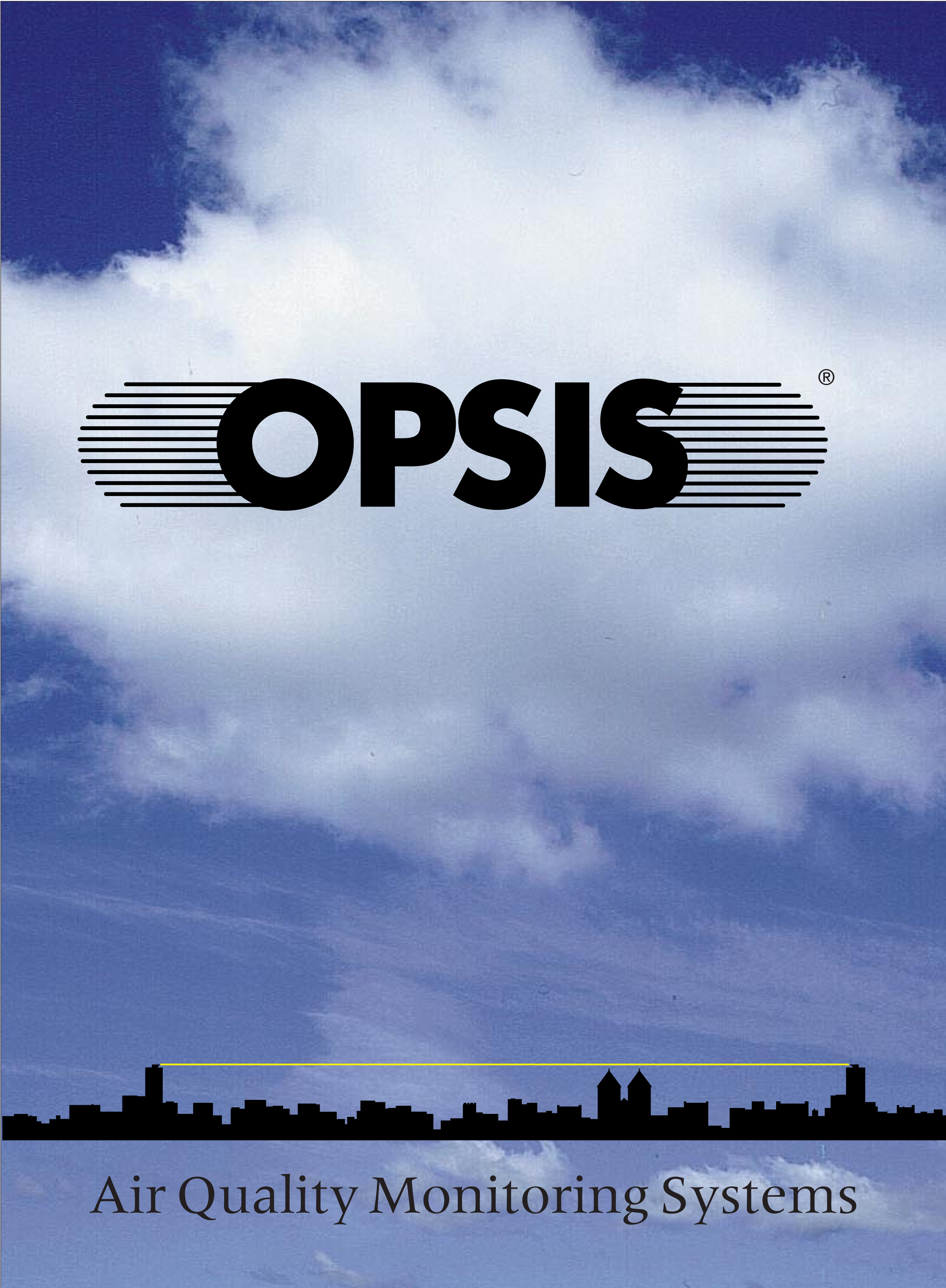


OPSIS®

Air Quality Monitoring Systems

The Opsis air quality monitoring system

Throughout the world, demands for air quality information continue to increase. Emissions legislation, scientific studies, environmental concerns and urban planning procedures are creating a variety of complex demands. These call for a single, cost-effective method of air quality monitoring: one that will acquire maximum data of highest quality and present it in any number of ways with minimum time involvement.

This brochure describes Opsis, a comprehensive, multi-analytical system acknowledged for its accuracy, flexibility, ease of use and low cost of ownership.

Some Opsis benefits

Multi-analytical. An Opsis system will measure any gas specified in the operating software. Opsis provides the freedom to meet the specific needs of a wide variety of applications.

Non-contact, open path measurement. Opsis detects gases by their light absorption, measuring over an open path that may be several hundred metres long. This gives a highly accurate picture of air quality, free from local distortion.

Fast. Opsis provides rapid, continuous measurements of all the gases specified in its system. Automatically logged data is available for any subsequent analysis in the future.

