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Gas turbines — Exhaust gas emission — **Part 2:** Automated emission monitoring

Turbines à gaz — Émissions de gaz d'échappement —
Partie 2: Surveillance automatisée des émissions



Reference number
ISO 11042-2:1996(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 11042-2 was prepared by Technical Committee ISO/TC 192, *Gas turbines*.

ISO 11042 consists of the following parts, under the general title *Gas turbines — Exhaust gas emission*:

- *Part 1: Measurement and evaluation*
- *Part 2: Automated emission monitoring*

Annex A of this part of ISO 11042 is for information only.

Gas turbines — Exhaust gas emission —

Part 2: Automated emission monitoring

1 Scope

This part of ISO 11042 establishes the monitoring programme and the requirements for the selection and operation of hardware to be used for continuous measurement over an extended, not limited, time. The concentration and absolute magnitude of specified emissions in the exhaust gas are monitored as well as related gaseous components from gas turbines together with essential operating conditions. Appropriate terms and symbols in addition to those defined in ISO 11042-1 are used. It presents requirements for the monitoring environment, the instrumentation and recording as well as for quality assessment and correction of data.

This part of ISO 11042 is applicable for all gas turbines producing mechanical shaft power and/or which are used as drivers for electrical generation as well as marine application but excluding application in aircraft. It can be used as a basis for installations equipped to utilize exhaust heat.

This part of ISO 11042 is applicable for gas turbines which utilize the open cycle process. It is also applicable as a basis for gas turbines which utilize the semi-closed cycle and for gas turbines equipped with free piston compressors or with special heat sources.

This part of ISO 11042 is not intended to be used for acceptance testing for gas turbine exhaust emissions except by mutual agreement between the parties involved.

Constituents, which are released into the air in significant quantities, greater than a certain limiting value, should be monitored. Such values are determined by mutual agreement between the parties involved.

In general, this part of ISO 11042 requires that the following parameters be continuously monitored: emissions, diluent gas (O_2 , CO_2), exhaust gas flow (calculated or, if required, measured), fuel consumption and gas turbine plant performance. Chemical analysis of the fuel is required on fuel samples taken at regular intervals.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 11042. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 11042 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 2314:1989, *Gas turbines — Acceptance tests*.

ISO 4225:1994, *Air quality — General aspects — Vocabulary*.

ISO 6879:1995, *Air quality — Performance characteristics and related concepts for air quality measuring methods*.

ISO 7504:1984, *Gas analysis — Vocabulary*.

ISO 10396:1993, *Stationary source emissions — Sampling for the automated determination of gas concentration*.

ISO 11042-1:1996, *Gas turbines — Exhaust gas emission — Part 1: Measurement and evaluation*.

3 Definitions

For the purposes of this part of ISO 11042 the following definitions, as well as those given in ISO 11042-1:1996, clause 3, apply.

3.1 monitoring

(1) In the wide sense of the term, repeated measurements to follow changes over a period of time.

(2) In the restricted sense of the term, regular measurements of the pollutant level in relation to some standard in order to assess the effectiveness of the system of regulation and control.

See ISO 4225:1994.

3.2 reference measurement: Independent measurement for acceptance tests and recalibration and for checking of actual measurement.

3.3 analyser: Assembly comprising:

- a) lines permitting removal and transfer of gas to be analysed and/or of calibration gas;
- b) a measuring device which, from the physical or chemical properties of the components of the gas sample analysed, gives signals allowing the quantification of the components;
- c) signal processing devices (amplification, recording) or, if needed, data processing devices.

See ISO 7504:1984.

3.4 sampling principle: Representative sampling of gases in the duct including both extractive and non-extractive methods.

See ISO 10396:1993.

NOTE 1 In extractive sampling, these gases must be conditioned to remove aerosol, particle matter and other interfering substances before being conveyed to the instruments. In non-extractive sampling, the measurements are *in situ*, therefore no sample conditioning will be required.

3.4.1 extractive sampling: Includes extraction of the sample, removal of interfering materials and maintenance of gas concentration throughout the sampling system for subsequent analysis by appropriate instrumentation (see figure 1).

3.4.2 non-extractive sampling: Does not involve removal of a sample and sampling is confined to the gas stream in the duct (see figures 2 and 3).

3.5 system operating characteristics: Aspects of performance from statistical, functional and operational points of view as defined in ISO 6879.

The following aspects are taken into consideration.

3.5.1 response time: Time taken for a system to respond to a rapid change in value of the air quality characteristics. It can be divided into two parts as follows.

3.5.1.1 lag time: Time taken for a representative sample to enter the instrument.

3.5.1.2 instrument response: Time taken for the instrument to give an output equal to 90 % of the total change in sample concentration.

3.5.2 zero instability (drift): Change in instrument output in response to a zero sample over a stated period of unattended operation.

3.5.3 span: Difference between the instrument readings for a stated value of air quality characteristic and for a zero sample; by convention, this value of air quality characteristic is selected to be 95 % of the upper limit of a gas concentration measurement range as it may be specified for affected source categories.

