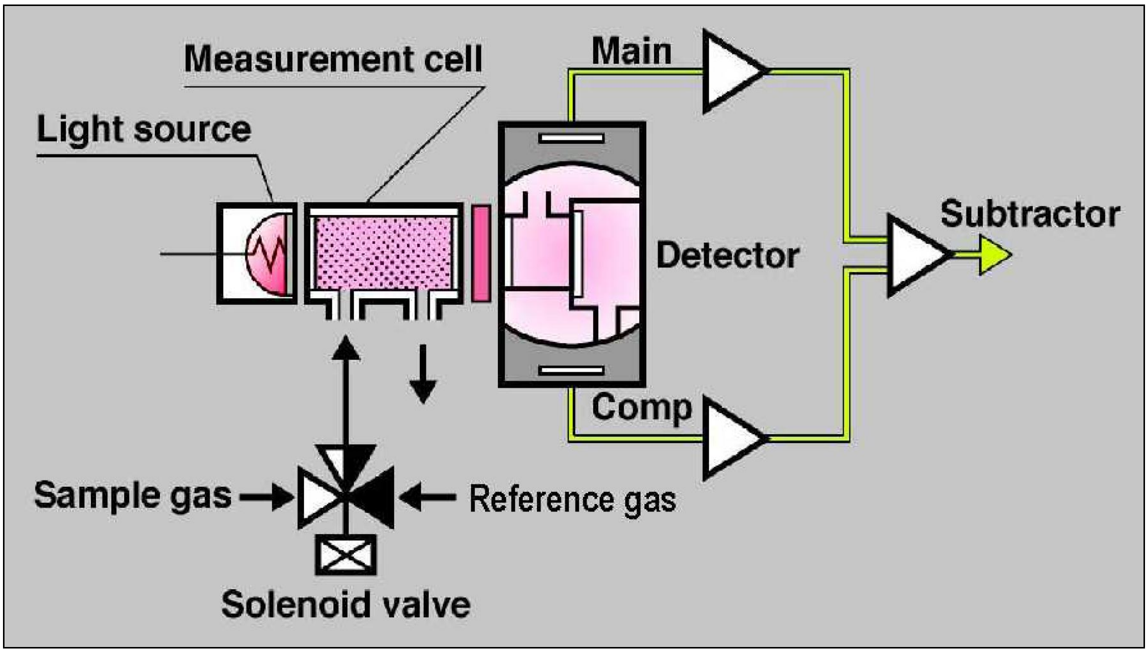
HORIBA

CO Analyzer, HORIBA Model APMA-360

Flow Diagram: NDIR
patented cross flow modulation



1. Field of Application

Continuous and automatic monitoring of carbon monoxide in ambient air.

The suitability of the device has been tested by Umweltbundesamt, Pilotstation Frankfurt, Offenbach, Testbericht (Test report) No. 22/96, August 1996.

The monitor is a further development of the Model APMA 350 E, the suitability of which was also successfully tested.

2. Set-up and Mode of Operation

The principle of the Monitor is: Cross flow modulation, non-dispersive infrared absorption technology (NDIR).

The APMA-360 uses a solenoid valve modulation. Fixed amounts of the sample gas and the reference gas are injected alternately into the measurement cell. With the cross flow-modulation method, if the same gas is used for both the sample gas and the reference gas (e.g., zero gas could be used for both), no modulation signal will be generated. This has the great advantage that, in principle, when analyzing minute amounts of gas there is no generation of zero-drift. An additional advantage is that the elimination of rotary sectors precludes the need for optical adjustment. These features assure greatly improved stability over long periods of measurement. A further improvement is that in the front chamber of the detector, the measurable components, including interference components, are detected; in the rear chamber, interference components only are detected. By means of subtraction processing, the actual signal obtained is one that has only very little interference influence.

The APM-360 uses an AS-type interference-compensating detector, and a flowing reference gas. The reference gas is generated by purging sample through an oxidation process, where an oxidizing catalyst burns the CO to CO_2. These features eliminate the interference effect of other elements, resulting in extremely high accurate measurements.

3. Technical Data

3.1 Results of Suitability Test

Calibration function	linear
Lower detection limit	≤ 0.15 mg/m^3
Range	0 - 62 mg/m^3 (50 ppm)
Reproducibility (R)	

IW1	IW2	2 · IW2
116.8	324.9	287.5

Temperature dependence of the zero point (ambient temperature) 5 - 40°C	≤ 2%
Temperature dependence of the sensitivity (ambient temperature) 5 - 40°C	≤ 2%
Drift of the zero point	
within 24 h	≤ 2%
within period of unattended operation	≤ 10%
Drift of the sensitivity	
within 24 h	≤ 2%
within period of unattended operation	≤ 10%
Voltage dependence of the measured signal	no dependence
Availability	> 95%
Preparation time and warm-up time	approx. 1 h
Response time	≤ 70 s
Calibration time	≤ 2% of measuring time
Period of unattended operation	approx. 1 month
Interference error; response to stated levels of interfering substances present in the sample CO_2, SO_2, H_2S, NH_3, CH_4, C_6H_6, NO, NO_2, H_2O (85% r.H.)	≤ 6% of IW2 value sum of all components

3.2 Further Technical Data

Space requirements	w x h x d 430 x 221 x 550 mm
Weight	approx. 20 kg
Power supply	220V AC, 50Hz, approx. 150VA
Signal output	RS 232 C or 0 - 1V, 0 - 10V and 4 - 20mA DC

Manufacturer (resp. Agency in Germany)

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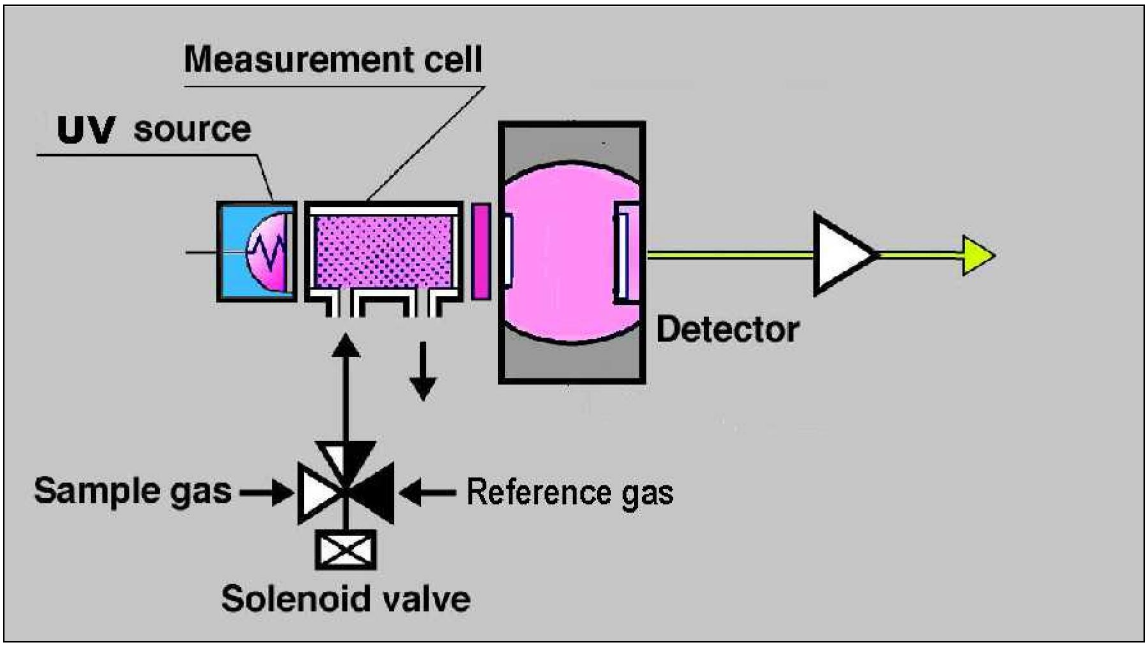
HORIBA

O_3 Analyzer, HORIBA Model APOA-360

Flow Diagram: UV absorption, patented cross flow modulation



1. Field of Application

Continuous and automatic monitoring of ozone in atmospheric air.

The suitability of the device has been tested by Technischer Überwachungs-Verein (TÜV) Rheinland, Institut für Umweltschutz und Energietechnik, Köln, TÜV Report 936/805008/O_3, 29.02.1996.

The Monitor is a further development of the Model APOA-350 E, the suitability of which was also successfully tested.

2. Set-up and Mode of Operation

The ultra-violet-absorption method works on the principle that ozone absorbs ultra-violet rays in the area of 254 nm. Measurements are taken from continuous, alternate injections of the sample gas and the reference gas into the measurement cell, controlled by a long-life solenoid valve. The cross flow modulation method is characteristically zero drift-free. All fluctuations in the mercury-vapor light source and in the detector are automatically compensated for by a comparative calculation circuit. This means that, in principle, the APOA-360 makes it possible to carry out zero-span drift-free, continuous measurements. In addition, HORIBA’s unique de-ozonizer for the comparison gas line is unaffected by interference elements or moisture retention, prolonged, stable measurement is possible.

The monitor has a built-in ozone generator.

3. Technical Data

3.1 Results of Suitability Test

Calibration function	linear
Lower detection limit	0.47 ppb
Range	for example 0 - 200 ppb (428 $\mu g/m^3$)
Reproducibility (R)	Laboratory : 49 Field : 104
Temperature dependence of the zero point (ambient temperature) 5 - 40°C	max. -0.4%
Temperature dependence of the sensitivity (ambient temperature) 5 - 40°C	max. +0.3%
Drift of the zero point	
within 24 h	0.00%
within period of unattended operation	0.09%
Drift of the sensitivity	
within 24 h	0.00%
within period of unattended operation	-0.07%
Voltage dependence of the measured signal	no dependence
Availability	99%
Preparation time	approx. 15 min
Response time	74 s
Warm-up time	approx. 60 min
Calibration time	< 5% of measuring time
Period of unattended operation	3 weeks
Interference error; response to stated levels of interfering substances present in the sample CH_4, C_2H_4, C_6H_6, CO, CO_2, H_2S, SO_2, NO, NO_2, N_2O, NH_3, H_2O	< 5 ppb (< 6% of ambient air quality limit value IW 2) sum of all components

3.2 Further Technical Data

Space requirements	w x h x d 430 x 221 x 550 mm
Weight	approx. 30 kg
Power supply	220V AC, 50Hz, approx. 180VA
Signal output	RS 232 C or 0 - 1V, 0 - 10V and 4 - 20mA DC

Manufacturer (resp. Agency in Germany)

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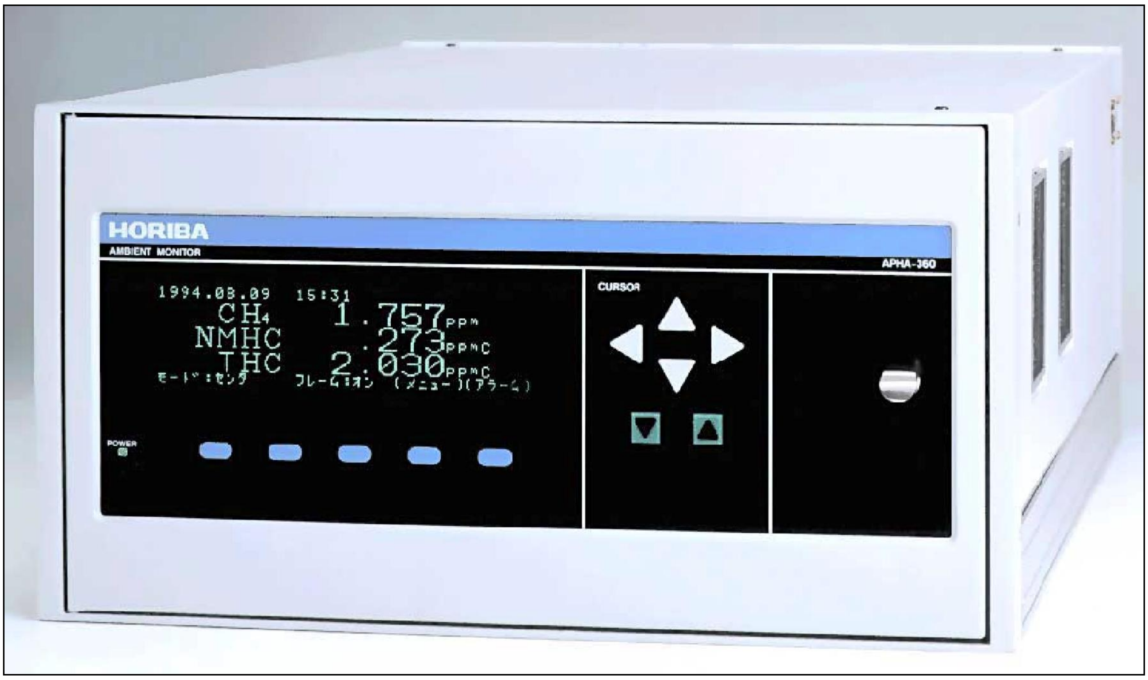
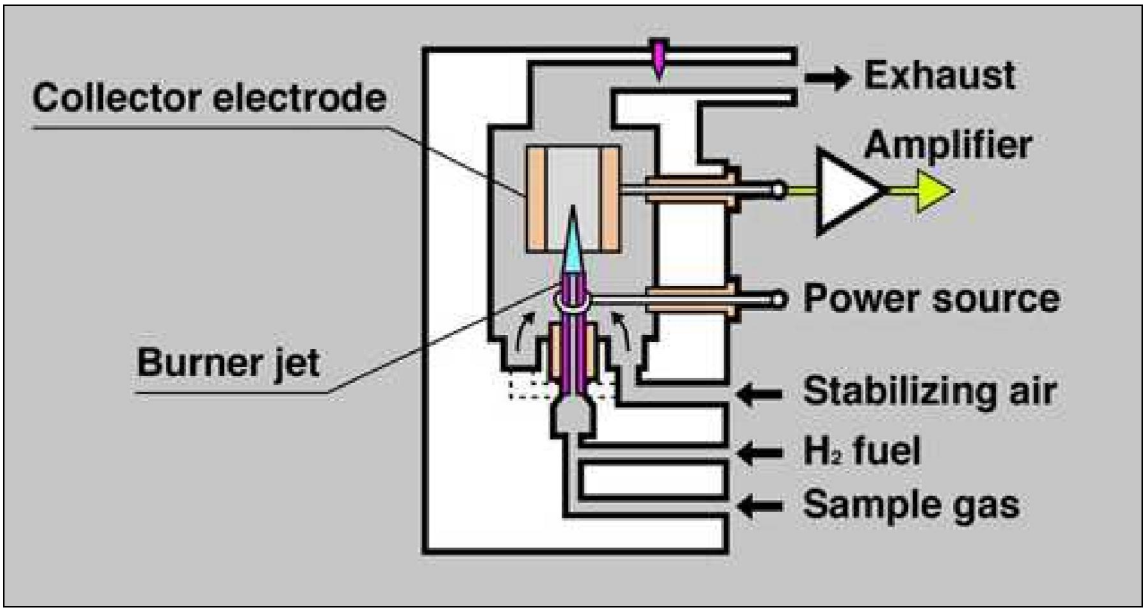
HORIBA

THC/CH_4/non-CH_4 Analyzer
HORIBA Model APHA-360



Flow-Diagram:
FID, Flame Ionisation Detector



1. Field of Application

The instrument is designed for continuous and automatic measurement of total hydrocarbons, methane and non-methane hydrocarbons (NMHC) in atmospheric air.

The suitability of the device has been tested by Umweltbundesamt, Pilotstation Offenbach, Bericht-Nr. 25 (Test-Report), August 1997.

The Monitor is a further development of the Model APHA-350 E, the suitability of which was also successfully tested (Technischer Überwachungs-Vereins Rheinland, Köln, Institut für Energietechnik und Umweltschutz Prüfbericht (Test-Report) Nr. 936/800005, 8 March 1991).