Wide application. Opsis is an ideal system for background air quality or fenceline monitoring, and for locations such as airports; here, speed of data capture allows detailed analysis of rapidly occurring events. Several lightpaths may be operated by one system.

Simple report generation. Opsis software allows any report or analysis to be generated automatically, or 'on demand' through a few keystrokes. Data is easily portable to other systems for integration into wider studies.

Low maintenance. A minimum of downtime for maintenance and calibration allows Opsis to meet the most stringent operating criteria.

Easy to install. Opsis equipment will mount onto any permanent structure – walls, roofs and parapets are typical. There is no need for special ground-level installations. Mobile and vehicle-mounted systems are also available.

On line supervision. All remote aspects of an Opsis system are accessible via telemetry from the central station. This allows routine checking of system parameters without site visits.

Approved on an international basis. Opsis open-path technology has been evaluated and approved by scientific institutions and authorities on an international basis.

World wide coverage. Opsis is supported internationally by a world wide network of representatives.

By correlating the data from an Opsis multipath system with weather information, the air quality of an entire city sector can be mapped.

Opsis – a fully computerized air quality monitoring system

Opsis measures gases by DOAS (Differential Optical Absorption Spectroscopy), using Beer-Lambert's Law.

In an Opsis system, a beam of light is projected to a receiver, and passed to the Opsis analyser through a fibre optic cable. In an air quality monitoring application, the path travelled by the light will typically be some hundreds of metres long. Here, specific gases will absorb light from known parts of the spectrum. This allows the analyser's computer to measure gases (as a function of light absorption) through a spectrometer and to log results for immediate display or future analysis.

Major benefits are speed, reliability and Opsis' multi-analytical capability. The analyser will measure all gases whose characteristics are resident in software, with the further benefit that dedicated sensors are not required.

A flexible response to a wide range of applications

Opsis is an extremely flexible system: depending on the application, criteria such as path length, monitoring times and the range of gases monitored can be chosen to provide the best possible response to a user's needs. One Opsis system will operate several separate lightpaths, allowing a single system to monitor very wide areas.

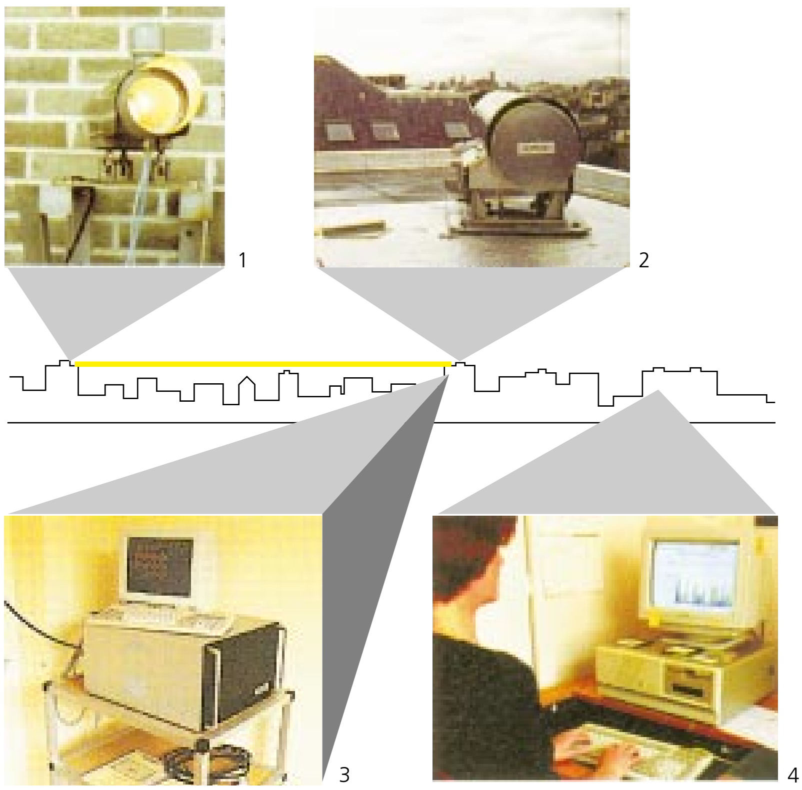
Opsis offers a completely modular approach to system building. This means that a system may be extended at any time to meet the user's changing needs with no redundancy of existing equipment.

Opsis is now in use on hundreds of sites around the world. Some applications include:

- Roof-top monitoring, typically to measure background air quality for environmental surveillance and long-term trend analysis in urban areas.
- Street-level monitoring using stationary or mobile stations, for immediate, on-line information on the air quality affecting pedestrians and other city dwellers.
- Fence-line monitoring. The Opsis lightpath provides an ideal method of monitoring emissions that may leave industrial areas to affect the wider community.
- Airport monitoring. Opsis will provide rapid, simultaneous measurement of the gases emitted by the aircraft engines. High resolution data allows detailed study of aircraft types, with the potential for informed planning to reduce environmental impact.
- Background monitoring. Opsis' sensitivity allows the measurement of very low levels of background pollution to gain better knowledge of local environments.