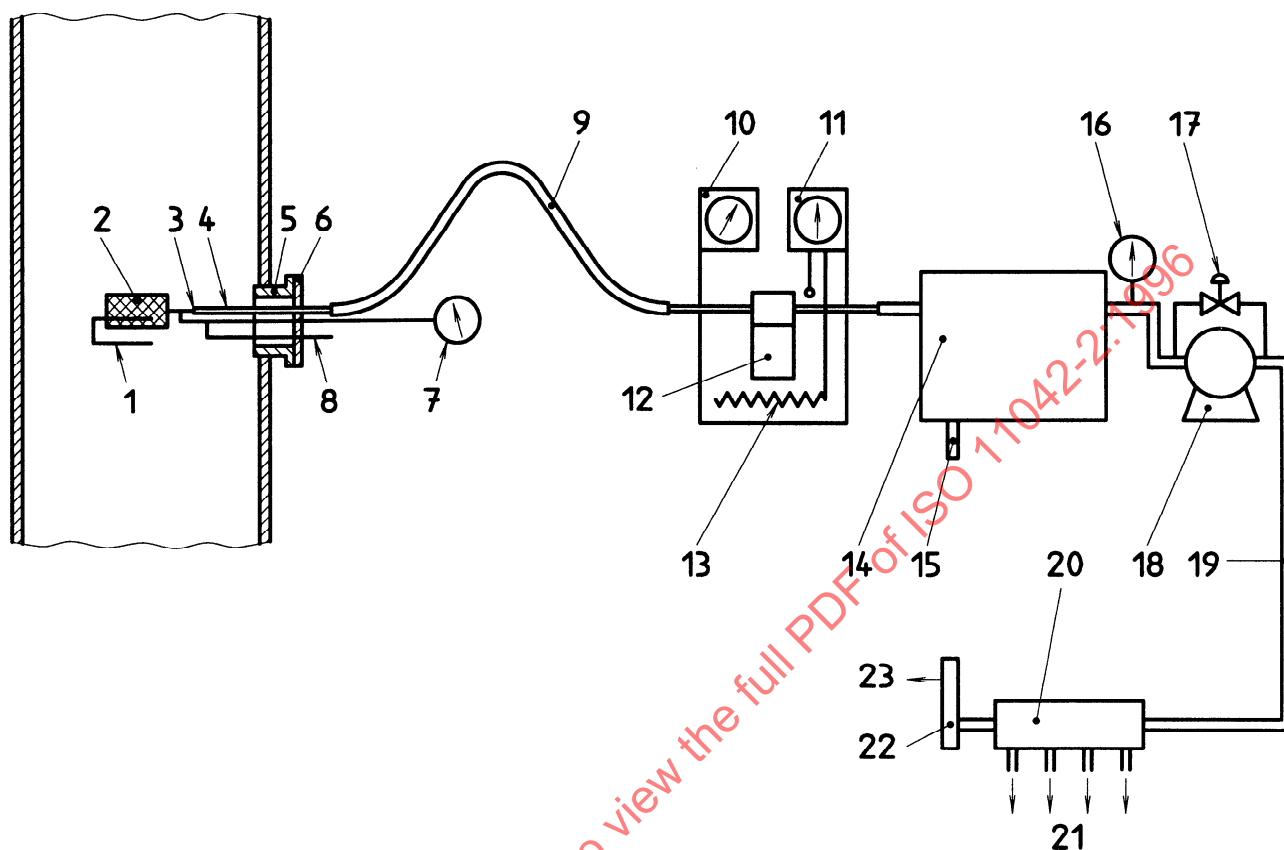
3.5.4 span instability (drift): Change in instrument output in response to a calibration gas of 90 % of the measuring range(s) of the instrument over a stated period of unattended operation.

3.6 system calibration characteristics: Aspects of measurement functions with pertinence to calibration.

The following aspects are taken into consideration.