2. Set-up and Mode of Operation

The essential elements of the instrument are:

- Flame ionisation detector (FID)
- Cross-flow modulation system
- Continuous signal for
  - hydrocarbons,
  - methane and
  - non-methane hydrocarbons (NMHC)
- Catalytic hydrocarbon cutter
- Air supply system
- Flame shut-off function

Filtered sample gas is channelled through two lines. From line 1, it passes directly into rotary valve 1. In line 2, it passes through an integral HC cutter, which burns heavier hydrocarbons and leaves methane unburned, before being introduced to rotary valve 2. After purification, the reference gas is also divided into separate lines to the two rotary valves, which have different rotational frequencies. The THC and CH_4 sample flows modulated at valves are mixed and introduced into one detector. Inside the detector, the sample gas is mixed with hydrogen fuel for injection through a nozzle. Air from the internal air purifier supports combustion. An electrical potential between the nozzle and the collector electrode inside the detector produces an ion current proportional to the hydrocarbon count. The modulated hybrid signal from the detector is de-modulated to continuous THC and CH_4 signals. The difference between the two signals is electronically processed to produce output for non-methane hydrocarbons (NMHC).

3. Technical Data

3.1 Results of Suitability Test

Calibration function	linear
Lower detection limit	THC: 0.017 ppm CH_4: 0.021 ppm C_3H_8: 0.017 ppm
Range	4 ranges between 0 - 50 ppm C lower range: 0-10 ppm C
Reproducibility (R)	

Reproducibility	IW1 2ppm	IW2 4ppm	2*IW2 6ppm
THC	689.71	502.27	585.17
CH_4	399.46	476.69	426.12
C_3H_8	434.77	369.88	452.89

Temperature dependence of the zero point (ambient temperature)	max. 2 %
Temperature dependence of the sensitivity (ambient temperature)	max. 2 %
Drift of the zero point	
within 24 h	< 2 %
within 14 days	< 10 %
Drift of the sensitivity	
within 24 h	< 2 %
within 14 days	< 10 %
Voltage dependence of the measured signal	not detectable
Availability	> 95 %
Calibration time	approx. 10 min
Preparation time	4.5 h
Response time	< 70 s
Period of unattended operation	< 1 month
Interference error CO_2, SO_2, H_2S, NH_3, NO, NO_2, H_2O, O_3. CO	no interferences

3.2 Further Technical Data

Space requirements	w x h x d 430 x 221 x 550 mm
Weight	approx. 30 kg
Power supply	110, 115 or 220V 50 or 60Hz
Signal output	0 - 1V, 0 - 10V 4 - 20mA RS 232 C

Manufacturer (resp. Agency in Germany)

Horiba Europe GmbH
Julius-Kronenberg-Str. 9
D-42799 Leichlingen

Phone +49 2175 8978-0
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Internet www.horiba.de

MCZ
Umwelttechnik

SYNTECH SPECTRAS GC 855

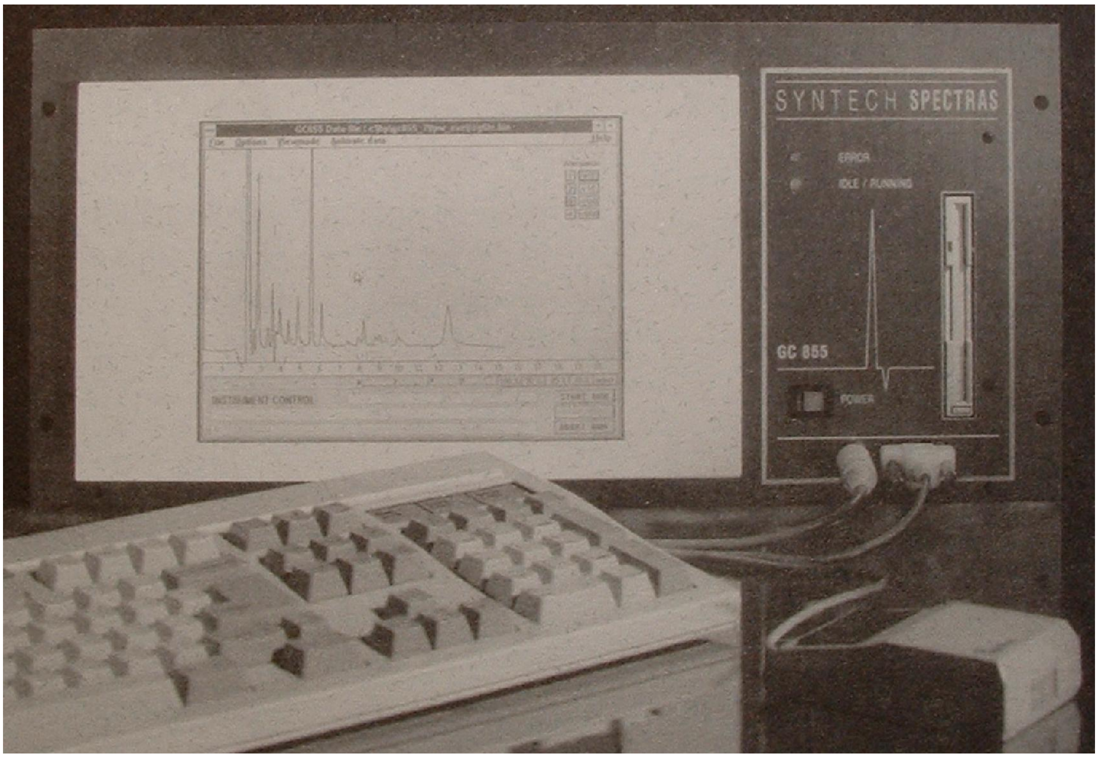
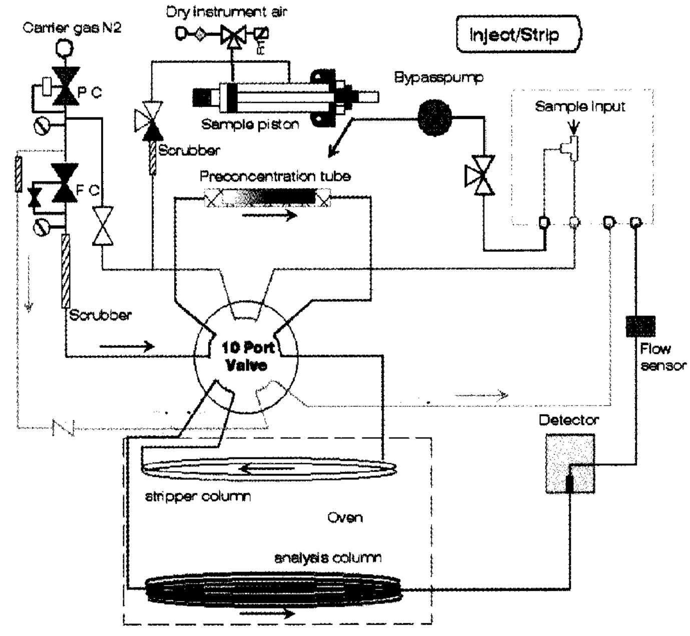


Diagram of the GC 855 injection mode



1. Field of Application

Automatic and continuous measurement of benzene in ambient air.

The suitability of the device has been tested by Umweltbundesamt, Pilotstation Offenbach, Report No. 26, January 1998.

2. Set-up an Mode of Operation

The gas-chromatograph GC 855 series 600, Benzene, is an analyser for the automatic, quasi-continuous measurement of benzene in ambient air with enriching sampling and subsequent gas-chromatographic separation.

In a first step, the sampling pipe is rinsed by an internal pump in order to move the sample to the inlet of the analyser. A sample volume of 18.5 ml or a multiple of this amount is pushed over an adsorption column by means of a piston. The TENAX GR^{TM} filling adsorbs the gaseous benzene contained in the sample at ambient temperature. Following a quick heating to 180°C, the component is desorbed into a carrier gas stream of 2.0 ml/min and transported into the separation column.

The separation of the air sample takes place in two capillary columns which are connected in series: stripper column and analysis column. When the considered component has reached the analysis column, the stripper column is rinsed back so that boiling material, which would considerably increase the analysing period, cannot reach the analysis column.

The quantitative detection of the compound is carried out by means of a photo ionisation detector (PID). The molecules are ionised by a UV lamp with an ionisation potential of 10.6 eV. The current thus created is amplified and indicated as a voltage value.

The analysing software integrates the electric signal and quantifies the component by setting off against the calibration.

3 Technical Data

3.1 Results of Suitability Test

Calibration function	linear
Lower detection limit	≤ 0.21 µg/m^3
Range	0 – 300 µg/m^3
Reproducibility (R)	4.64-5.25
Temperature dependence of the zero point (ambient temperature)	≤ 0.5%
Temperature dependence of the sensitivity (ambient temperature)	≤ 4.6 %
Voltage dependence of the measured signal (zero gas)	not detectable
Voltage dependence of the measured signal (relation value)	≤ 1.9 %
Drift of the zero point	not detectable
Drift of the sensitivity	
within 24 h	< 3.2 %
within 14 days	< 7.3 %
Availability	> 91 %
Period of unattended operation	30 days
Interference error	< 5.7 %;
Response to stated levels of interfering substances present in the sample H_2O, O_3, and 11 organic substances	

3.2 Further technical Data

Space requirements	19“, 5 HU, 37,2 cm
Power supply	220V / 50Hz, 100 –200 VA optionally 110V-version
Signal outputs	RS 232 , 0-10 V

Manufacturer

Syntech Spectras B. V.,
Groningen, Netherlands

Agency Germany

MCZ Umwelttechnik GmbH
Dieselstr. 20a
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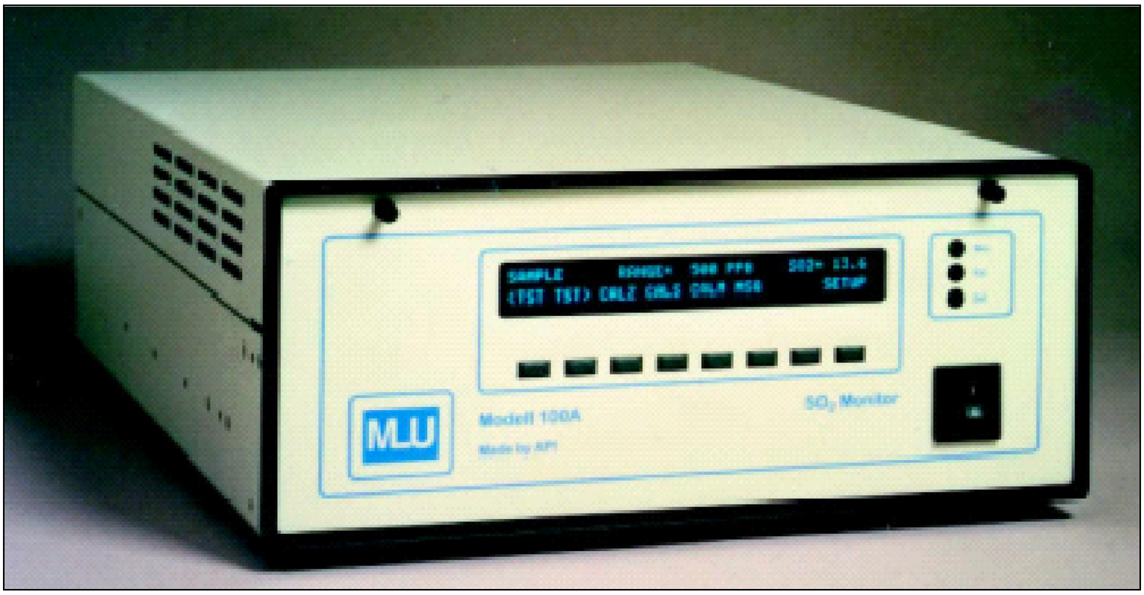
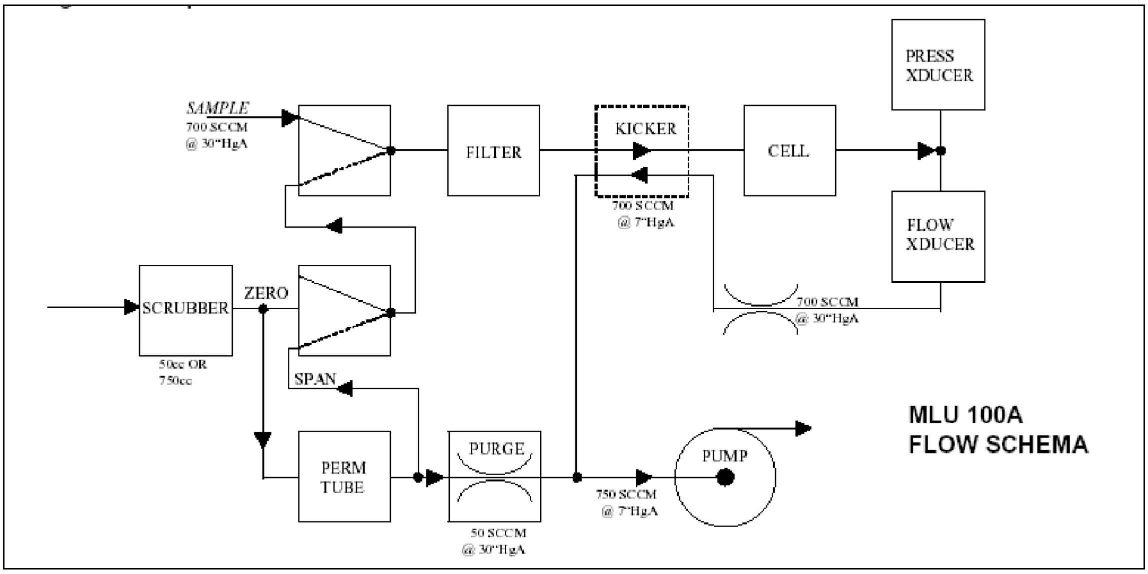
Internet www.mcz.de

Messtechnik für Luft und Umwelt GmbH

MLU 100A SO_2 Analyzer





1. Field of Application

Automatic and continuous measurement of sulphur dioxide (SO_2) in ambient air.

The suitability of the device has been tested by Rheinisch-Westfälischer Technischer Überwachungs-Verein, Institut für Umweltschutz, Chemie und Biotechnologie, Zentralabteilung Umweltberatung und -projekte, Essen, Report No. 3.5.1/101/91 - 389005/01, February 1997.

2. Set-up and Mode of Operation

The MLU 100A uses the proven UV fluorescence principle coupled with state of the art microprocessor technology to provide accurate and dependable measurement of low level SO_2. Exceptional stability is achieved with the use of an optical shutter to compensate for PMT drift and a reference detector to correct changes in lamp intensity. A hydrocarbon “kicker” and advances optical design combine to prevent inaccuracies due to interferents. The multitasking software gives real time indication of a large number of operational parameters and provides automatic alarms if diagnostic limits are exceeded. All instruments of the “A series” include built-in data acquisition capability using the analyzer´s own internal memory. This allows the logging of multiple parameters including averaged or instantaneous concentration values, calibration data and operating parameters such as flows, pressure and lamp intensity. Stored data is easily retrieved through the RS-232 port or from the front panel allowing operators to perform predictive diagnostics by tracking parameter trends. The MLU 100A combines rugged construction, ease of use, powerful diagnostics and outstanding performance.