More than just gas concentrations

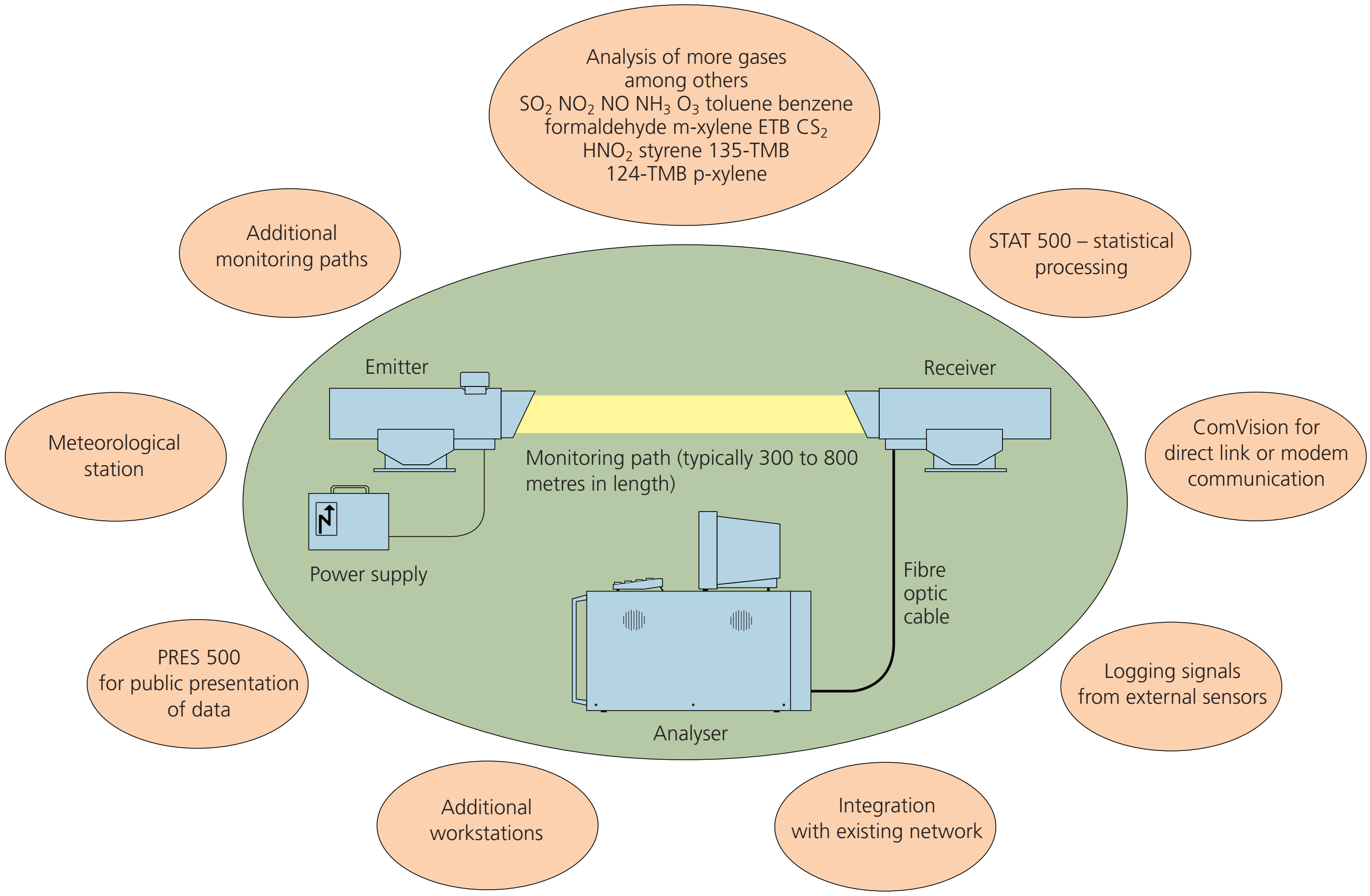
Opsis data can be automatically integrated with temperature and pressure information to provide automatic compensation. This information is logged to a hard disk with Opsis' validation data.



The Opsis long-path air quality monitoring system brings new standards of accuracy and data quality to environmental monitoring. Every minute, several thousand cubic metres of air interact with a beam of light between the lightsource (1) and the receiver (2). When captured by the receiver, this light contains information on gases in the air it has penetrated.

This information is extracted by spectrographic analysis (3). Because of the long monitoring path, the results represent averages over both the length of the lightpath and the user-defined measurement interval.

Results are logged as data that can be collected for further analysis by modem (4) – from anywhere in the world.