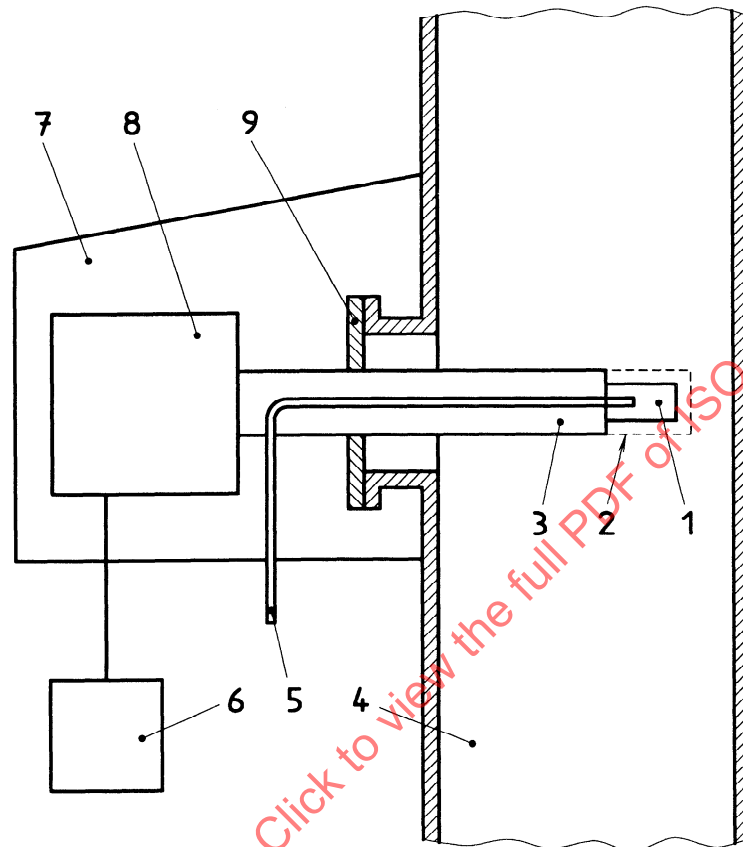
3.6.1 calibration function: Instrument reading as a function of some measurable property of the specific component(s) under investigation and obtained by the reference manual method (see ISO 11042-1) with all the interferences remaining constant.

3.6.2 linear function: Calibration function wherein the instrument reading is linear with respect to the concentration of specific component(s) measured by the reference manual method (see ISO 11042-1).

**Key**

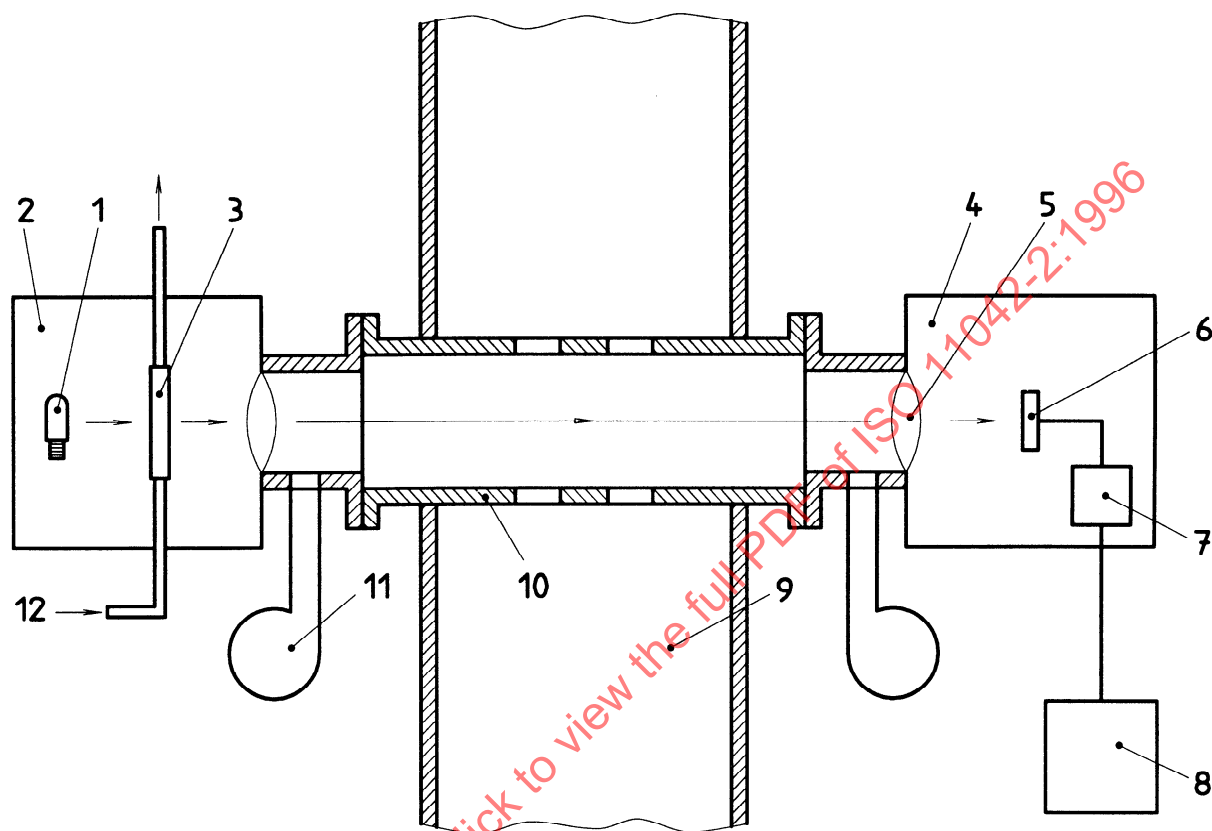
- | | |
|-------------------------------------|-------------------------------------|
| 1 Baffle | 13 Heater |
| 2 In-stack filter | 14 Refrigeration unit |
| 3 Tee | 15 Water discharge |
| 4 Probe | 16 Vacuum gauge |
| 5 Port | 17 Bypass valve |
| 6 Cap | 18 Pump |
| 7 Pressure gauge | 19 Sampling line (heating optional) |
| 8 To zero and reference gases | 20 Manifold |
| 9 Thermally insulated sampling line | 21 To analyser(s) |
| 10 Temperature controller (line) | 22 Rotameter |
| 11 Temperature controller | 23 Excess sample gas discharge |
| 12 Filter | |