3. Technical Data

3.1 Results of Suitability Test

Calibration function	linear
Lower detection limit	< 0,0018 mg/m^3
End of Range	500ppb (1.429 mg/m^3)
Reproducibility (R)	141.5 (IW2)
Temperature dependence of the zero point (ambient temperature)	< -1.356 %
Temperature dependence of the sensitivity (ambient temperature)	< +1.576 %
Drift of the zero point	
within 24 h	< +0.039 %
within period of unattended operation	< +1.16 %
Drift of the sensitivity	
within 24 h	< +0.108 %
within period of unattended operation	< +3.25%
Voltage dependence of the measured signal 200 - 235V	< +1.1 %
Availability	100%
Preparation time	< 10 min
Response time	< 73 s
Calibration time	< 3%
Period of unattended operation	30 d
Interference error; Response to stated levels of interfering substances present in the sample NH_3, NO, NO_2, O_3, H_2S, CO, CO_2, CH_4, C_2H_4, C_6H_6, H_2O	< +3.1 %

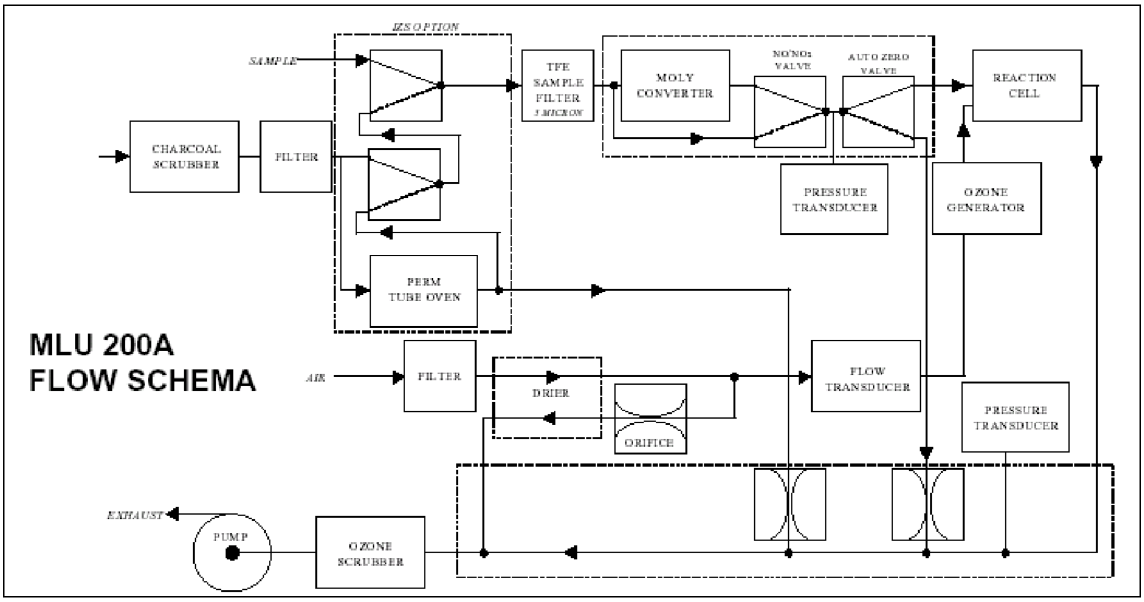
3.2 Further Technical Data

Space requirements	W x H x D 432 x 178 x 597
Weight	20.5 kg
Power supply	100V / 50 / 60Hz; 115V / 60Hz; 220V / 50Hz; 240V / 50Hz
Signal output	10V, 5V, 1V, 100mV, 4 – 20mA (option)

Manufacturer	Teledyne Advanced Pollution Instrumentation, Inc., San Diego, California, USA
Agency in Germany	MLU Messtechnik für Luft und Umwelt GmbH Altendorferstr. 97-101 D-45143 Essen Phone +49 201 281091 Fax +49 201 281094 Email customer-service@mlu-d.de Internet www.mlu.at

Messtechnik für Luft und Umwelt GmbH

MLU 200A NO/NOx/NO$_2$ Analyzer



1. Field of Application

Automatic and continuous measurement of nitrogen monoxide (NO), nitrogen oxides (NO_x) and nitrogen dioxide (NO_2) - as calculated difference - in ambient air.

The suitability of the device has been tested by Rheinisch-Westfälischer Technischer Überwachungs-Verein, Institut für Umweltschutz, Chemie und Biotechnologie, Zentralabteilung Umweltberatung und -projekte, Essen, Report No. 3.5.1/101/91 - 389004/01, 25. 07.1996.

The API Model 200A is marked MLU Model 200A by the Agency in Germany.

2. Set-up and Mode of Operation

The API Model 200A is a switched single channel chemiluminescent $NO/NO_2/NO_x$ analyzer. The fast switching time plus special software algorithms minimizes negative NO_2 artifacts. A software adaptive filter allows fast response for rapidly changing concentration levels while providing a quiet signal for steady state conditions.

Excellent measurement stability is accomplished through the use of temperature controlled critical orifices for sample flow. Zero drift is essentially eliminated by an auto-zero circuit which corrects for zero drift once per minute.

Temperature and pressure compensation minimizes the effects caused by changes in environmental conditions. An internal permeation dryer provides dry air to the ozone generator eliminating desiccant thereby reducing maintenance.

The Model 200A uses a powerful multi-tasking operating system which allows viewing of test parameters while monitoring $NO/NO_2/NO_x$ concentrations. Test parameters including PMT voltage, vacuum, sample and ozone flow, high voltage setting, DC power supplies, and temperatures of the reaction cell , PMT, moly converter and internal permeation tube oven can all be viewed without disrupting data collection.

Data can be reported in units of ppb, ppm, $\mu g/m^3$ or mg/m^3. Converter efficiency software allows automatic correction for converter efficiency. The independent range feature allows the operator to set NO, NO_2 and NO_x ranges independent of one another.

The auto-ranging feature allows automatic selection between two user-chosen ranges. The last 100 averages of $NO/NO_2/NO_x$ are stored in reliable battery backed RAM. Invalid data during calibration and diagnostics is excluded from the average.

All program and set-up parameters are stored in non-volatile memory. The microprocessor and other critical circuits are protected from transients on the power line. A watchdog feature protects against brown out conditions.

Diagnostics include an Electrical Test and Optical Test as well as the ability to check all digital I/O and the RS232 output. A DAC output test allows users to set up external recorders and dataloggers easily. The Model 200A continuously does a self-check on key parameters and a warning is issued immediately upon any out-of-tolerance condition.

The internal zero/span self-check option includes a temperature-controlled permeation tube, stainless steel zero and span valves, and a zero air scrubber. Zero and span checks can be performed manually from the keyboard, automatically on a timed basis or remotely from contact closures or a remote RS232 command. Dynamic adjust allows the zero and span to be automatically reset after a calibration.

The powerful bi-directional RS232 serial port provides output of average values, instantaneous data, test values and warning condition. In addition, this bi-directional output enables a remote computer to download set-up variables and to perform all functions which can be performed from the keyboard. The Model 200A can be totally controlled from a remote location.

The API Model 200A is based on the field-proven Model 200 design and is designed for maximum on-site uptime. Fold-down front and rear panels provide easy access. All subassemblies can quickly be removed for repairs or replacement making field maintenance easy to perform. The Model 200A has a two year warranty and is designed for years of trouble-free performance.

3. Technical Data

3.1 Results of Suitability Test

Calibration function	linear
Lower detection limit	NO and NO_x : < 0.0015 mg/m^3 NO_2 : < 0.00069 mg/m^3
Range	NO and NO_x : 0 - 1000 ppb (1.34 mg/m^3) NO_2 : 0 - 500 ppb (1.025 mg/m^3)
Reproducibility (R)	> 188 > 190
Temperature dependence of the zero point (ambient temperature)	NO : < +0.183% NO_x : < +0.11% NO_2 : < -0.273%
Temperature dependence of the sensitivity (ambient temperature)	NO : < -0.85% NO_x : < -0.947% NO_2 : < -1.023%

	NO	NO_x
Drift of the zero point		
within 24 h	< +0.0074%	< +0.005%
within period of unattended operation	< +0.005%	< +0.105%
Drift of the sensitivity		
within 24 h	< 0.415%	< -0.427%
within period of unattended operation	< -8.71%	< -8.97%

Voltage dependence of the measured signal (in the range 200 - 245V)	NO : < +0.393% NO_x : < +0.566%
Availability	100%
Preparation time	< 10 min
Response time	NO : 44.7 s NO_x : 44.3 s
Calibration time	< 3% of the measuring time
Period of unattended operation	21 d
Interference error; response to stated levels of interfering substances present in the sample	NO: < -4.87% NO_x: < -4.73% NO_2: < -4.90%

NH_3, H_2S, SO_2, CO_2,
CH_4, C_2H_4, C_6H_6, H_2O

3.2 Further Technical Data

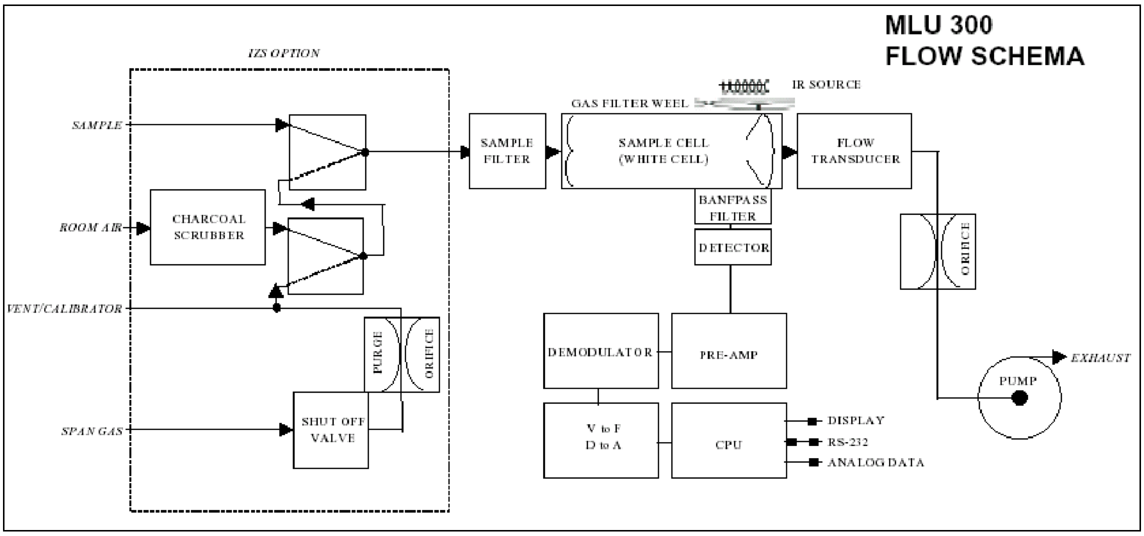
Space requirements	w x h x d 432 x 178 x 597 mm
Weight	23 kg
Power supply	110V / 50 / 60Hz; 115V / 60Hz; 220V / 50Hz; 240V / 50Hz
Signal output	10V; 5V, 1V; 100mV, 0 – 20mA (option)

Manufacturer	Teledyne Advanced Pollution Instrumentation, Inc., San Diego, California, USA
Agency in Germany	MLU Messtechnik für Luft und Umwelt GmbH Altendorferstr. 97-101 D-45143 Essen Phone +49 201 281091 Fax +49 201 281094 Email customer-service@mlu-d.de Internet www.mlu.at

MLU

Messtechnik für Luft und Umwelt GmbH

MLU 300 CO Analyzer



1. Field of Application

Automatic and continuous measurement of carbon monoxide in ambient air.

The suitability of the device has been tested by Rheinisch-Westfälischer Technischer Überwachungs-Verein, Institut für Umweltschutz, Chemie und Biotechnologie, Zentralabteilung Umweltberatung und -projekte, Essen, Report No. 3.5.1/1046/93 - 57303801, 03.08.1995.

The API Model 300 is marked MLU Model 300 by the Agency in Germany.

2. Set-up and Mode of Operation

The Model 300 is a microprocessor controlled gas filter correlation infrared analyzer. The Beer-Lambert law is used to calculate CO concentration from the amount of infrared energy absorbed. A correlation wheel is used to achieve low LDL and stability. The infrared beam, generated by a special high energy long life source, is alternately passed through a cell filled with CO and another with no CO. The measuring cell is a white cell with 32 passes for an equivalent length of 16 metres. The two signals pass through an interference filter to a solid state, cooled detector and are then compared by the software. This cancels out interfering gases, provides excellent zero and span stability, and high signal to noise ratio.

The powerful API software package coupled with a microprocessor and proven hardware make the Model 300 the most advanced instrument of its kind. Adaptive data filtering gives rapid response during dynamic conditions and smooth stable data during periods of small changes. An internal data buffer collects and stores averages at intervals of 1 to 60 minutes, allowing stand alone data collection and logging. Remote control and programming permits long distance operation by modem to the analyzer via the RS 232 port. All functions addressable from the front panel including diagnostics, tests, and set-ups, are accessible using a remote computer or terminal.

Test functions, the most advanced diagnostics package in the industry and constant self-checking allow any problems in the MLU 300 to be quickly diagnosed and repaired. A check function continually reviews the analyzer status. Any parameters out of specification are reported to the front panel display and RS232 output.

A test function displays sample pressure, sample flow, detector readings and other conditions. Unique and powerful diagnostics allow any test parameter to be output to a strip chart. The multi-tasking software continues to collect sample information during test functions.

The optional zero/span valve assembly includes a cylinder flow control orifice to limit cylinder gas flow to the desired level and a safety shut-off valve. Span gas can also be provided from a calibrator. The optional zero/span system (IZS) uses an internal heated long-life catalyst to provide zero air. Span is done using an external cylinder. Span and Zero checks can be performed manually, through the internal software timer, remote contact closures or RS232 commands. The time and frequency of the zero-span period is adjustable from the front panel for auto-cal or by the remote control function.

3. Technical Data

3.1 Results of Suitability Test

Calibration function	linear
Lower detection limit	< 0.37 mg/m^3
Range	0 - 50 ppm (62.5 mg/m^3)
Reproducibility (R)	56.9
Temperature dependence of the zero point (ambient temperature)	< +0.575%
Temperature dependence of the sensitivity (ambient temperature)	< -0.67%
Drift of the zero point	
within 24 h	< +0.047%
within period of unattended operation	< +1.3%
Drift of the sensitivity	
within 24 h	< -0.059%
within period of unattended operation	< -1.64%
Voltage dependence of the measured signal	< +0.2% (in the range 200 - 245V)
Availability	99%
Preparation time	< 10 min

Response time	< 180 s
Calibration time	< 3% of the measuring time
Period of unattended operation	28 d
Interference error; response to stated levels of interfering substances present in the sample NH_3, NO, NO_2, O_3, H_2S, SO_2, CO_2, CH_4, C_2H_4, C_6H_6, H_2O	< -4.3% per substance

3.2 Further Technical Data

Space requirements	w x h x d 432 x 178 x 660 mm
Weight	22.7 kg
Power supply	220V / 50Hz
Signal output	0.1V; 1V; 5V; 10V; 4 – 20mA (option)

Manufacturer

TeledyneAdvanced Pollution
Instrumentation, Inc.,
San Diego, California, USA

Agency in Germany

MLU Messtechnik für Luft
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Altendorferstr. 97-101
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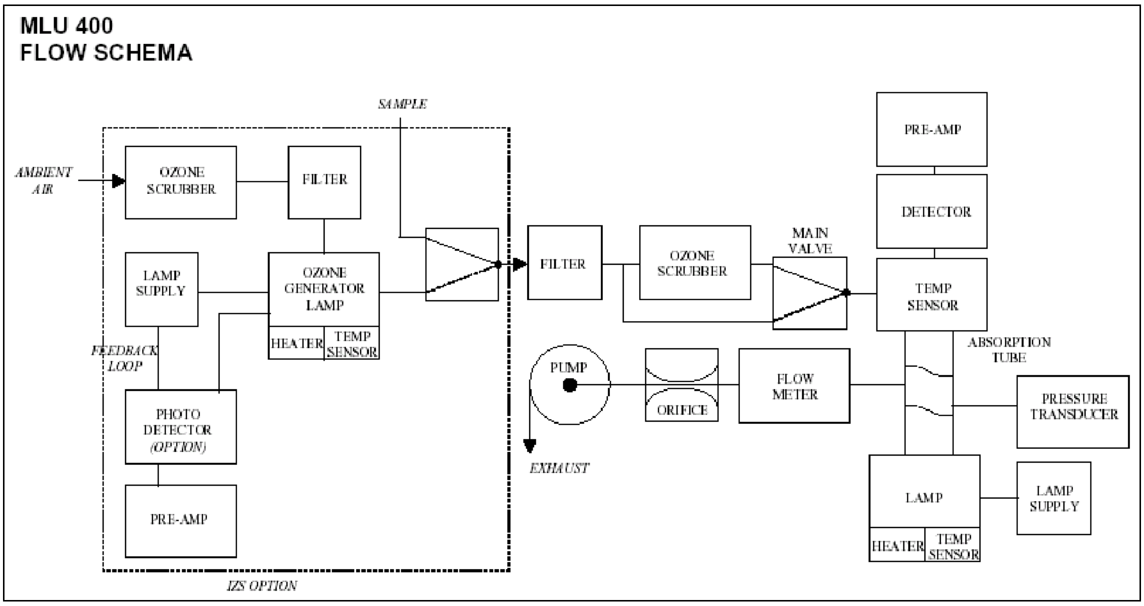
Messtechnik für Luft und Umwelt GmbH

MLU 400 Ozone Analyzer


MLU 400
FLOW SCHEMA

1. Field of Application

Automatic and continuous measurement ozone in ambient air.