An Opsis air quality monitoring system includes:
- At least one emitter with xenon lamp and power supply.
- At least one receiver which captures light from the emitter.
- A fibre optic cable which takes light from the receiver to the analyser.
- An analyser, which is the system's central unit. Here, received light is analysed and measurements evaluated. Data is then available for display or analysis.

Opsis technology is subject to a continual process of development. This, with the modular construction of Opsis systems, means that it is always possible to expand or update an installation without redundancy of viable equipment.

At the same time, other environmental information may be accepted from suitable sensors. Typically, this might include wind speed and direction, rainfall and barometric pressure. All this information is available for integration into air quality reports available through standard Opsis software packages.

Clear, concise data presentation

Air quality data and other information logged to the analyser's hard disk is available for rapid processing, analysis and presentation through user-friendly Opsis software modules. These provide report generation (automatically or on demand), statistical analysis, a wide range of graphic data presentation formats and communications with other systems. Fully automatic public information displays are available, for example.

Opsis' software has been specifically developed for non-specialist operators, and allows rapid familiarisation after a short period of training.

A minimum of supervision and maintenance

Opsis is a fully automatic system requiring a minimum of human intervention. This extends to self-evaluation of data, and means that daily operation is essentially limited to report collection and routine confirmation of basic operation.

Neither is it necessary to visit the analyser to check system parameters. The analyser is fully accessible via telemetry, allowing the operator to review and adjust the system from an office desk exactly as if he or she was actually on site.

Product overview

Hardware

The analyser is the central unit in every Opsis system, and may be programmed for the simultaneous measurement of a range of compounds. As an example, these might include toluene, benzene, formaldehyde, ozone, sulphur dioxide and nitrogen dioxide. The analyser uses a standard PC, and all data is logged to the computer's hard disk. Data can also be transmitted to other systems via modem or serial communication, or as analogue signals.

The chosen path (or paths – several can be operated by one system) is monitored by projecting light between an emitter and a receiver. There is a range of systems available to suit different applications, designed for different path lengths.

Each emitter requires a power supply to operate its lamp.

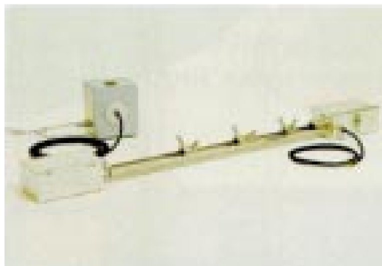
Certain applications require a mobile monitoring system. For these, there is an Opsis system which includes a combined emitter and receiver. Here, light is returned by a retroreflector – a specialised mirror (not shown) – which may easily be mounted on any firm support such as a lamp post. Several retroreflectors may be placed as required, as an optical sighting device will automatically locate them in turn under computer control, optimizing reception before taking measurements.

Received light is passed from the receiver to the analyser through a fibre optic cable. This means that only a minimum of equipment is exposed to the elements, while the analyser is housed under suitable cover.
A range of cable types is available to suit different applications.

In multi-path systems, the analyser accesses the fibre optic cable from each receiver through an optical multiplexer. The analyser itself handles all switching functions automatically.

Opsis will also accept information from other instruments for logging and integration with air quality data. This allows, for example, meteorological data (wind direction, temperature, barometric pressure) to be included in air quality reports. This external information is routed to the Opsis analyser via a data logger.

The Opsis equipment range includes a comprehensive set of calibration equipment. Calibration basically consists of taking normal measurements with controlled path lengths and calibration gas levels.



Software

Standard programme packages supplied with all analysers perform the complete range of measurement, validation and datalogging functions. Additional packages are available for more advanced data processing, report generation and communications.

ComVision is a communications programme for installation on an external PC. ComVision provides automatic data retrieval (from the analyser or other logging systems) via direct link or modem. Data may be presented numerically or graphically in user-defined formats. A range of alarm functions may also be installed.

Opsis' powerful statistics program STAT500 open up a wide range of possibilities for advanced data processing, with presentations as, for instance, histograms, wind roses or correlation graphics. These may be produced on demand, or generated automatically to a user-defined timetable.

Opsis applications

Photo by the courtesy of Mr. Werner Loosli, Zürich Airport Authority.

Opsis at Zürich Airport

Opsis was installed at Zürich airport following the publication of an environmental impact study in 1991. This showed that air traffic was the region's largest single source of NOx and suggested that measures might have to be taken to improve the situation.

On the basis of this report, and the Canton's clean air programme, the Airport Authority decided to set up an air quality monitoring system. This was agreed in co-operation with the Canton's Office for Air Pollution Abatement. The objectives were to provide general information about air quality, and, if possible, to identify characteristics of the emission patterns from different types of aircraft engines, including the newer, cleaner types coming into use.

The requirements laid down in Zürich stated that there should be no distraction for air traffic, rapid measurement of several components, high reliability and low maintenance. The Airport Authority and the Canton chose Opsis for this task. It was already in use with other airports and, more directly, it met all the specific requirements.