Figure 1 — Example of an extractive sampling and conditioning system

**Key**

- | | |
|------------------------|--------------------------|
| 1 Measurement cell | 6 Data recorder |
| 2 Probe filter | 7 Protective hood |
| 3 Probe | 8 Instrument transceiver |
| 4 Exhaust gas duct | 9 Probe mounting |
| 5 Gas calibration line | |

Figure 2 — Example of a point non-extractive monitor

**Key**

- | | | | |
|---|-------------------------------|----|----------------------------|
| 1 | Lamp | 7 | Electronic module |
| 2 | Transmitter assembly | 8 | Data recorder |
| 3 | Internal gas calibration cell | 9 | Exhaust gas duct |
| 4 | Receiver assembly | 10 | Alignment/calibration pipe |
| 5 | Protective window | 11 | Purge air blower |
| 6 | Detector | 12 | Gas calibration line |

Figure 3 — Example of a path non-extractive monitor

3.6.3 non-linear function: Calibration function wherein the instrument reading is not linear with respect to the concentration of specific component(s) measured by the reference manual method (see ISO 11042-1).

NOTE 2 Non-linearity may be expressed by higher order regression coefficients.

3.6.4 confidence interval: Interval with lower and upper limits within which the mean values of the regression line lie with a given level of confidence.

3.6.5 tolerance interval: Interval with lower and upper limits within which is contained a specified percentage of the population with a given level of confidence.

3.6.6 plausibility test: Test designed to compare the measured carbon content in the exhaust gas (from CO₂, CO and UHCs) with the calculated carbon content for the gas turbine fuel, the acceptable difference between these values being agreed between both parties.

4 Symbols and abbreviations

The symbols and abbreviations of ISO 11042-1:1996, clause 4, shall apply.

5 Monitoring programme

5.1 Monitoring system

See figure 4.

Monitoring requires sampling and analyser systems, which continuously sense the exhaust gas as well as status data of the gas turbine plant and produce signals for the electronic evaluation system.

5.2 Constituents to be measured

The constituents to be mandatorily measured shall be agreed upon between the parties in accordance with local regulations. The following list of constituents may be monitored.

— Dust and smoke: measurement only required in case of potential presence.

NOTE 3 In general not required for operation on natural gas unless specifically agreed between both parties or where alternative stand-by or start-up fuels may be needed.

— SO₂: measurement only required in the case where continuous sulfur removal is applied or sufficiently detailed fuel analysis is not provided or where specifically agreed by both parties.

— NO_x: measurement always required.

NOTE 4 If agreed upon, only the NO content is to be analysed providing the NO₂ content does not exceed 10 % of the total NO_x. A value of NO₂, which should be determined by a reference test, must be added to the NO reading.

— CO₂: measurement required if no direct O₂ measurement is performed.

— CO: measurement required if agreed upon between the parties, particularly when monitoring partial loads.

— UHCs: measurement required if agreed upon between the parties.

— VOCs: measurement required if agreed upon between the parties.

— O₂: measurement required for correction of data either by direct measurement or by calculation.

— NH₃: measurement only required for plant with catalytic reactor for NO_x reduction using NH₃.

Other constituents may be monitored by agreement, especially where fuels containing toxic components are utilized.