The suitability of the device has been tested by Rheinisch-Westfälischer Technischer Überwachungsverein, Institut für Umweltschutz, Chemie und Biotechnologie, Zentralabteilung Umweltberatung und -projekte, Essen, Report No. 3.5.1/262/92 - 461775/02, 07.03.1995.

The API Model 400 is marked MLU Model 400 by the Agency in Germany.

2. Set-up and Mode of Operation

The Model 400 is a microprocessor controlled single path/single pass ultraviolet absorption analyzer used for measuring ambient concentrations of ozone. The concentration of ozone is determined by the attenuation of 254 nm UV light along a single fixed path cell. The ozone molecule is a strong absorber of the 254 nm energy and thus the energy lost over the fixed path is proportional to the ozone concentration in the atmosphere. The Beer-Lambert Law is used to calculate the concentration of ozone. Since a reference condition is required for this calculation, a switching valve is incorporated to alternate between the sample mode and reference mode every 4 seconds. A selective scrubber is employed to provide the reference condition. Great care is taken to provide a scrubber that removes only ozone. This results in a true ozone measurement unbiased by interferents.

The powerful API software package coupled with a microprocessor and proven hardware configuration make the Model 400 a very advanced instrument of its kind. The adaptive data filtering provides rapid response during transient conditions yet smooth stable data during periods of small changes. The internal data buffer collects and stores the 1-60 minute averages allowing stand alone data collection and logging. The remote control/ remote programming capability permits long distance operation through modem communication to the analyzer via the RS232 port. All functions addressable from the front panel including diagnostics, tests, and set-ups, are accessible using a remote computer or terminal connected to the RS232 I/O.

The diagnostics package is the most advanced in the industry. A check function continually reviews the analyzer status and reports any parameters out of specification to the front panel display and RS232 output. A test function displays functions such as detector output, sample pressure, flow for the sample and IZS, temperatures for the sample, IZS lamp, and sample and reference detector readings.

A unique and powerful diagnostic function allows any one of the test parameter to be an analog output that can be recorded on a strip chart. All test functions are independent of data collection since the multi-tasking software continues to collect sample information during the review of the test functions.

The zero/span system (IZS) provides a source of zero air and variable concentrations of ozone to test the performance of the Model 400. A three point option allows zero, precision or span value. The operator sets up any daily sequence desired. The system can be operated manually or through the internal software timer allowing automatic testing. The time and frequency of the IZS period is adjustable from the front panel or by use of the remote control function.

3. Technical Data

3.1 Results of Suitability Test

Calibration function	linear
Lower detection limit	< 0.006 mg/m^3
Range	0 - 900 µg/m^3
Reproducibility (R)	119
Temperature dependence of the zero point (ambient temperature)	< 1.2%
Temperature dependence of the sensitivity (ambient temperature)	< 1.4%
Drift of the zero point	
within 24 h	< 0.015%
within period of unattended operation	< 0.41%
Drift of the sensitivity	
within 24 h	< 0.085%
within period of unattended operation	< 2.37%
Voltage dependence of the measured signal	< 0.5% in the range of 200 - 245V
Availability	99%
Preparation time	< 10 min
Response time	< 26 s
Calibration time	< 3% of the measuring time

Period of unattended operation	28 d
Interference error; response to stated levels of interfering substances present in the sample NH_3, NO, NO_2, C_2H_4, H_2S, SO_2, CO_2, CH_4, C_6H_6, H_2O	< 4.4% per substance

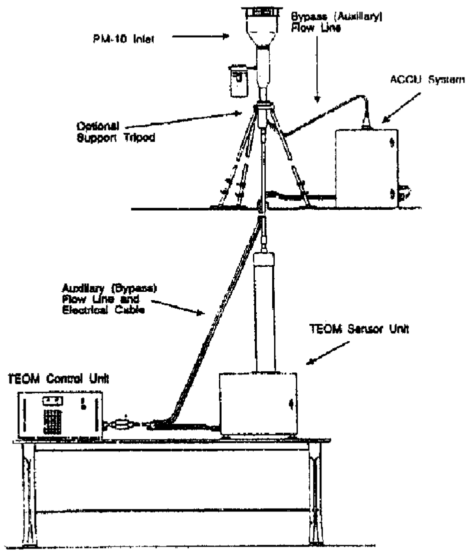
3.2 Further Technical Data

Space requirements	w x h x d 432 x 178 x 686 mm
Weight	24 kg
Power supply	100V / 50Hz
Signal output	0.1V; 1V; 5V; 10V, 0 – 20 mA, 4 – 20 mA

Manufacturer	Teledyne Advanced Pollution Instrumentation, Inc., San Diego, California, USA
Agency in Germany	MLU Messtechnik für Luft und Umwelt GmbH Altendorferstr. 97-101 D-45143 Essen Phone +49 201 281091 Fax +49 201 281094 Email customer-service@mlu-d.de Internet www.mlu.at

Messtechnik für Luft und Umwelt GmbH

Ambient Particulate Monitors TEOM 1400a, Rev. B



1. Field of Application

Real-time measurement of low concentrations of suspended particulate matter in ambient air. Determination of short-term mean values.

The suitability of the device has been tested by Rheinisch-Westfälischer Technischer Überwachungs-Verein (RWTÜV Anlagentechnik), Essen, Reports No. 3.5.1/205/90 - 483079/01 and - 577925/01, 02.09.1994 (Supplementary Test), by RWTÜV, Institut für Umweltschutz, Chemie und Biotechnologie, Zentralabteilung Umweltberatung und -projekte, Essen, Reports No. 3.5.1/205/90 - 577925/01, 27.02.1995 and 3.5.1/205/90 - 577925/01, 27.07.1995 (Supplementary Tests) and No. 3.5.1/205/90 - 614152/01, 08.08.1996 (Supplementary Test of the Model 1400a, Revision B, with some constructional modifications) and 5.01/205/90-714721/01 (PM_{10}; EN 12341).

The monitor is a further development of the Model 1400, the suitability of which was also successfully tested (Test Report G No. 3.5.1/205/ 90, 07.04.1992, of the RWTÜV, Essen).

2. Set-up and Mode of Operation

The TEOM Ambient Particulate Monitor is comprised of two main components: the TEOM Control Unit and the TEOM Sensor Unit. The system software gives the user control over data collection and evaluation. It allows to define the operating parameters.

The monitor incorporates an inertial oscillating microbalance that measures the mass collected on an exchangeable filter cartridge by monitoring the corresponding frequency changes of a tapered element. The sample flow passes through the filter, where particulate matter collects, and then continues through the hollow tapered element on its way to an electronic flow control system and vacuum pump. The TEOM mass transducer does *not* require recalibration because it is specially designed and constructed from non-fatiguing materials. Calibration may be verified, however, using an optional mass calibration verification kit that contains a filter of known mass.

Based upon the direct relationship between mass and frequency of oscillation, the instrument's microcomputer computes the total mass accumulation on the filter, as well as the mass rate and mass concentration, in real time.

The instrument provides half-hourly, hourly, eight-hourly and daily averages of particulate concentrations. The instrument's data may be stored for future use.

3. Technical Data

3.1 Results of Suitability Test

Calibration function	linear
Lower detection limit	$< 15\ \mu g/m^3$
Range	$< 5\ \mu g/m^3$ to several mg/m^3
Reproducibility (R)	29 - 374
Temperature dependence of the zero point (ambient temperature)	±0.04%
Temperature dependence of the sensitivity (ambient temperature)	max. -0.98% between 6 and 40°C
Drift of the zero point within period of unattended operation	±0.6%
Drift of the sensitivity within period of unattended operation	-0.7%
Voltage dependence of the measured signal	no dependence
Availability	90 - 100%
Preparation time	< 2 h
Calibration time	0.1% of the measuring time

3.2 Further Technical Data

Space requirements	w x h x d
Sensor Unit	38 x 33 x 21 cm
Control Unit	44 x 22 x 33 cm
Weight	
Sensor Unit	14 kg
Control Unit	12 kg
Power supply	120V / 60Hz, 4A or 240V / 50Hz, 2A

Manufacturer

Rupprecht & Patashnick
Co. Inc.
Albany, New York, USA

Agency in Germany

MLU Messtechnik für Luft
und Umwelt GmbH
Altendorferstr. 97-101
D-45143 Essen

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Messtechnik für Luft und Umwelt GmbH

rp 5400 Ambient Carbon Particulate Monitor

1. Field of Application

Automatic and continuous measurement of elemental and organic carbon content of particulate matter.

The suitability of the device has been tested by Rheinisch-Westfälischer Technischer Überwachungs-Verein, (RWTÜV Anlagentechnik), Essen, Reprt Nr. 3.5.1/205/90/676600/01, March 1997

2. Set-up and Mode of Operation

The Series 5400 monitor from Rupprecht & Patashnick (R&P) is a network-ready device that automatically measures the elemental and organic content of particulate matter in ambient air. Using a direct thermal CO_2 analysis technique patented by R&P, the instrument differentiates between organic and elemental carbon particulate matter by oxidizing collected samples at an intermediate temperature followed by a high final burn temperature. The monitor´s dual collector/furnace design allows sample collection to take place during analysis of the previous sample.

With zero and span gas sources attached, the instrument automatically performs audits and calibrations at user-defined intervals. Its hardware mounting panel slides out of the enclosure to provide easy access for the maintenance and service procedures. Sample oxidation during the analysis phase regenerates the system´s exchangeable collection cartridges.

Measuring both the organic carbon (OC) and elemental (EC) concentration (µg/m³) enables the instrument to compute the OC/EC ratio. A selection of sample inlets designed for the default flow rate of 1 m³/h (16.7 l/min) permits sampling of PM-10, PM-2,5, PM-1, TSP and other critical cut points. In the monitor`s advanced operating mode, users can pre-select up to four oxidation temperatures for detailed sample analysis.

3. Technical Data

3.1 Results of Suitability Test

Calibration function	linear
Lower detectioin limit	< 0.73 µg/m³
Range	< 0 – 240 mg/m³
Reproducibility (R)	10.9 – 12
Temperature dependence of the zero point (ambient temperature)	≤ -0.51%
Temperature dependence of the sensitivity (ambient temperature)	max. –1.13 % (6 - 40°C)
Voltage dependence of the sensitivity	max. –2.34 %
Voltage dependence of the measured signal	max. –0.5 %
Availability	> 97.5 %
Preparation time	approx 20 min
Warm-up time	max. 55 min
Calibration time	≤ 0.01% (6 month)
Interference error; response to stated levels of interfering substances present in the sample	< +3.24%

NH_3, NO_2,SO_2, CO, CH_4, C_2H_4, C_6H_6, Benzene, Toluene, Ethylbenzene, Xylene

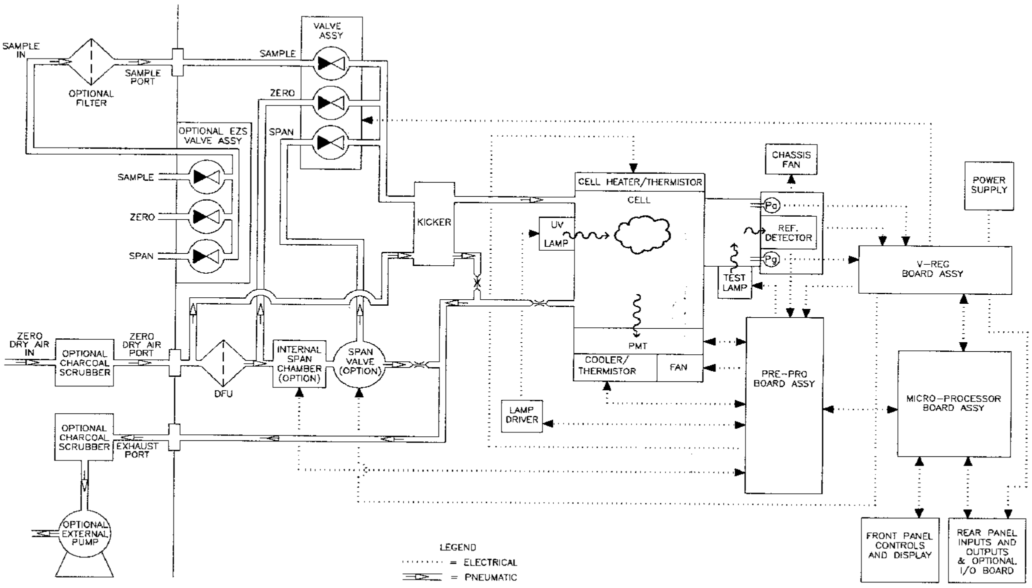
3.2 Further Technical Data

Space requirements	w x h x d 44 x 69 x 53 cm
Weight	47 kg
Power supply	220V / 50Hz 240V / 60Hz
Signal output	RS232; 0-1, 0-2, 0-5V optional 0-20, 4-20mA

Manufacturer	Rupprecht & Patashnick Co. Inc. Albany, New York, USA
Agency in Germany	MLU Messtechnik für Luft und Umwelt GmbH Altendorferstr. 97-101 D-45143 Essen Phone +49 201 281091 Fax +49 201 281094 Email customer-service@mlu-d.de Internet www.mlu.at

SO_2 Analyzer ML 9850

Flow diagram:



1. Field of Application

Automatic and continuous measurement of sulphur dioxide in ambient air.

The analyzer ML 9850 is a further development of the Model 8850, especially concerning the electronic equipment (modular construction).

The suitability of the device has been tested by Rheinisch-Westfälischer Technischer Überwachungs-Verein, Institut für Umweltschutz, Chemie und Biotechnologie, Zentralabteilung Luftreinhaltung, Immission, Essen, Test report No. 3.5.1/554/9-466140/01, 18.07.1995.

A converter enables the continuous measurement of hydrogen sulphide, oxidizing H_2S to SO_2 before monitoring.

2. Set-up and Mode of Operation

The ML 9850 Sulphur Dioxide (SO_2) Analyzer is an advanced design analyzer that uses U.V. fluorescence technology to measure concentration of SO_2 accurately and reliably.

The ML 9850 depends on the fluorescent radiation produced by SO_2 molecules when excited by U.V. radiation. The excitation U.V. radiation is measured by a photomultiplier tube (PMT). The two measurements are rationed in a classical dual-channel technique to minimize the effects of variation in source intensity, optical contamination, and common PMT drift characteristics.

Aromatic hydrocarbons are removed by a unique "kicker" that uses a differential partial pressure technique to selectively remove aromatics across a permeable membrane, without influencing the SO_2 sample.

The final concentration of SO_2, corrected for temperature and pressure changes, is displayed in units of parts per million (ppm) or milligrams per cubic meter (mg/m^3).

A built-in data display presents trends, averages, status, and historical information in a digital or graphic format. User selectable menu screens provide access to all available options and instrument set-up.

The ML 9850 automatically selects the optimum measuring range for the display, printer and RS232 outputs for each parameter. Values are reported as floating point numbers, making range reporting unnecessary.