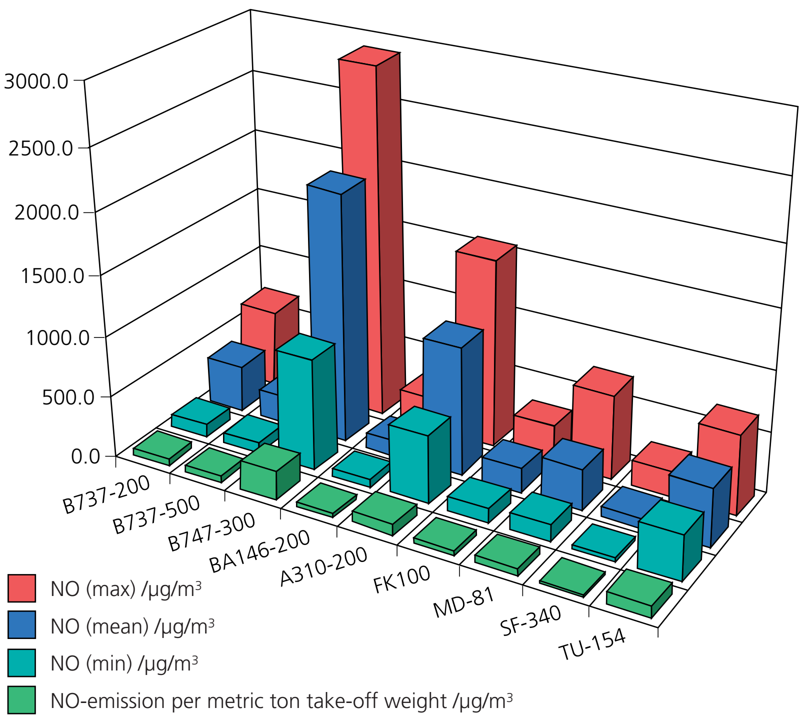
Opsis is located by the main runway, about 100 m behind the point where the aircraft wait for take-off clearance. A 220 m light-path is projected straight through the engine exhausts while the engines are at full thrust, measuring SO_2, NO, NO_2, benzene, toluene, 1–2–4-TMB and 1–3–5-TMB emissions every 40 seconds.

Due to safety requirements, no weather station has been installed with the system. Instead, data is gathered from a general purpose met station nearby.

For the present, data is immediately serving two purposes. Firstly, it provides information about general air quality and the impact of air traffic. Here, information is calculated by the Canton and is provided as half-hourly, daily and monthly mean averages.

Secondly, Opsis data is being used to provide information on the environmental impact of specific aircraft. Here, correlation with air traffic data provides information on emissions in respect of aircraft type and take-off weight. These are calculated by the Airport Authority. The graph shown here is an example of NO emissions presented in this way.

Emissions of Nitric Oxide for various Aircraft Types



Opsis in the City of Helsingborg

Opsis has been used to monitor air quality in the city of Helsingborg in southern Sweden since 1989. One monitoring station is located in the city centre and another in the industrial areas to the south. Each station operates four lightpaths and measures toluene, p-xylene, formaldehyde, ozone, sulphur dioxide, nitric oxide and nitrogen dioxide. The lightpaths themselves are between 95 and 1500 metres in length.

Both stations also include meteorological sensors measuring wind speed, wind direction and temperature.

The Helsingborg systems are sited so as to monitor air quality in the most exposed regions of the city. In the city centre, much pollution arises from the harbour area with the heavy road traffic connected with the ferry services to Denmark. In the southern area, Opsis lightpaths are deployed as fenceline monitors to measure emissions from major industrial sites.

The two systems provide comprehensive data on the current air quality situation. At the same time, information is used to compile databases allowing detailed studies of long term trends. In Helsingborg, these show a reduction in industrial emissions as improvements come into effect.

Two major applications of the Helsingborg data relate to Swedish environmental law and to the city's urban planning.

The law requires industrial sites to be licensed. Two chemical plants have an agreement with the City Health Department under which Opsis data is used as the reference for diffuse emission control. There are also overall guidelines laid down by the Swedish EPA for substances such as SO_2 and NO_2, and Opsis has proved to be an ideal system for providing data for comparison.

The City also uses Opsis data for an air surveillance system, providing a sophisticated spreadsheet model of air quality. This, together with other information, allows Opsis to become a valuable planning tool, since the environmental impact of proposed new development can be assessed under a wide range of conditions.

Opsis with Westminster City Council

Westminster City Council has always been environmentally conscious. The City is the seat of the UK Government, the home of nearly 180,000 people and the daytime workplace of hundreds of thousands more. It also attracts the majority of London's tourists.

This population of residents, workers and visitors shares an intensely developed area with some of the heaviest road traffic in the United Kingdom. The Council, along with its widespread initiatives to maintain high standards in the visible environment, attaches a particular importance to modern air quality monitoring techniques.