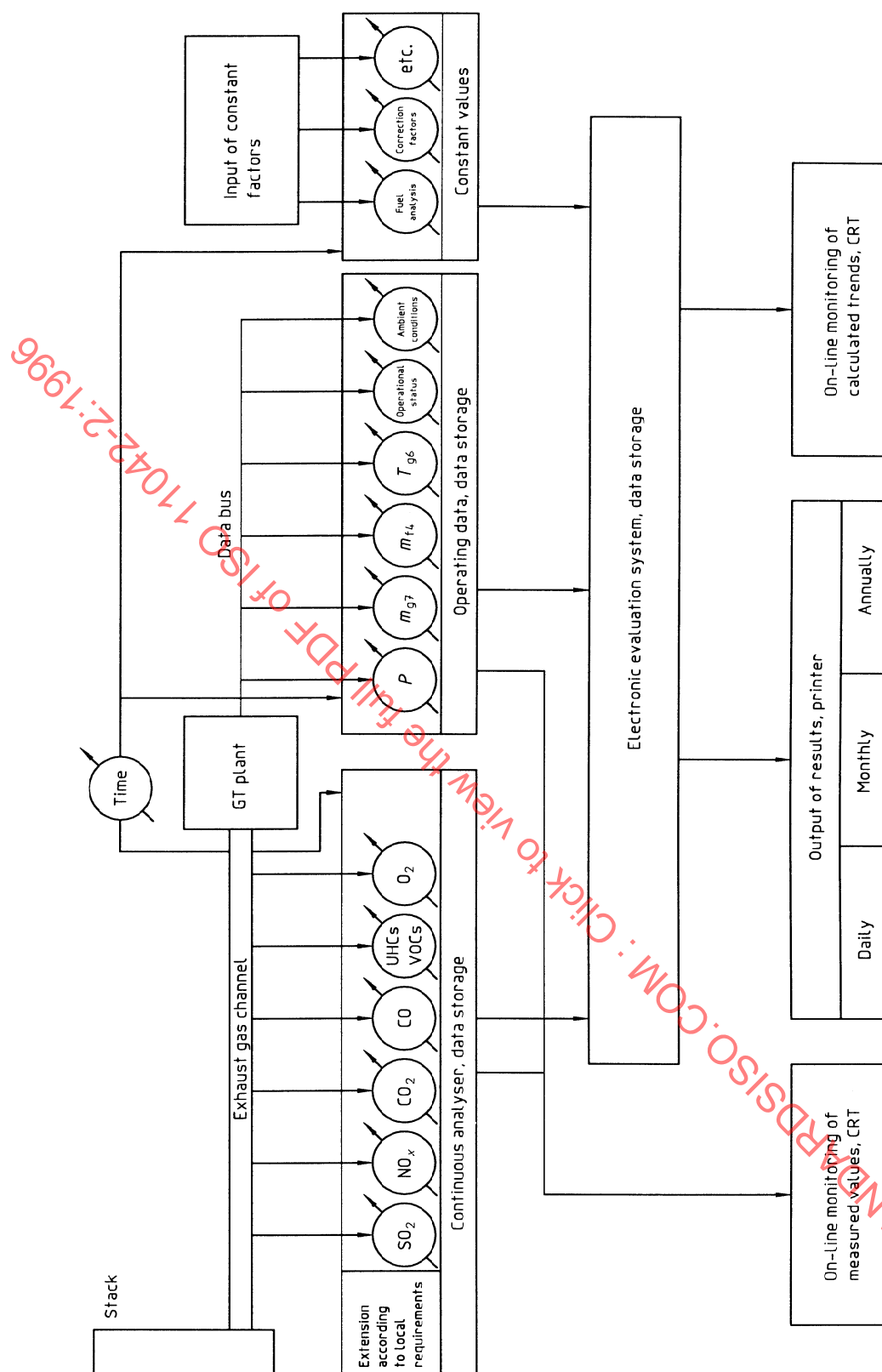
NOTE 5 It should be noted that CO₂, CO and UHC measurements are required to determine, by calculation, the plant mass flow. This value may then be compared with the manufacturer's design mass flow as a test for measurement plausibility.

5.3 Operating data to be recorded

These data shall be recorded at the time of measurement of the constituents.

5.3.1 Ambient air conditions

— temperature;
— pressure;
— relative humidity.



NOTES

- m_{t4} denotes mass rate of fuel entering the control volume.
- m_{g7} denotes mass rate of gas leaving the turbine.
- P denotes net shaft power output.
- T_{g6} denotes reference turbine inlet temperature.
- CRT = cathode-ray tube.

Figure 4 — Principal layout of the monitoring system

5.3.2 Gas turbine/plant performance

- power output;
- fuel consumption;
- exhaust gas mass flow, calculated or, if required, measured;
- exhaust gas temperature behind gas turbine and, where applicable, behind equipment for utilization of exhaust gas heat;
- quantity of water or steam injected into the working fluid, where applicable.

Methods for the determination of the exhaust gas mass flow shall be agreed upon (see ISO 2314).

5.3.3 Status of operation

- start in progress;
- stop in progress;
- emission monitoring system in or not in operation or in calibration mode during operation of the plant;
- continuous sulfur removal not in operation for 72 h, if applicable;
- continuous sulfur removal not in operation for 240 h, if applicable;
- type of fuel in the case of dual fuel operation;
- status of bypass in the case of heat utilization;
- in the case of water or steam injection into the working fluid, the operational status of the injection system.

5.3.4 External inputs

- identification of gas turbine plant;
- correction factors used;
- at suitable intervals a fuel analysis which determines constituents to be monitored as well as net heat energy and total content of carbon and hydrogen;
- data representing limits on constituents considered as air pollutants (such limits shall be determined by agreement between the interested parties).

5.3.5 Automated data collection and processing

5.3.5.1 The automated data collection and processing system shall have the capability of performing all operations required for the monitoring programme. Data shall be recorded every half hour based on averaging the continuously monitored values, during the "in mode" of operation. Also maximum and minimum values shall be recorded.

5.3.5.2 The following steps shall be performed.

- a) Conversion of the data to standard conditions.
- b) Producing of relevant status signals for the gas turbine plant.
- c) Checking of the plausibility of the data as per a).
- d) Producing of average values for each day on the basis of values as per a).
- e) Classification (acceptable or exceeding limits) of average values as required by local regulations.
- f) Classification of values as per e) regarding status signals as per b).
- g) Storage of classification results as per e) and f).
- h) Issue of data on daily, monthly and annual basis.