3. Technical Data

3.1 Results of Suitability Test

Calibration function	linear
Lower detection limit	< 0.0081 mg/m^3
Range	0 - 20 ppm (57.14 mg/m^3) (for example)
Reproducibility (R)	111
Temperature dependence of the zero point (ambient temperature) 5 - 40°C	< 0.375%
Temperature dependence of the sensitivity (ambient temperature) 5 - 40°C	< 0.233%
Drift of the zero point	
within 24 h	< 0.03%
within period of unattended operation	< 0.84%
Drift of the sensitivity	
within 24 h	< 0.28%
within period of unattended operation	< 7.84%
Voltage dependence of the measured signal	200 - 245V: < 0.93%
Availability	97%
Preparation time + Warm-up time	max. 10 + 33 min
Response time	< 161 s
Calibration time	< 4% of the measuring time
Period of unattended operation	28 d
Interference error; response to stated levels of interfering substances present in the sample NH_3, NO, NO_2, O_3, H_2S, CO_2, CH_4, C_6H_6, C_2H_4, H_2O	< 5.5% per substance

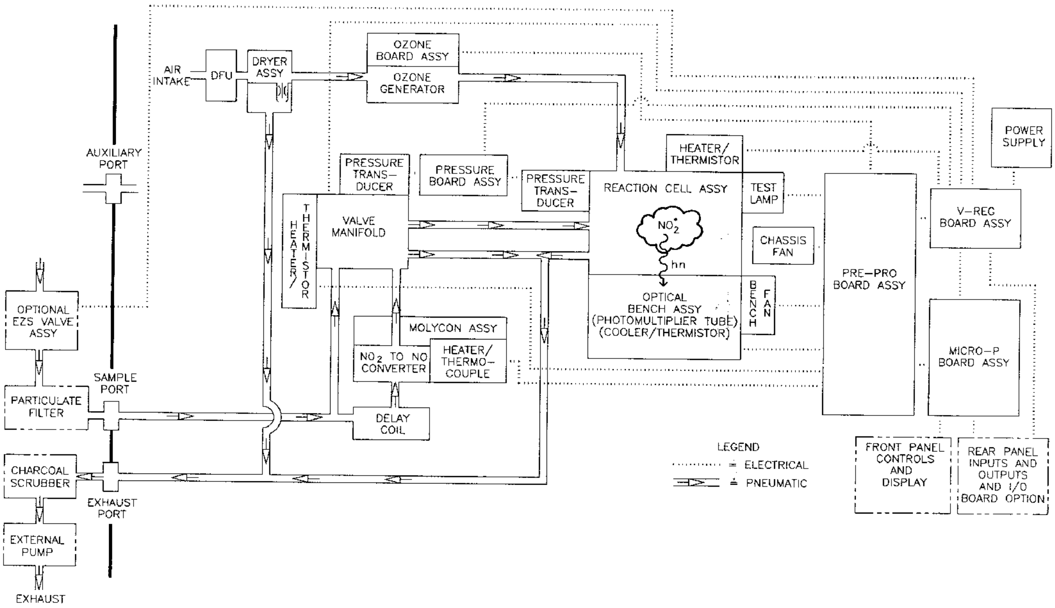
3.2 Further Technical Data

Space requirements	w x h x d 432 x 178 x 648 mm
Weight	approx. 25 kg
Power supply	198 - 264V AC, 50Hz or 99 - 132V AC, 60Hz
Signal output	100mV, 1V, 5V, 10V or 0, 1, 2, 4 - 20mA RS 232

Manufacturer	Monitor Labs/Monitor Europe (U.K.)
Agency in Germany	MS-4 Analysentechnik GmbH Am Sandberg 20 D-35519 Rockenberg Phone +49 6033 9235-0 Fax +49 6033 9235-19 Email office@ms4-analysentechnik.com Internet www.ms4-analysentechnik.com

NO$_2$ Analyzer ML 9841

Flow diagram:



1. Field of Application

Automatic and continuous measurement of nitrogen oxides (NO, NO_2, NO_x) in ambient air.

The Analyzer ML 9841 is a further development of the Model 8841, especially concerning the electronic equipment (modular construction).

The suitability of the device has been tested by Umweltbundesamt, Pilotstation Frankfurt, Offenbach, Testbericht (Test report) No. 21, August 1995.

A Converter enables the measurement of ammonia, oxidizing NH_3 to NO before monitoring.

2. Set-up and Mode of Operation

The 9841 uses a single-channel architecture for maximum reliability and simplified operation. A single reaction cell and photomultiplier tube (PMT) measure the chemiluminescence produced by the NO/O_3 reaction. The inlet stream to the main reaction cell is periodically switched between a reference and a measurement gas stream. The sample used for measurement is alternately switched either through or around a converter (heated Molydenum) that converts NO_2 to NO. Thus, the instrument alternately measures NO and NO_x, with the difference between the two readings providing the computed NO_2 value.

A gas sample accumulator provides exactly the correct volume of storage so that the NO and NO_x measurements involve a common sample volume. This ensures that there are no misleading artifacts due to stream switching.

The concentrations of NO_x, NO and NO_2, corrected for temperature, pressure, and flow changes, are displayed in units of parts per million (ppm) or milligrams per cubic meter (mg/m^3).

A built-in data display presents trends, averages, status, and historical information in a digital or graphic format. User selectable menu screens provide access to all available options and instrument setup.

The ML 9841 automatically selects the optimum measuring range for the display, printer, and RS 232 outputs for each parameter. Values are reported as floating numbers, making range reporting unnecessary.

3. Technical Data

3.1 Results of Suitability Test

Calibration function	linear
Lower detection limit	NO, NO_x < 8 µg/m^3 NO_2, < 3.1 µg/m^3
Range	0 - 408 µg/m^3
Reproducibility (R)	NO :69 - 220 NO_x :37 - 123 NO_2 :28 - 137 (depending on the concentration)
Temperature dependence of the zero point (ambient temperature) 5 - 40°C	≤ 0.12%
Temperature dependence of the sensitivity (ambient temperature) 5 - 40°C	≤ 2%
Drift of the zero point	
within 24 h	≤ 2%
within period of unattended operation	≤ 10%
Drift of the sensitivity	
within 24 h	≤ 2%
within period of unattended operation	≤ 10%
Voltage dependence of the measured signal	no dependence
Availability	> 95%
Preparation time	approx. 1 h
Response time	≤ 60 s
Calibration time	≤ 2% of the measuring time
Period of unattended operation	approx. 1 month
Interference error; Response to stated Levels of interfering Substances present in the sample CO_2, SO_2, NH_3, CO, CH_4, C_2H_4, C_6H_6, H_2O	NO: ≤ 0,1 % per substance NO_x: ≤ 1% sum of substances NO_2: H_2O ≤ 1% (85% r.h.)

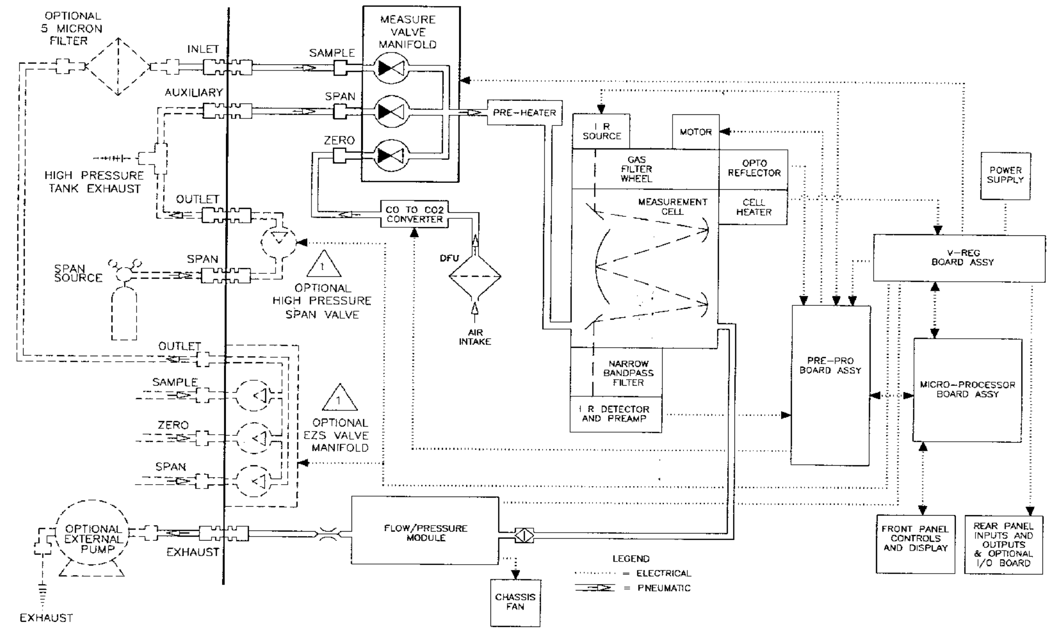
3.2 Further Technical Data

Space requirements	w x h x d 432 x 178 x 648 mm
Weight	28 kg
Power supply	198 - 264V AC, 50Hz or 99 - 132V AC, 60Hz
Signal output	100mV, 1V, 5V, 10V or 0, 1, 2, 4 - 20mA RS 232

Manufacturer	Monitor Labs/Monitor Europe (U.K.)
Agency in Germany	MS-4 Analysentechnik GmbH Am Sandberg 20 D-35519 Rockenberg Phone +49 6033 9235-0 Fax +49 6033 9235-19 Email office@ms4-analysentechnik.com Internet www.ms4-analysentechnik.com

CO Analyzer ML 9830

Flow diagram:



1. Field of Application

Automatic and continuous measurement of carbon monoxide in atmospheric air.

The Analyzer ML 9830 is a further development of the Model 8830, especially concerning the electronic equipment (modular construction, disk drive).

The suitability of the device has been tested by Rheinisch-Westfälischer Technischer Überwachungs-Verein, Institut für Umweltschutz, Chemie und Biotechnologie, Zentralabteilung Luftreinhaltung, Immission, Essen, Prüfbericht (Test report) No. 3.5.1/554/92 - 461774/01, 08.03.1995.

2. Set-up and Mode of Operation

The ML 9830 Carbon Monoxide (CO) Analyzer is a non-dispersive infrared (NDIR) photometer which uses gas filter correlation technology to measure low concentrations of CO accurately and reliably.

Infrared broadband radiation is passed through a rotating gas filter wheel where half of the wheel contains CO and half contains nitrogen. When the IR radiation passes through the CO half of the wheel, all wavelengths at which CO can absorb are completely removed from the radiation, leaving those wavelengths that are unaffected by CO to create a "reference" beam.

When IR radiation passes through the nitrogen half of the wheel, CO-specific wavelengths are not removed from the radiation and a "measure" beam, which will be attenuated by any CO in the sample, is created. The rotation of the gas filter wheel, in effect, creates a beam which alternates between "reference" and "measure" phases.

The alternating beam is passed through a multi-pass absorption cell (White cell) where CO is monitored by measuring the attenuation of the measurement beam. Since both the "reference" and "measure" phases of the beam have the same source, detector, and optical path, only the amount of CO in the sample cell can affect the difference in intensity between the two phases. This methodology results in an instrument that is very insensitive to interferant gases, fluctuations in the IR source, vibration, and accumulation of dust on the optics.

The final concentration of CO, corrected for temperature and pressure changes, is displayed in units of parts per million (ppm) or milligrams per cubic meter (mg/m^3).

3. Technical Data

3.1 Results of Suitability Test

Calibration function	linear
Lower detection limit	< 0.7 mg/m^3
Range	0 - 230 mg/m^3
Reproducibility (R)	58.8
Temperature dependence of the zero point (ambient temperature)	< 1.35%
Temperature dependence of the sensitivity (ambient temperature)	< 0.93%
Drift of the zero point	
within 24 h	< 0.13%
within period of unattended operation	< 3.7%
Drift of the sensitivity	
within 24 h	< 0.13%
within period of unattended operation	< 3.7%
Voltage dependence of the measured signal	< 0.7% (220 - 245V)
Availability	99%
Preparation time + Warm-up time	max. 10 min + 24 min
Response time	< 44 s
Calibration time	< 3% of the measuring time
Period of unattended operation	28 d
Interference error; per substance response to stated levels of interfering substances present in the sample NH_3, NO, NO_2, O_3, SO_2, CO_2, CH_4, C_6H_6, H_2O	< 3.2%

3.2 Further Technical Data

Space requirements	w x h x d 432 x 178 x 648 mm
Weight	21 kg
Power supply	198 - 264V AC, 50Hz or 99 - 132V AC, 60Hz
Signal output	100mV, 1V, 5V, 10V or 0, 1, 2, 4 - 20mA RS 232

Manufacturer Monitor Labs/Monitor Europe (U.K.)

Agency in Germany
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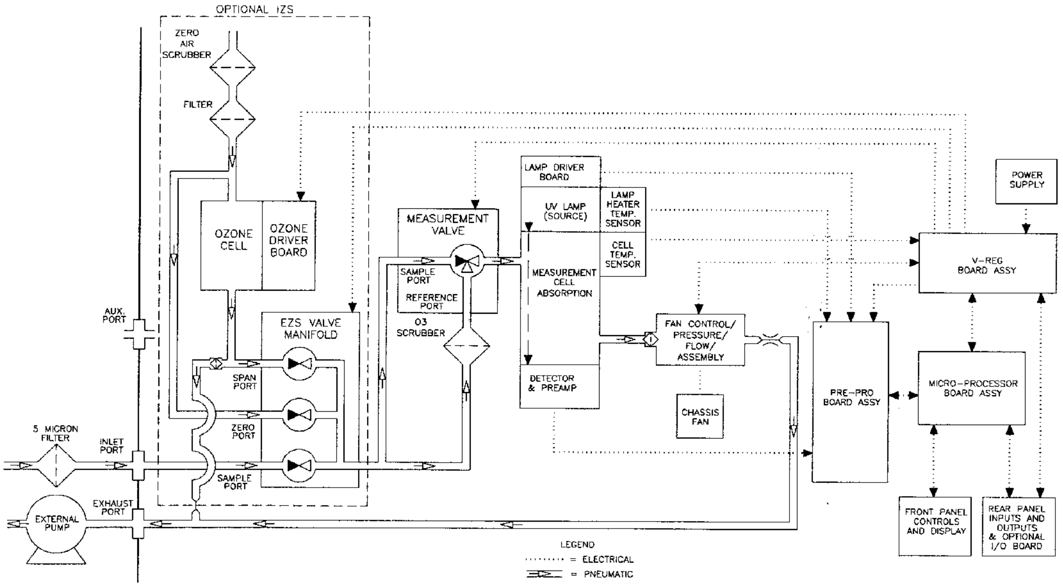
Ozone Analyzer ML 9810

Flow diagram:



1. Field of application

Automatic and continuous measurement of ozone in atmospheric air.

The Analyzer ML 9810 is a further development of the 8810 Model, especially concerning the electronic equipment (modular construction).

The suitability of the device has been tested by Gesellschaft für Umweltmessungen und Umwelterhebungen mbH (UMEG), Karlsruhe, Report No. 33-2/94, August 1994.

The Analyzer ML 9812 (built-in ozone generator) is supplied as ML 9810 with IZS Model.

Suitability test (supplementary test) by Gesellschaft für Umweltmessungen und Umwelterhebungen mbH (UMEG), Karlsruhe, Bericht Nr. 33-06/95, March 1995.

Both analyzers are identical in their basic construction.

2. Set-up and Mode of Operation

The ML 9810 Ozone analyzer is a U.V. photometer which accurately and reliably measures ozone concentrations in ambient air. The ML 9810 with ISZ has the capability to internally generate two user selectable span gas concentrations for the purpose of periodic span checks.

Upon entering the pneumatic system, the gas sample containing ozone passes through a catalyst (ozone scrubber) which converts the ozone to oxygen. The sample, without ozone, passes through an absorption cell where a detector measures the amount of 254 nm U.V. radiation transmitted. This "reference" measurement is defined as "I_O" and its value includes any other gases and particulate matter which may be present in the sample.

Upon completion of the reference measurement, the gas sample containing ozone bypasses the ozone scrubber and goes directly into the absorption cell. This "sample" measurement of U.V. radiation transmitted with ozone present is defined as "I".

The analyzer's microprocessor uses the Beer-Lambert relationship to calculate the ozone concentration using "I_O" and "I". The ozone concentration, automatically corrected for temperature and pressure changes, is displayed in units of parts per million (ppm) or milligrams per cubic meter (mg/m^3).

A built-in data display presents trends, averages, status, and historical information in a digital or graphic format. User selectable menu screens provide access to all available options and instrument setup.

The ML 9810 automatically selects the optimum measuring range for the display, printer and RS232 outputs for each parameter. Values are reported as floating point number, making range reporting unnecessary.