Air quality is a widespread concern, and Westminster Council feels it must maintain its own source of authoritative data for both public information and professional study.

Westminster also encourages its residents to play an active part

in minimizing vehicle pollution, and the ability to report on air quality helps foster cooperation by providing positive feedback.

A major reason for selecting Opsis was the ease with which the system could be specified to monitor major components of traffic and other pollution. Westminster Council wanted to measure both criteria pollutants (SO_2, NO_2 and O_3) and hydrocarbons (benzene and toluene), and the Council felt that Opsis was the only single system that could perform the whole task. It was also the only system that would free them from the need to maintain dedicated sensors. Since Opsis has been running, ease of operation and low maintenance have been acknowledged as outstanding benefits.

Westminster City Council publishes Opsis data in the form of public displays, reports and press statements. Together, these provide immediate information to answer public and professional enquiries as well as data for long-term studies. Within months of the first regular reports being published, data was being requested from neighbouring Authorities for such applications as new traffic management and engineering projects.

In Westminster, Opsis monitors air quality along the Marylebone Road, one of Central London's busiest thoroughfares. Here, data is integrated with meteorological information, wind and temperature.

The City of Westminster is adjacent to the City of London, another Opsis user. Together, these two Authorities cover a major part of the capital's central area north of the Thames. Data sharing arrangements now exist between the two users, which are offering opportunities for still wider environmental studies in the future.

Opsis in the City of Milan

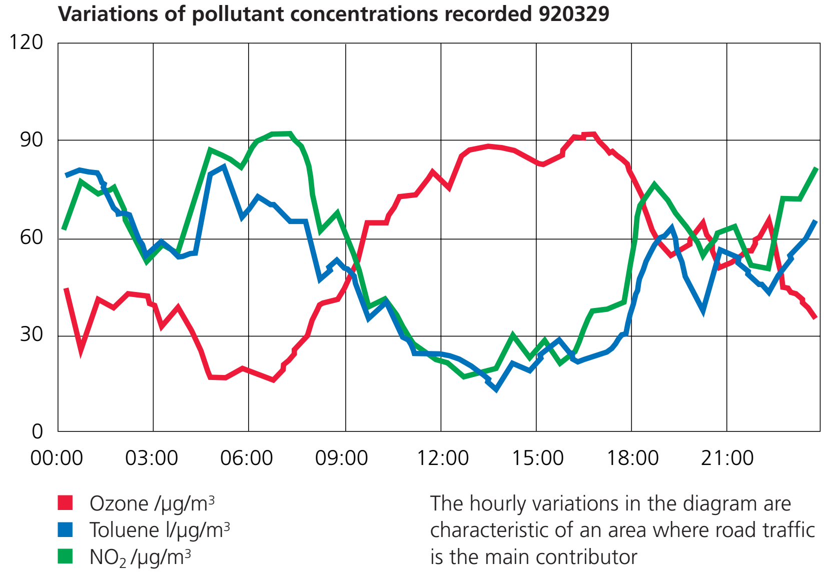
The Italian city of Milan has air pollution problems arising from its location and weather pattern. It is situated in a river valley where a cold, humid climate – plus periods of heavy fog during the winter – combine to trap emissions near ground level.

The City felt it very important to be able to monitor air quality, and selected an Opsis system. This was chosen for its ability to monitor benzene, toluene, nitrous acid and formaldehyde as well as the criteria pollutants – SO_2, NO_2 and O_3 – over more than one path.

The system is located in central Milan and uses two lightpaths, each approximately 25m above ground level. One of these is directed at the city's famous Duomo monument, while the other is located over the Via Larga, an area of very heavy traffic intensity.

Since installation, the system has provided very high availability (over 90%) and negligible operational difficulties. Data comparisons have been made with existing conventional analysers measuring criteria pollutants, and these have shown very good correlation.

Variations of pollutant concentrations recorded 920329



The hourly variations in the diagram are characteristic of an area where road traffic is the main contributor

How the Opsis technique works

The basis of the principle used by Opsis to identify and measure concentrations of different gases is scientifically well established: Differential Optical Absorption Spectroscopy (DOAS), which is based on Beer-Lambert's absorption law. It states the relationship between the quantity of light absorbed and the number of molecules in the lightpath.

Because every type of molecule, every gas, has its own unique absorption spectrum properties, or "fingerprint", it is possible to identify and determine the concentrations of several different gases in the lightpath at the same time.

DOAS is based on transferring a beam of light from a special source – a high-pressure xenon lamp – over a chosen path and then using advanced computer calculations to evaluate and analyse the light losses from molecular absorption along the path. The light from the xenon lamp is very intense, and includes both the visible spectrum and ultraviolet and infrared wavelengths.

The light is captured by a receiver and conducted through an optical fibre to the analyser. The fibre allows the analyser to be installed away from potentially aggressive environments.