All above data shall be stored:

- for daily data, for two years;
- for monthly data, for five years;
- for annual data, for lifetime of plant.

A typical flow chart diagram for automated data collection and processing is presented in figure 5.

5.3.5.3 The evaluation system shall be fed with sufficient data to also allow the automatic analysis and evaluation of emissions produced by multifuel operation when applied.

6 Arrangement of monitoring system

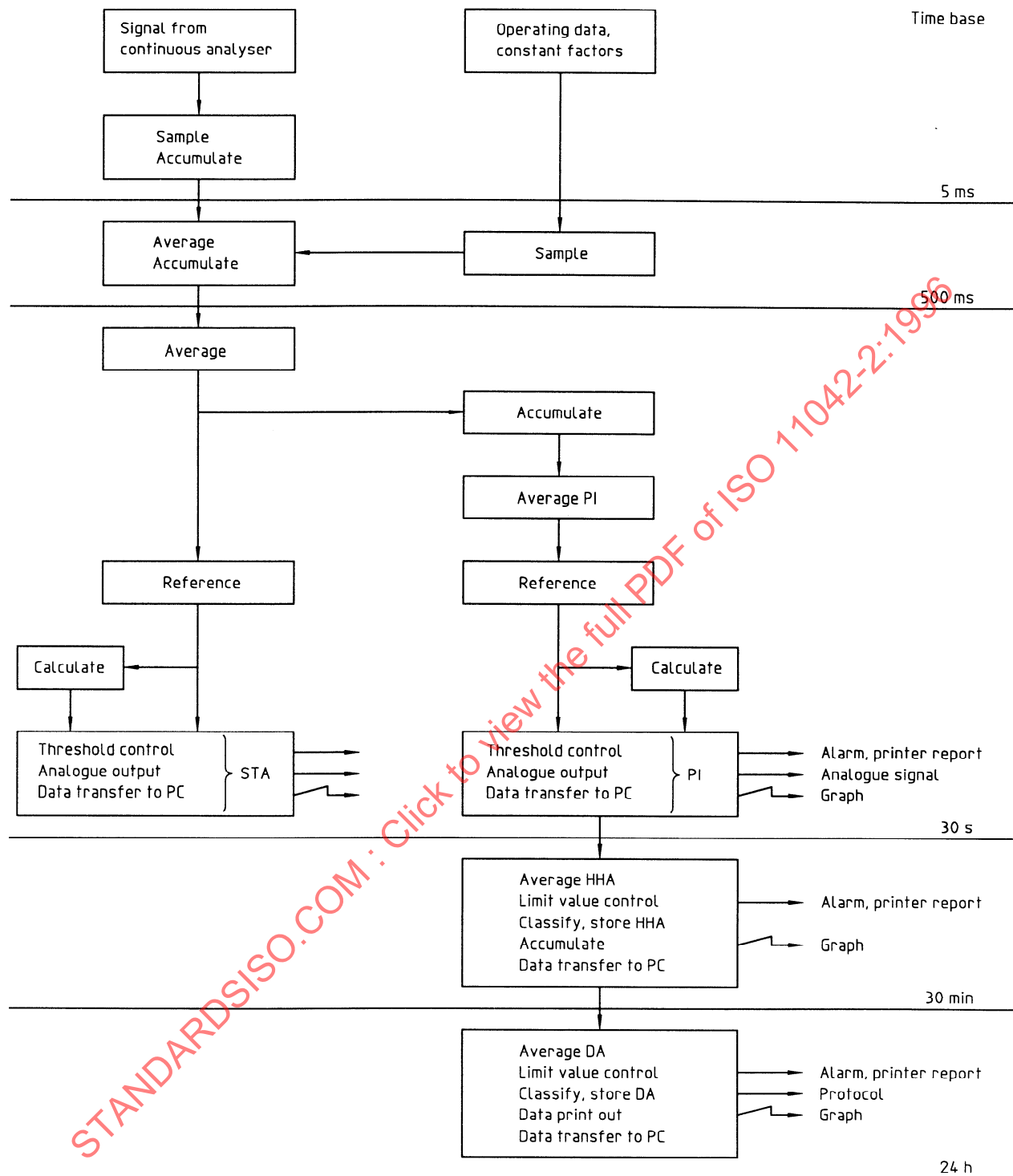
6.1 Measurement locations for gaseous emissions

The probes shall be installed at an accessible location where constituent concentration or emission rate measurements are directly representative or can be corrected so as to be representative of the total emissions from the facility or at the measurement cross-section.

Possible air leakage into the exhaust gas in front of the measurement system may dilute the sample gas and could affect the measurements. Dilution could occur due to damaged ducting, poorly fitting dampers, fired or unfired heat recovery equipment, etc.