3. Technical Data

3.1 Results of Suitibility Test (ML 9810)

Calibration funktion	linear
Lower detection limit	1.8 ppm
Range	0 - 200 ppm (for example)
Reproducibility (R)	Laboratory: 92 Field: 19
Temperature dependence of the zero point (ambient temperature)	< -1.3% (10 – 20°C)
Temperature dependence of the sensitivity (ambient temperature)	< 1.7% (10 – 20°C)
Drift of the zero point	
within 24 h	< 0.04%
within period of unattended operation	-1,1%
Drift of the sensitivity	
within 24 h	0.01%
within period of unattended operation	0.2%
Voltage dependence of the measured signal	no dependence
Availability	> 98%
Preparation time + Warm-up time	15 + 45 min
Response time	< 144 s
Calibration time	> 5% of the measuring time
Period of unattended operation	28 d

Interference error; per substance response to stated levels of interfering substances present in the sample CH_4, C_2H_6, C_3H_8, C_6H_6, CO, CO_2, H_2S, NH_3, NO_2, SF_6, SO_2	< 6%
H_2O, Styrene	> 6%

3.2 Further Technical Data

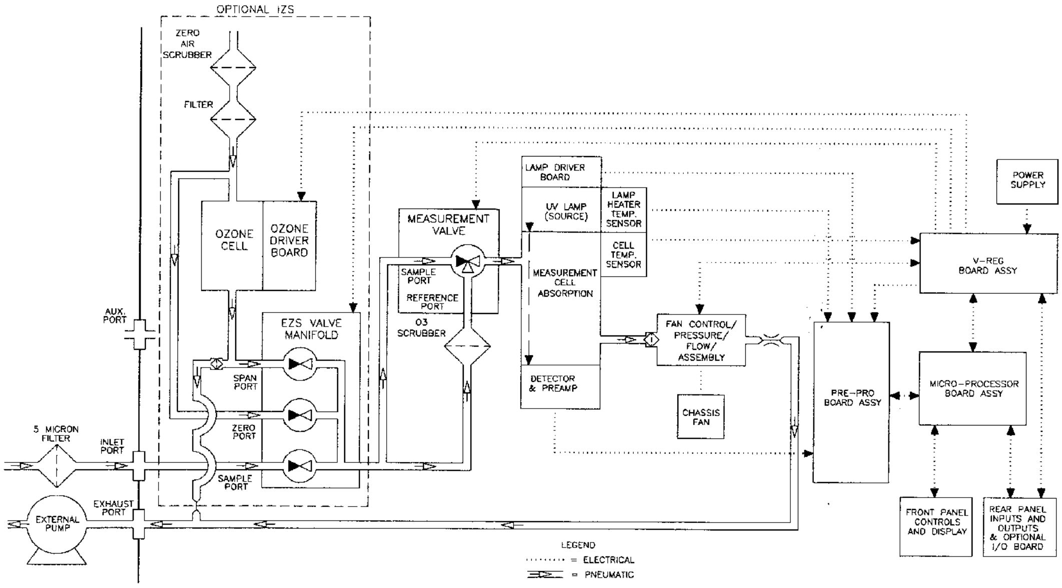
Space requirements	w x h x d 432 x 178 x 648 mm
Weight	16 kg
Power supply	198 - 264V AC, 50Hz or 99 - 132V AC, 60Hz
Signal output	100mV, 1V, 5V, 10V or 0, 1, 2, 4 - 20mA RS 232

Manufacturer	Monitor Labs/Monitor Europe (U.K.)
Agency in Germany	MS-4 Analysentechnik GmbH Am Sandberg 20 D-35519 Rockenberg Phone +49 6033 9235-0 Fax +49 6033 9235-19 Email office@ms4-analysentechnik.com Internet www.ms4-analysentechnik.com

MS 4
Analysentechnik
GmbH

Ozone Analyzer ML 9811

Flow diagram:



1. Field of Application

Automatic and continuous measurement of ozone in atmospheric air.

The suitability of the device has been tested (supplementary test) by Gesellschaft für Umweltmessungen und Umwelterhebungen mbH (UMEG), Karlsruhe, Report No. 33-06/95, March 1995.

2. Set-up and Mode of Operation

The Analyzer ML 9811 differs from the suitability-tested Model 9810 in additional installations for calibration resp. function control.

The ML 9811 Ozone (O3) Photometer has been designed to meet the U.S. EPA requirements for an ozone primary/transfer standard as required for the calibration of ozone analyzers. The ML 9811 combines the benefits of microprocessor control with the accuracy of U.V. photometric analysis.

The U.V. photometer measures concentration of ozone accurately and reliably by detecting the absorption of U.V. radiation at 254 nm by the ozone molecule. The microprocessor uses the Beer-Lambert relationship to calculate the ozone concentration.

The single path/single detector optical system is easy to maintain. With only one cell, low flow and no mirrors, cleaning frequency is less than that needed for other systems, while expendables' lifetimes are extended. An internal, vibration free pump provides up to 5 lpm of air to the scrubbing system which produces zero air for both the photometer reference and the ozone generator.

The instrument's powerful software allows the user to select either the "photometer" mode or the "analyzer with zero/span" mode. The choice determines how the photometer cycles and how the ozone generator interacts with the photometer.

The ML 9811 has the most complete status and predictive diagnostic system ever incorporated into a photometer. The multi-tasking computer operating system continuously monitors all critical operating points of the instrument to confirm proper operation. If an out of limit value is detected, an error message is sent to the display as well as serial and parallel outputs.

A built-in data display presents trends, averages, status, and historical information in a digital or graphic format. User selectable menu screens provide access to all available options and instrument setup.

The ML 9811 automatically selects the optimum measuring range for the display, printer and RS232 outputs for each parameter. Values are reported as floating point numbers, making range reporting unnecessary.

3. Results of the Supplementary Test

Calibration function	linear
Range	0 - 400 µg/m^3
Temperature dependence of the zero point (ambient temperature) 5 - 40°C	max. -1.3%
Temperature dependence of the sensitivity (ambient temperature) 5 - 40°C	max. 1.2%
Voltage dependence of the measured signal 210 - 250V	no dependence

3.2 Further Technical Data

Space requirements	w x h x d 432 x 178 x 648 mm
Weight	16 kg
Power supply	198 - 264V AC, 50Hz or 99 - 132V AC, 60Hz
Signal output	100mV, 1V, 5V, 10V or 0, 1, 2, 4 - 20mA RS 232

Manufacturer Monitor Labs/Monitor Europe (U.K.)

Agency in Germany
MS-4 Analysentechnik GmbH
Am Sandberg 20
D-35519 Rockenberg

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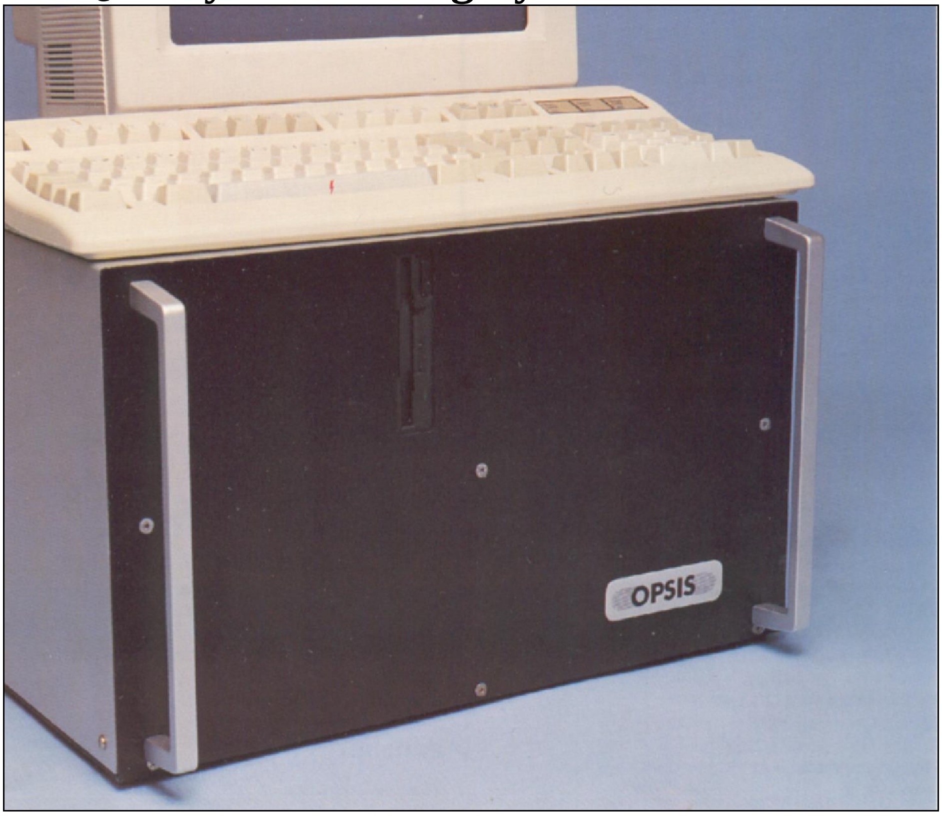
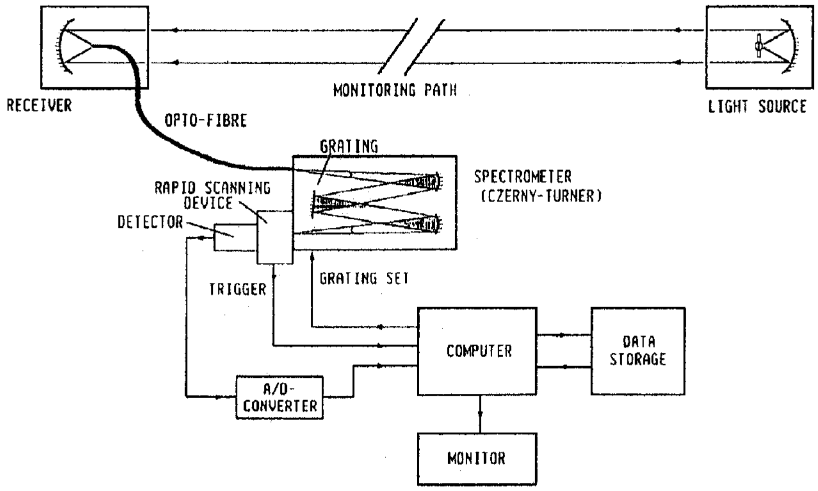
OPSIS®

Air Quality Monitoring System OPSIS AR 500





1. Field of Application

Path length monitoring of sulphur dioxide, nitrogen dioxide and ozone in ambient air (tested path length: 50 and 300 m). The measuring principle can be applied to other gases.

The suitability of the device is tested by the Gesellschaft für Umweltmessungen und Umwelterhebungen mbH (UMEG), Karlsruhe, Report No. 33-01/93, March 1993 (sulphur dioxide) and by the TÜV Rheinland, Institute für Umweltschutz und Energietechnik, Test-Reports No. 936/807014/A, February 2000 (nitrogen dioxide) and 936/807014/B, February 1999 (ozone).

2. Set-up and Mode of Operation

The Opsis system measures gaseous substances in atmospheric air using the Differential Optical Absorption Spectroscopy (DOAS). The absorption follows the Lambert-Beer law. The device is an optical remote sensing system basing on the light absorption at wave-lenghts of approx. 200 to 2000 nm.

In the Opsis air pollution monitoring system light is generated by a spark discharge in a xenon lamp installed in the emitter. A beam of light is directed over a monitoring path length until several hundred meters to the receiver connected by a fibre cable with the opto-analyzer. The analyzer measures the light absorption caused by sulphur dioxide (or other gases) spectrometrically and calculates the concentration in the air.

3. Technical Data

3.1 Results of Suitability Test

Lower detection limit	< 14 µg/m³ (SO_2) < 1.1 µg/m³ (NO_2) < 2.7 µg/m³ (Ozone)
Range	free settable
Tested path length	50 – 300 m
Reproducibility (R)	> 10
Temperature dependence of the zero point (ambient temperature)	0% (SO_2) <± 1.9 % (NO_2) <± 0.8 % (Ozone)
Temperature dependence of the sensitivity (ambient temperature)	1.6% (SO_2) <± 1.7 % (NO_2) <± 0.8 % (Ozone)
Drift of the zero point	0% (SO_2) ≤ -0.01% (NO_2, field) ≤ -0.02% (NO_2, during period of unattended operation) ≤ -0.01% (O_3, field) ≤ -0.14% (O_3, during period of unattended operation)
Drift of the sensitivity	0% (SO_2) ≤ -0.03% (NO_2, field) ≤ -0.1% (NO_2, during period of unattended operation) ≤ -0.0% (O_3, field) ≤ -0.003% (O_3, during period of unattended operation)
Voltage dependence of the measured signal	no dependence
Availability	98% (SO_2) > 98,6 % (NO_2, Ozone)
Period of unattended operation	28 d (SO_2) approx. 3 month (NO_2, Ozone)
Interference error; Response to stated levels of interfering substances present in the sample 28 tested anorganic and organic substances	< 2% (SO_2)
Interference error; Response to stated levels of interfering substances present in the sample (CO_2, SO_2, H_2S,NH_3, NO_2, NO, CH_4, C_2H_4, C_6H_6, H_20)	< 6% (NO_2, Ozone)

3.2 Further Technical Data

Space requirements	w x h x d 440 x 260 x 600 mm
Weight	approx. 30 kg
Power supply	220V AC (± 10%)
Power requirement	110 W

Manufacturer
Opsis AB
Furuland, Sweden

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OPSIS GmbH,
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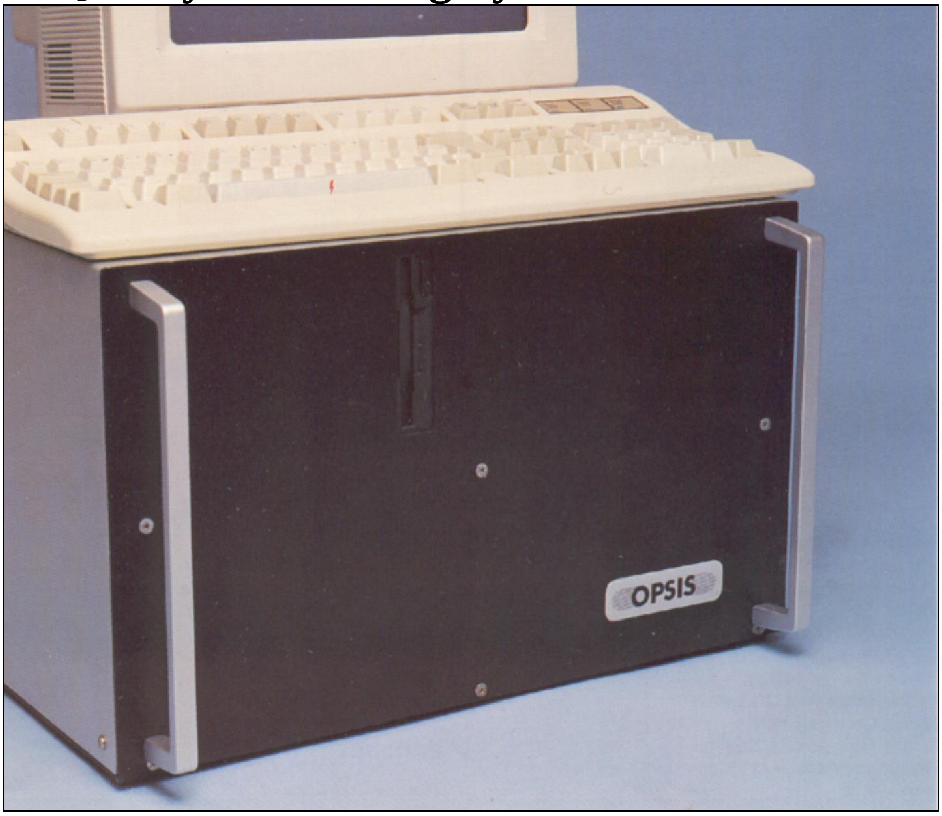
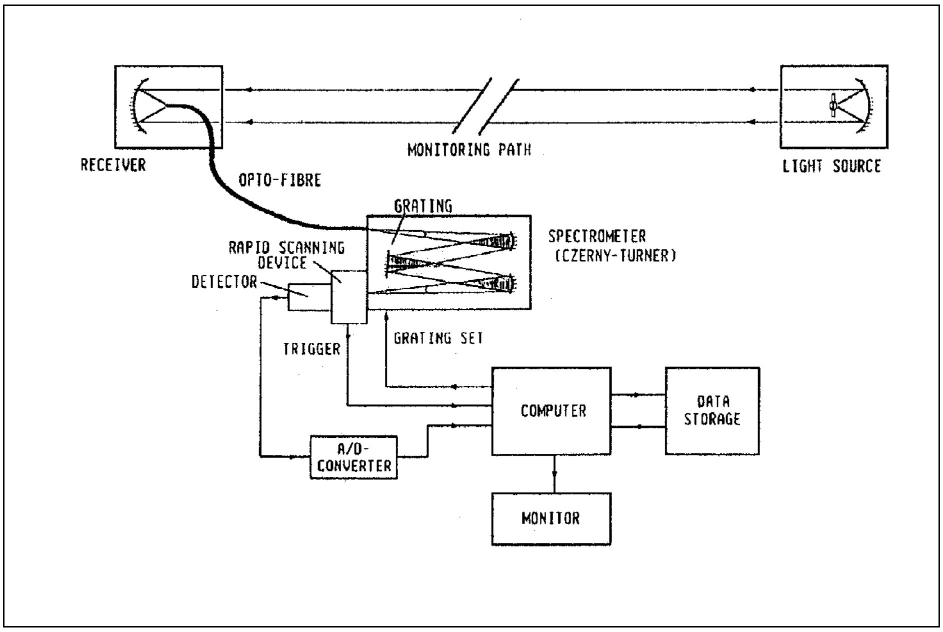
OPSIS®

Air Quality Monitoring System OPSIS AR 502 Z





1. Field of Application

Path length monitoring of benzene in ambient air (tested path length: 50 and 300 m). The measuring principle can be applied to other gases.