The analyser includes a high quality spectrometer, a computer and associated control circuits. The spectrometer splits the light into narrow wavelength bands using an optical grating.

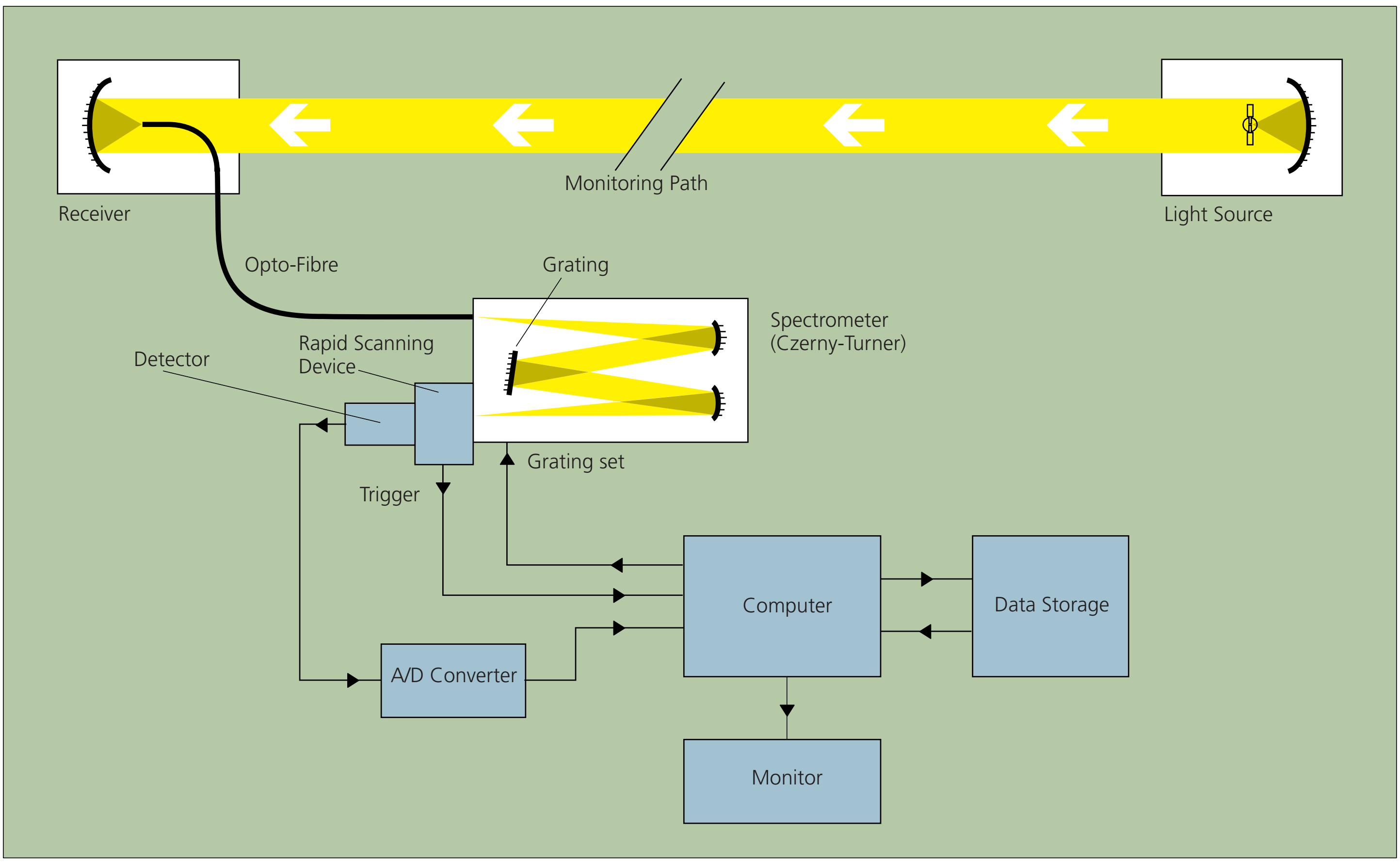
This can be adjusted so that an optimum range of wavelengths is detected.

The light is transformed into electrical signals. A narrow slit sweeps past the detector at high speed, and a large number of instantaneous values are built up to form a picture of the spectrum in the relevant wavelength range. This scan is repeated a hundred times a second, and the registered spectra are accumulated in the computer's memory while awaiting evaluation.

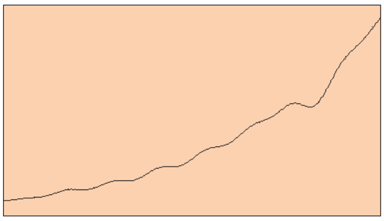
Evaluation is carried out for one wavelength range at a time. It works by comparing absorption curves.

The absorption spectrum just registered from the light path is compared with one calculated by the computer. The calculated spectrum consists of a well-balanced summation of the reference spectra for the analysis concerned.