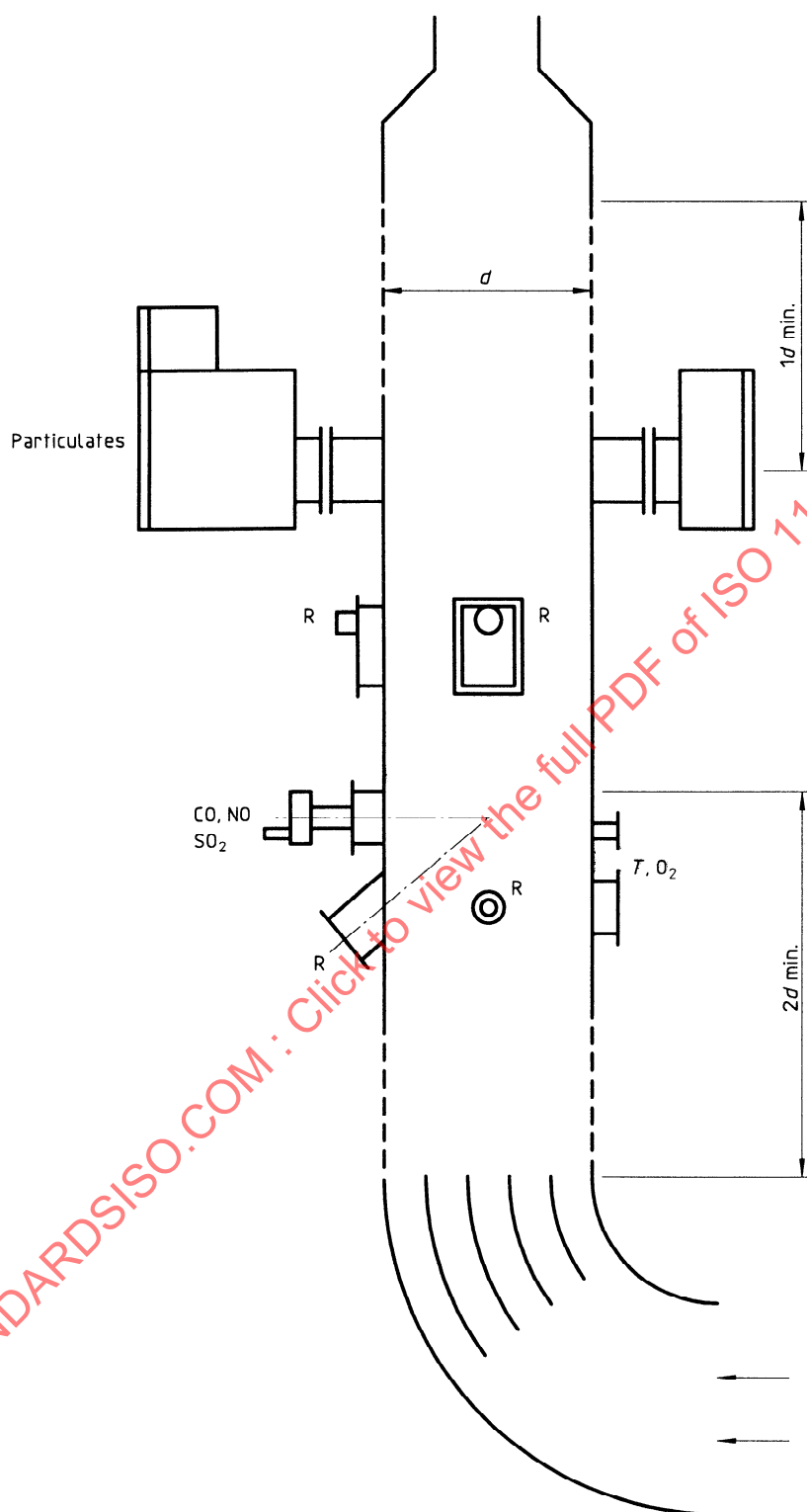
Suggested measurement locations and points that are most likely to provide representative data that meet requirements are shown in figure 6.

The instrumentation shall be arranged in an area more than 2 diameters downstream of the last flow disturbance (i.e. bend or damper) and more than 1 diameter

**Key**

STA — Short time average
 PI — Part integral
 HHA — Half hour average
 DA — Daily average
 PC — Process computer

Figure 5 — Flow chart for automated data collection and processing

**Key**

R = Reference measurement

T = Temperature

Figure 6 — Typical arrangement of the equipment for monitoring and reference measurements

upstream of the discharge to the exterior or, where applicable, upstream of any downstream-located equipment.

NOTE 6 For probe location for measurement of solid particles see ISO 11042-1:1996, 7.9.3.1.

It is suggested that measurements be taken where a stack or duct is of constant cross-section. The measurement location

- a) is recommended to be at least two equivalent diameters downstream of the nearest control device or bend, the point of constituent generation, or other point at which a change in the constituent concentration or emission rate may occur and
- b) shall be at least one equivalent diameter upstream of the exhaust gas outlet or control device. When supplementary firing, catalytic converters, etc. are in use, then the location of the sampling position shall be agreed upon by the parties involved, e.g. directly behind the turbine section (see also 7.1.1).