The suitability of the device has been tested by Gesellschaft für Umweltmessungen und Umwelterhebungen mbH (UMEG), Karlsruhe, Report No. 33-01/93, March 1993.

The device is a further development of the OPSIS AR 500 model (see foregoing pages) which was successfully tested (measurement of sulphur dioxide, Ozone and nitrogen dioxide.

2. Set-up and Mode of Operation

The Opsis system measures gaseous substances in atmospheric air using the Differential Optical Absorption Spectroscopy (DOAS). The absorption follows the Lambert-Beer law. The device is an optical remote sensing system basing on the light absorption at wave-lenghts of approx. 200 to 2,000 nm.

The device generates light by a spark discharge in a xenon lamp installed in the emitter. A beam of light is directed over a monitoring path length until several hundred meters to the receiver connected by a fibre cable with the opto-analyzer. The analyzer measures the light absorption caused by benzene (or other gases) spectrometrically and calculates the benzene concentration in the air.

The basic construction of the AR 502 Z is similar to the AR 500 model. For the measurement of benzene, the following improvements are necessary:

- a higher spectral resolution of the grating
- introduction of a feedback control loop between transceiver and receiver
- introduction of the FC 150 calibration unit

3. Technical Data

3.1 Results of Suitability Test

Lower detection limit	< 0.39 µg/m^3
Range	free settable
Tested path length	300 m
Reproducibility (R)	> 10
Temperature dependence of the zero point (ambient temperature)	<± 1.1 % (0°C-35°C)
Temperature dependence of the sensitivity (ambient temperature)	<± 2.7 % (0°C-35°C)
Drift of the zero point	≤ -0.01% (field) ≤ -0.01% (during period of unattended operation)
Drift of the sensitivity	≤ -0.03% (field) ≤ -0.03% (during period of unattended operation)
Voltage dependence of the measured signal	no dependence
Availability	> 92.4 %
Period of unattended operation	approx. 3 month
Calibration time	approx 30 min
Interference error; Response to stated levels of interfering substances present in the sample (CO_2, SO_2, H_2S,NH_3, NO_2, NO, CH_4, C_2H_4, C_6H_6, H_20)	< 6%

3.2 Further Technical Data

Space requirements	w x h x d 440 x 260 x 600 mm
Weight	approx. 30 kg
Power supply	220V AC (± 10%)
Power requirement	110 W

Manufacturer

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Agency in Germany

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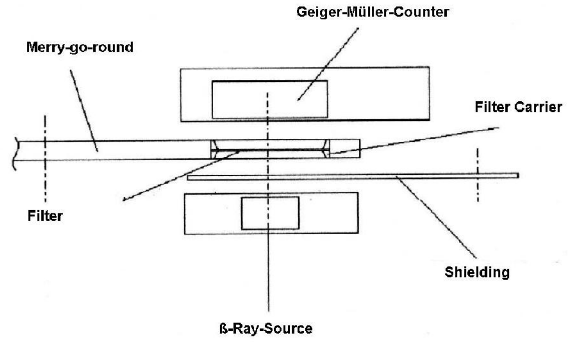
Ambient Particulate Monitor OPSIS SM 200 (PM 10)

Measuring System



1. Field of Application

Automatic continuous measurement of suspended particulate matter in ambient air with PM_{10} pre-separation.

The suitability of the device has been tested by TÜV Rheinland, Institut für Umweltschutz und Energietechnik, Test report 936/801013/A of 29 January 2003.

2. Set-up and Mode of Operation

The device is based on the measuring principle of beta absorption of suspended particulate matter which, during the sample taking process, is separated onto a membrane filter.

The measuring instrument consists of sampling head and suction inlet, pump module, sampling/ measuring module, and filter containers for the storage of new and used filters.

A PM_{10} sampling inlet, which functions as a pre-separator for the suspended particulate matter sucked in from ambient air (volume flow: 1.0 m^3/h), is used as a sampling head.

Optionally, TSP-, $PM_{2.5}$- or PM_1 sampling inlets can be used as well.

The sampling/measuring module controls the pump and also contains the mechanical system for the filter transport inside the device. It also controls big parts of the pneumatic system, the measuring instruments as well as all the electronic installations and microprocessors required for its operation and control.

3. Technical Data

3.1 Results of Suitability Test

Lower detection limit	≤ 1.29 µg/m^3
Range	0 - 1000 µg/m^3
Reproducibility (R)	> 10 (field)
Temperature dependence of the zero point (ambient temperature)	5°C - 40°C < ± 0.48 µg/m^3
Temperature dependence of the sensitivity (ambient temperature)	5°C - 40°C < ± 1.22 %
Drift of the zero point within 24 h	< 2 µg/m^3
Drift of the sensitivity	≤ 3.14%
Voltage dependence of the measured signal	no disturbance > 0.77% detectable
Availability	> 97.8%
Calibration time	< 5% of the measuring time
Period of unattended operation	1 month
Interference error	< 0.2 µg/m^3
Deviation of the sampling volume	< 3 % average value 24 h < 5 %instantaneous value

3.2 Further technical Data

Sampling and Measuring module

Space requirements	43 x 60 x 26 cm
Weight	approx. 45 kg
Power supply	220V / 50Hz, approx. 800 W

Pump module

Space requirements	32 x 22 x 30 cm
Suction tube	1.5 m
Weight	20 kg

Hersteller	OPSIS AB, Furuland, Sweden.
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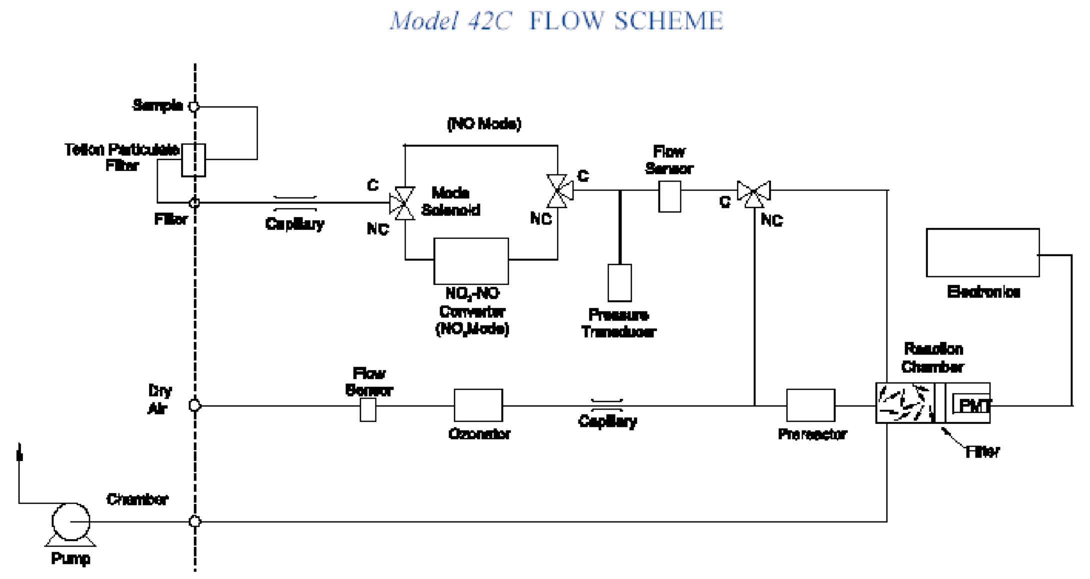
Thermo ESM Andersen

$NO/NO_2/NO_X$ Analyzer
Model TE 42 C


Model 42C FLOW SCHEME

1. Field of Application

Continuous and automatic measurement of nitrogen oxides in ambient air (NO and NO_2).

Suitability test (supplementary test) by RWTÜV Anlagentechnik GmbH, Bericht Nr. (test report) 20 385 383/01, November 2001.

The Trace Level version of this model has a detection limit of only 50 ppb.

The device outputs ammonia values, using a special converter module which oxidizes NH_3 to NO before the chemiluminescence analysis.

2. Set-up and Mode of Operation

The chemiluminescence NO-NO_2-NO_X Analyzer utilizes one small diameter (28 mm) photomultiplier tube and one reaction chamber which are time-multiplexed for NO and NO_X measurements. The difference between the two measurements allow the generation of three continuous signals of NO, NO_2 (NO_X –NO) and NO_X .

As illustrated in the diagram, sample gas enters the TE 42C, flows through the sample capillary and then either flows through the mode valve (“NO” or ”NO_X”) and the NO_2 to NO converter to the reaction chamber.

There, the NO reacts with ozone (O_3) to produce a characteristic chemiluminescence. Reacted gas is drawn from the reaction chamber through the internal pump. The pump exhaust is fed through a charcoal trap where any residual ozone is removed and vented.

The TE 42C model automatically cycles between the NO and NO_X modes. Signals from the photomultiplier tube are conditioned and then fed to the microprocessor where a sophisticated mathematical algorithm is utilized to calculate the three independent outputs: NO, NO_2 and NO_X.

3. Technical Data

3.1 Results of the Suitability Test

Calibration function	linear
Lower detection limit:	< 5 µg/m^3
Range	0 - 1350 µg/m^3
Reproducibility	40...202
Temperature dependence of the zero point	< 2 %
Temperature dependence of the sensitivity	< 2%
Drift of zero point	< 10%
Drift of sensitivity	< 2%
Voltage dependence Of the measured signal	no disturbance
Availability	> 96%

3.3 Further Technical Data

Signal Output	RS232 Bayern/Hessen-Protocol, 4 - 20 mA; Voltage: free settable
Display	LCD/LED, remote control
Space requirements	17“ ; 5 HU ; 58,5 cm
Weight	approx 24 kg

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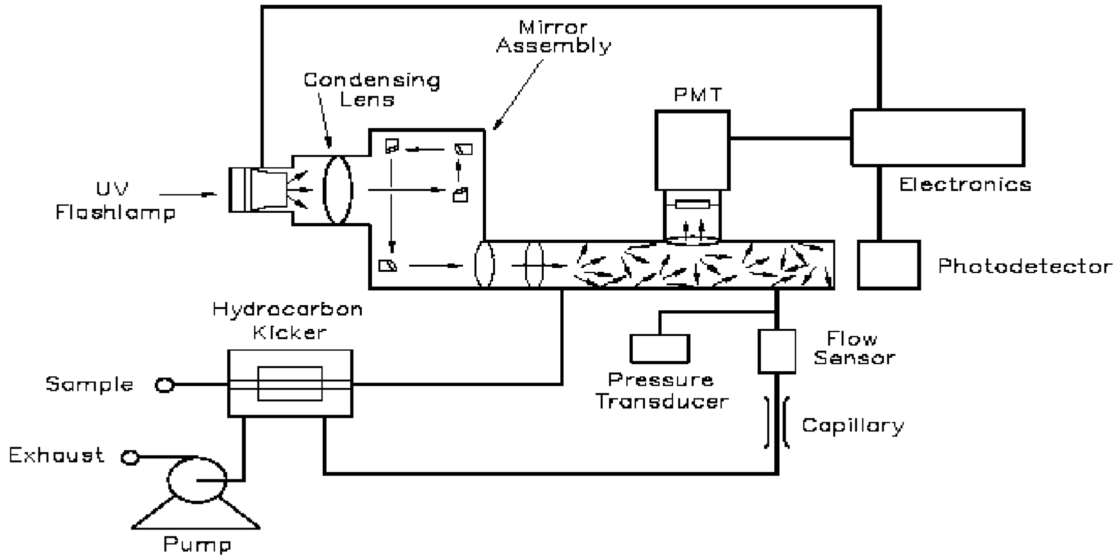
Thermo ESM Andersen

SO_2 Analyzer
Model TE 43 C

Model 43C - Optical System



1. Field of Application

Continuous and automatic measurement of sulphur dioxide (SO_2) in ambient air, without requirement of consumable gases or wet chemicals.

Suitability test (supplementary test) by RWTÜV Anlagentechnik GmbH, Bericht Nr. (test report) 3.5.1/324/95-598031/01, September 1996.

An optional converter enables continuous measurements of hydrogene sulfide, oxidizing H_2S to SO_2 before monitoring.

2. Set-up and Mode of Operation

As illustrated in the above diagram, pulsed ultraviolet light passes through a reflection mode optical filter system to a measurement chamber where it exites SO_2 molecules. As these molecules return to the ground state they emit a characteristic fluorescence with intensity linearly proportional to the concentration of SO_2 molecules in the sample. The fluorescence light then passes through a second filter to illuminate the sensitive surface of a photomultiplier tube. Electronic amplification of the output of the photomultiplier tube provides a meter reading and an electronic analogue signal and RS 232 data output.

A second UV detector senses the lamp intensity and maintains a constant UV excitation level by a closed loop feedback control of the lamp power supply. This assures a long-term span stability. The reflective filter optics result in a very low and unvarying level of scattered light. This assures a long-term zero stability.

Interferences from hydrocarbons are reduced using a hydrocarbon kicker. In this system a permeable membrane eliminates aromatic compounds from the air sample.

3. Technical Data

3.1 Results of the Suitability Test

Calibration function	linear
Lower detection limit:	< 3 µg/m³
Range	0 – 2 ppm
Reproducibility	45...180
Temperature dependence of the zero point	< 0.5 %
Temperature dependence of the sensitivity	< 2 %
Drift of zero point	< 2 %
Drift of sensitivity	< 2 %
Voltage dependence of the measured signal	no disturbance
Availability	> 97 %

3.3 Further Technical Data

Signal Output	RS232 Bayern/Hessen-Protocol, 0 - 10 V
Display	LCD/LED
Space requirements	17“ ; 5 HU ; 58.5 cm
Weight	approx 19.5 kg

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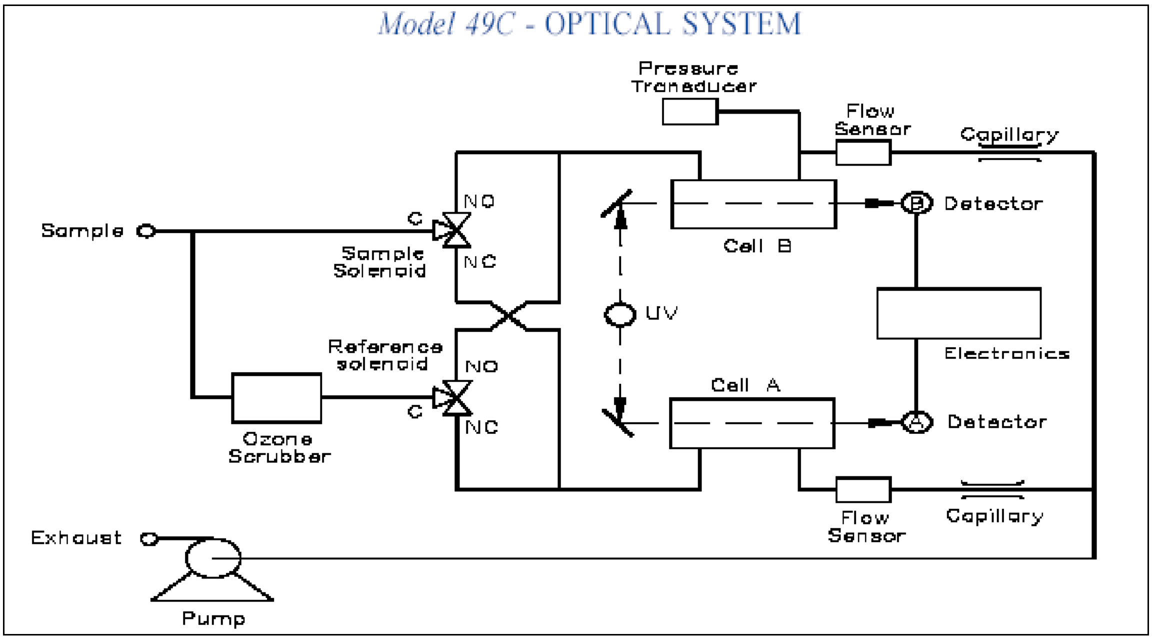
Thermo ESM Andersen

Ozone Analyzer
Model TE 49C


Model 49C - OPTICAL SYSTEM

1. Field of Application

The instrument is designed for the automatic and continuous measurement of ozone (O_3) in ambient air.