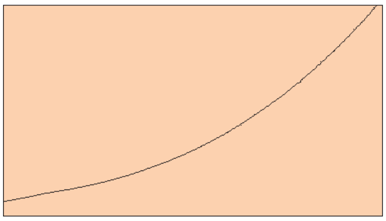
The computer proceeds by varying the size factors for each reference spectrum until it reaches the best possible match. From this the different gas concentrations can be calculated with high accuracy.



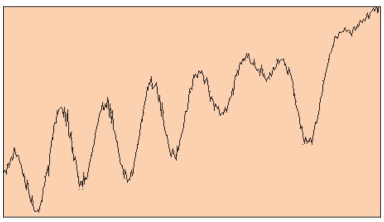
What happens in the computer



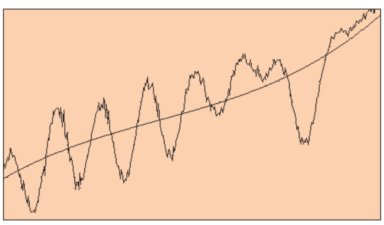
1. Once the data has been collected, the raw spectrum is stored in the computer's memory.



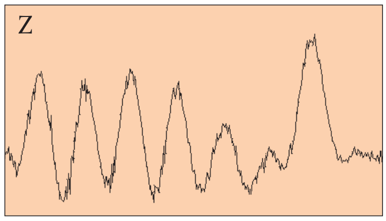
2. First the raw spectrum is compared with a zero-gas spectrum. This has previously been registered with no absorption gases present and is used as a system reference.



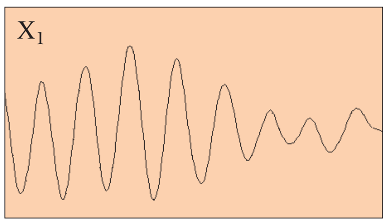
3. After division by the zero-gas spectrum, the total light absorption between the transmitter and the receiver is obtained. This result is caused not just by the gases that are present but also by e.g. dust in the atmosphere or dirty optics. The task now is to separate the light absorption of the gases from other influence.

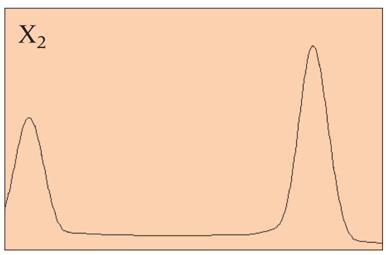


4. To do this, the system takes advantage of the fact that only gas molecules will cause rapid variations in the absorption spectrum. The slow variations, which give rise to the gradient on the absorption curve, result from a large number of known and unknown factors. Their influence can be eliminated completely by mathematically matching a curve which does not follow the rapid variations in the spectrum.



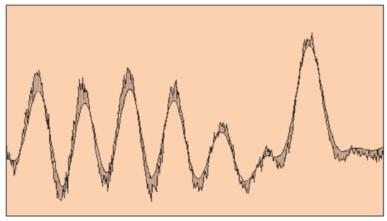
5. After a new division, all that remains are the rapid variations. For the remaining calculations, the logarithm of the curve is taken, which turns the curve upside down. A differential absorption spectrum has now been obtained. This spectrum is a combination of the various gases present between the transmitter and the receiver at the moment of detection. In the example this is called Z.





6–7. The gases that absorb light in this wavelength range are already known, and a pre-recorded reference spectrum for each gas is stored in the computer's memory. In this example there are only two gases, called X_1 and X_2. The task is to determine the proportions of X_1 and X_2 that combine to give the best match for Z. The system achieves this by very rapidly creating a new curve out of the sum of the two reference spectra, varying values until the best correspondence is achieved.

The equation the computer uses can be expressed as $C_1X_1 + C_2X_2 = Z$, where C_1 and C_2 are the proportions of each gas. From C_1 and C_2 it is then possible to calculate the current concentrations.



8. Finally, the result is checked by determining the difference between the measured and the calculated curves (the shaded area). This means that every measurement result can be stated with a standard deviation.

The more reference curves stored in the computer's memory, the more accurate the result of the calculation will be. However, even if there should be some unknown interference, i.e. when the measurements are affected by a gas whose reference spectrum is not stored in the computer's memory, the computer nevertheless evaluates the gases it is programmed for.

The influence of the unknown gas is presented as an increase in the standard deviation in the measurement result.

The Opsis benefits

Multi-component, multi-path system
Open path measurements
No sample system required
Fast response time
High accuracy
High sensitivity
Remote control capabilities
Low maintenance costs
Identifies individual hydrocarbons
Application-tailored software packages
Internationally approved
Several hundred systems installed worldwide

Opsis AB, Box 244, SE-244 02 Furulund, Sweden
Telephone Int. +46 46 72 25 00
Telefax Int. +46 46 72 25 01
E-mail info@opsis.se, URL http://www.opsis.se

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