Suitability test (supplementary test) by RWTÜV Anlagentechnik GmbH, Bericht Nr. (test report) 5.01/324/95-598031/01, February 1999.

2. Set-up and Mode of Operation

As illustrated in the schematic, the TE 49C model is a dual call UV (ultraviolet) photometer. No gaseous or liquid consumables are required.

This instrument is cyclic. In the beginning of each cycle, sample enters one cell and reference air (sample with ozone catalytically converted to oxygen) enters the second cell. Detectors then measure the light intensity transmitted through each cell.

During the second half of the cycle, the roles of the two cells are interchanged by appropriate switching of the solenoid valves.

The instrument then determines the ozone concentration by computing the attenuation ratio of light, due to ozone absorption, from the two half cycles. The ozone concentration is directly related to the attenuation ratio. A transducer to measure changes in the temperature and pressure is directly interfaced with the micro-computer to continually correct for changes in ambient temperature and pressure.

The monitor is available with an integrated ozone generator for ozone calibration gas.

3. Technical Data

3.1 Results of the Suitability Test

Calibration function	linear
Lower detection limit:	< 1.95 µg/m³
Range	0 – 1 ppm
Reproducibility	224...674
Temperature dependence of the zero point	< 2 %
Temperature dependence of the sensitivity	< 2 %
Drift of zero point	< 2 %
Drift of sensitivity	< 2 %
Voltage dependence of the measured signal	no disturbance
Availability	> 98 %

3.2 Further Technical Data

Signal Output	RS232 Bayern/Hessen-Protocol, 0 – 10 V; free settable
Display	LCD/LED, remote control
Space requirements	17“ ; 5 HU ; 58.5 cm
Weight	approx 16 kg

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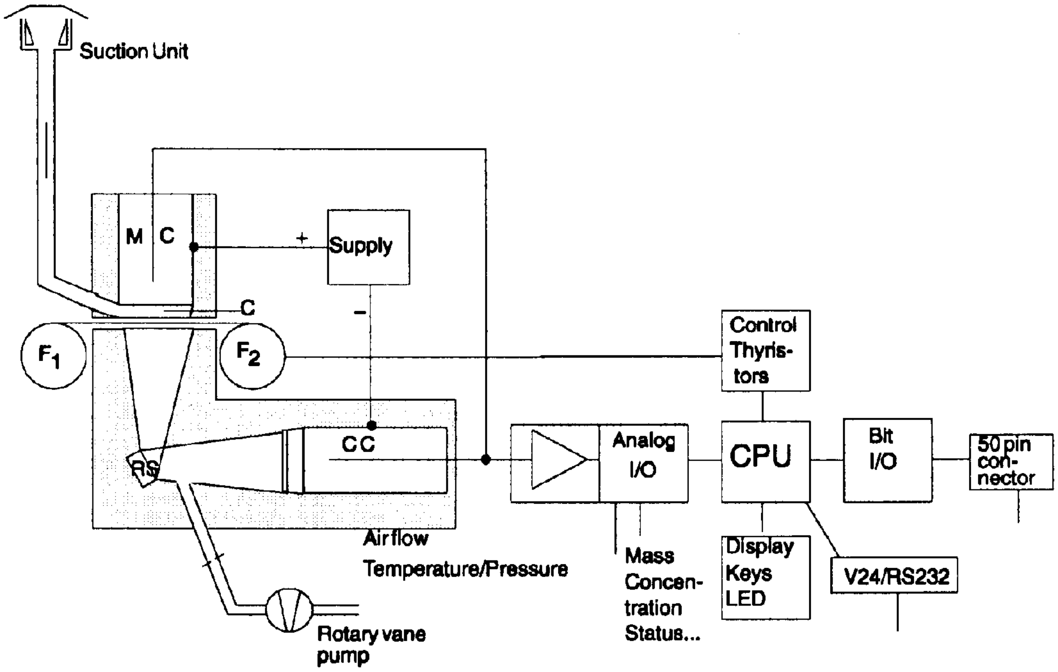
Thermo ESM Andersen

Particulate Monitoring Instrument FH 62 I-N



1. Field of Application

- Federal Republic of Germany
Approved according to the federal guidelines for continuous measurement of dust and the guidelines for telemetric air quality networks. Application for comply with the federal immission control act and for the practice of the SMOG- protection laws of the german states. The instruments FH 62 I and FH 62 I-N are the "standard" for the 16 air quality networks of the german states.

Approvals:

FH62I (1 m^3/h): Test Report-No.11,1980, LIS Essen; Federal Work Sheet 12,1981 // FH62I (3 m^3/h) Test Report-No.68,1986, LIS Essen, Joint Ministerial Sheet No 24,1986 // FH62I-N (1 and 3 m^3/h) Test Report No.104,1991,LIS Essen, Joint Ministerial Sheet No 45,199, Page 1142
Guideline VDI 2463 Part 5

- USA
Approved for automatic and continuous measurement of PM-10 with the inlet SA 246 b
Approval: FH62I-N PM-10 Beta Attenuation Monitor (1 m^3/h) by EPA; Approval-No. EQPM-0990-076

- EC
The EPA equivalent test is nearly comparable with the thoracic convention of the EEC directive 80/779

Other Field of Application:

Measurement of the MPC-values (max. permissible concentration) for work place monitoring.

2. Set-up and Mode of Operation

The particulate monitoring instrument FH 62 I-N uses the radiometric principle of the beta ray attenuation by a 2-beam compensation method. It is the only system which employ that the accumulated mass of particles is measured, observed and displayed; doing this at the same time during the dust sampling. From this measurement process is resulted a real-time measurement of the dust on a single filter spot. One filter spot remains in a single filter spot position for a long time (e.g. at 50 µg/m^3 for 48 hours) until the maximum load is reached. A step-wise response with pre-selected time and range interval is not necessary.

The picture shows the principle of the FH 62 I-N. The place C for dust sampling and measurement is located between source RS and chamber MC. The power supply of the chambers has an opposite voltage. The chamber MC gives a positive and the chamber CC a negative output voltage. The output of both chambers are switched together. At the common output A zero volt is the result, if no particles are between source and the chambers.

The dust-laden air is drawn through the sampling system. A section of filter uncoated by dust is indexed into the measuring section. Only a single filter spot is used during the long sampling time. The pump is switched on and the system is balanced to zero at the output A. With the dust sampling on the spot C more and more particles are collected. This increasing dust layer produces a progressive attenuation of the beta beam in RS-C-MC and the electrical output is growing. The growing mass of particles produces an integral output-signal as an accumulated mass-curve over time. This system is a "direct observer" of the mass of particles on point C. The mass value (µg) on the spot C is known every time and it is easy to observe the velocity of particle sampling.

The measured values are amplified and passed via an analog/ digital converter to the processor unit. From the progressive growth of the dust per unit of time and the air flow rate, the dust concentration is computed and displayed in real-time. The single filter spot is remaining in one position for the duration of the measuring time (e.g. 48 hours at 50 µg/ m^3). After reaching the max. load, the cycle is beginning with a filter change.

3. Technical Data

3.1 Results of Suitability Test FH 62 I-N (1 and 3 m^3/h)

Calibration function	$x=1/b\ y - a/b$ $x=1.024-0,9$
Lower detection limit	10 $\mu g/m^3$
Tested range	0 to 2400 $\mu g/m^3$ max. 20 mg/m^3
Reproducibility	42 to 28
Temperature dependence of the zero point	not detectable
Temperature dependence of the sensitivity	not detectable
Drift of the zero point	0 %
Drift of the sensitivity	0 %
Voltage dependence of the measured signal	none
Availability	99.5 %
Calibration time	not necessary
Maintenance interval	> 3 months

3.2 Further Technical Data

Signal output	RS 232 , 0 - 10 V; 0 - 20 mA
Signal indication	LCD/LED, remote connection
Space requirements	w x h x d 485x488x563mm (19",10 HU)
Source	^{85}Kr ; 1,85 GBq (50 mCi)
Rad. approval	By 33/88

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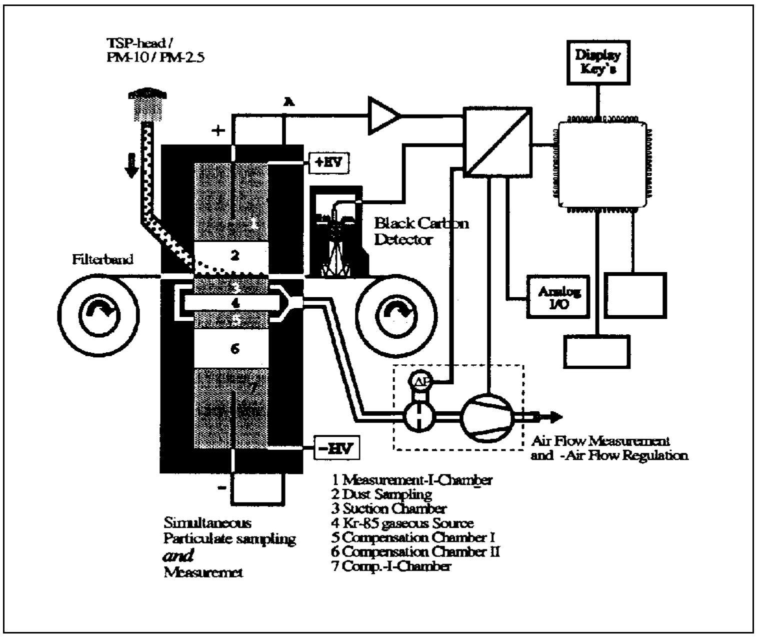
Thermo ESM Andersen

Particulate Monitoring Instrument FH 62 I-R (TSP, PM_{10})



1. Field of Application

- Federal Republic of Germany
Approved according to the federal guidelines for continuous measurement of dust and the guidelines for telemetric air quality networks. Application for comply with the Federal Immission Control Act. The instruments FH 62 is the "standard" for the 17 air quality networks of the German states (worldwide approx. 45 networks).

<u>Approvals:</u>
TSP:
TÜV-report No. 240 11676 (1995)
TÜV Umwelttechnik GmbH, München
Joint Ministerial Sheet-No. 33 (1996), Page 705;
Guideline VDI 2463 Page 5

PM_{10}:
TÜV-report No. 240 22605 (2000), according to the European standard <u>EN 12341</u> to demonstrate reference equivalence of monitors for controlling the limit values of the Council Directive 1999/30/EC to fulfill the Council Directive 96/62/EC "ambient air quality assessment and management". The approval was published in the Joint Ministerial Gazette of the Federal Ministers (GMBl) No. 60 (2000) page 1195

Other Field of Application:
Measurement of the MPC-values (max. permissible concentration) for work place monitoring.

2. Set-up and Mode of Operation

The Particulate Monitoring Instruments of the type FH 62 are the only radiometric instruments measuring, observing and displaying accumulated particle mass **simultaneously** during the collection of the dust. This mode of operation permits real time measurement of the dust on a filter and on-line measurement/ display of the mass concentration the suspended particulate in ambient air.

The Particulate Monitoring Instrument FH 62 I-R utilizes the radiometric principle of beta - attenuation by a two - beam - compensation method. Due to this process a very high measurement stability is achieved, because for each measurement value a reference value is determined simultaneously in a separate measuring section:

This reference section is interconnected with the measuring section physically, having an equal effect from ambient temperature and pressure fluctuations in both systems. This is a basic condition for a precise and steady compensation. A clean section of the filter tape moves into the measuring position (2). Ambient air is pulled through the sample system. The dust particles contained in the air are deposited on the filter.

For particle sampling the single filter spot principle is used. A single filter area remains for an extended period in the "chamber for particulate collection and measurement" (2) until the full load has been reached (1500 µg), or if one of filter change parameters has elapsed (time of day, pre-selected sample time, low pressure, air flow rate, maximum, mass). Following the full filter section moves out and a fresh filter section in the measuring position (automatic filter change). A new cycle starts.

The chamber for particulate collection and measurement (2) is located between source (4) and the ionization chamber (1). The supply voltages of the ionization chambers (1 + 7) have opposite polarities. As output signal chamber 1 delivers a positive and 2 a negative current. The outputs of both I- Chambers are interconnected and display the continuous and compensated signal. This is comparable with an "arm balance". In this process different thickness and/or different ambient conditions are compensated. After each filter changes an automatic zero adjustment is made.

During filter sampling on the area 2 with dust, an increasing number of particles is precipitated. This layer of dust that is building up continuously, weakens the intensity of the beta - beam in the section (4 - 2 - 1). The electric signal at the output A rises. At any time this output signal delivers the actual information of the sampled mass on the filter spot. This system is a so-called "direct observer" of the dust mass at point 2. To each point in time the mass value (in µg) on the filter spot is known and one can observe the speed the particle sampling. The measuring signal at the output A is amplified and reaches via one analog/digital - converter the processor - unit (CPU). From the temporal increase of the dust mass the calculation and display of the concentration result. For the calculation of the dust concentration the current air flow rate is exactly measured with a probe. Thus, the current concentration is computed exactly even the air flow rate should fluctuate. By using size-selective inlets (PM_{10}, cyclone, $PM_{2.5}$), the flow rate has to be constant. Therefore either a RPM-regulated vacuum pump or a proportional valve is provided. The influence of unsteady humidity in ambient air as well as the danger of water condensation in the sampling tube can be prevented through the employment the heated sampling tube. This possible influence is only important to consider at high humidity in the summer or at foggy days.

3. Technical Data

3.1 Results of Suitability Test FH 62 I-R (TSP)

Calibration function	y = 0.99 x – 5.06 R^2 = 0.997
Lower detection limits	2 µg/m^3, 0.5 µg\m^3 (24 h)
Tested range	0 to 5000 µg/m^3
Reproducibility	29 - 149
Temperature dependence of the zero point	< 0.1% / 10 K
Temperature dependence of the sensitivity	< 0.1% / 10 K
Drift of the zero point	0.1 %
Drift of the sensitive	0.1 %
Voltage dependence of the measured signal	none
Availability	99.8 %
Calibration time	< 0.1 %
Maintenance interval	> 6 months

3.2 Results of Suitability Test FH 62 I-R (PM$_{10}$) with 2 different PM-10 Inlet Models (Digitel; US-EPA)

Calibration function	y = 1,07x-7,27 R^2= 0.96
Lower detection limit	0.5 µg\m^3 (24 h)
Tested range	0 to 5000 µg/m^3
Reproducibility	29 - 149
Temperature dependence of the zero point	< 0.1 % / 10 k
Temperature dependence of the sensitivity	< 0.1 % / 10 k
Drift of the zero point	0.1%
Drift of the sensitive	0.1%
Voltage dependence of the measured signal	none
Availability	99.8 %
Calibration time	< 0.1 %
Maintenance interval	> 6 months

3.3 Further Technical Data

Signal output:	two RS 232 , 0 - 10V ; 0 - 20mA RS 232 Bayern/Hessen-Protocol
Signal indication	LCD/LED, remote con.
Space requirements	w x h x d= 485x488x563 mm 19", 7 HE
Source	^{85}Kr ; 1.85 GBq
Rad. approval	By 43/95

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