6.2 Point measurement of gaseous emissions

In addition to 6.1 it is suggested that for a non-extractive measurement of gaseous emissions the measurement point be

- a) no less than 1 m from the stack or duct wall or
- b) within or centrally located over the stack area or duct cross-section.

6.3 Path measurement of gaseous emissions

In addition to 6.1 it is suggested that for a non-extractive measurement of gaseous emissions the effective measurement point

- a) be totally within the inner area bound by a line 1 m from the stack or duct wall or
- b) have at least 70 % of the path within the inner 50 % of the stack or duct cross-sectional area or
- c) be centrally located over any part of the central area.

6.4 Particulate measurement location

The measurement device will preferably be an optical cross-duct monitor. The ports shall be separate to those of the continuous gaseous emission measurement and reference measurement points. The reference measurement points may include separate ports for both gaseous emission measurement and calibration of the continuous particulate monitor.

The path length shall be long enough to permit accurate determination of particulate matter at the low levels associated with many gas turbines. It should be noted that it may be necessary to install the equipment so that the path is axial, or at an angle to the duct axis, rather than at right angles to the duct axis (normal cross-duct orientation). It is important that the path length be not obscured by any other probes.

The installation of the equipment shall take account of vibration, thermal insulation of temperature sensitive components and potential distortion of ducting (misalignment of optical components), and indirect sunlight.

Care should be taken that there be no air ingress immediately upstream of the particulate monitor as temperature gradients can affect the signals from some optical devices. For this reason any purge gas flow across optical emitters, reflectors and collectors needs to be strictly controlled, i.e. constant. It should be noted that it may be necessary to clean the optics on the flue gas side at certain intervals.

6.5 Measurement locations for reference measurements

The same conditions as detailed above for monitoring shall apply. The locations for monitoring and reference measurements need not be the same.

Measurement traverses may be used initially to locate the representative monitoring point.

Figure 6 shows the arrangement of the equipment for monitoring and for reference measurements.

7 Components of the monitoring system

All components which form the monitoring system shall be designed for reliable, long, uninterrupted operation and shall be compatible with each other.

The utilization of test and reference gases should be minimized.

7.1 Extractive sampling

7.1.1 General

Extractive sampling, if applied, concerns that portion of the monitoring system used for

- sample acquisition,
- sample transportation,
- sample conditioning and
- protection of the analyser(s) from the effects of the effluent.

It is the purpose of the gas sampling system to extract a representative fraction of the exhaust gas and to transfer the sample, without change or with a known change in composition, to the measuring instruments. For obvious reasons, the physical properties of sample gas must be acceptable to the measuring instruments. Therefore, the sample gas must be conditioned by removing dust and, if necessary, by removing or maintaining the moisture content.

The sampling probe shall be capable of providing a representative sample of the exhaust gas flow during monitoring. A demonstration that the sample obtained is representative of the mean flow shall be made. This requirement shall be complied with whether a multi-hole or a single-hole (single-point) probe is used.

When supplementary firing, catalytic converters, etc. are in use, then the location of the sampling position shall be agreed upon by the parties involved, e.g., directly behind the turbine section.

The sampling probe to be used for the test shall be capable of continuously supplying a sufficient volume of sample gas to the analysers.

Further, the requirements according to ISO 11042-1 shall be adhered to.

7.2 Analysers

7.2.1 Arrangement of analysing system

See figure 7.

7.2.2 Types of measuring device

Table 1 shows available types of analyser. Detailed specifications are provided in ISO 11042-1. For a number of particular constituents, one combined analyser may be used. Special analysers are available which are suitable for monitoring. Analysers not listed below but meeting the accuracy requirements stated in this part of ISO 11042 may be used by agreement between the parties involved.

7.2.3 Accuracy of analysers

The accuracy of analysers used shall meet the requirements of ISO 11042-1.

8 Calibration, functional checking and maintenance

8.1 General

Quality of measurement is influenced by measurement system design and installation, operational procedures (calibration and measurement) and maintenance pro-

Table 1 — Analyser types for measurement of constituents

Constituent	Analyser type
NO _x	Chemiluminescence (CL) or non-dispersive infrared (NDIR) or non-dispersive ultraviolet (NDUV)
CO	Non-dispersive infrared (NDIR)
CO ₂	Non-dispersive infrared (NDIR)
SO ₂	Non-dispersive infrared (NDIR) or non-dispersive ultraviolet (NDUV) or pulsed UV fluorescence (PUVF)
UHCs	Flame ionization detector (FID)
VOCs	Gas chromatograph ¹⁾ (GC)
Solid particles and smoke	Photometric method or dispersed light method
O ₂	Magnetodynamic method or paramagnetic cell method or zirconia cell method
NH ₃	Chemiluminescence method ²⁾ or spectrophotometric (indophenol) method or non-dispersive infrared (NDIR)
1) Alternative method to be agreed upon.	
2) After oxidizing ammonia.	

cedures. System design has been covered in the previous clauses. The remainder of this clause covers calibration, functional checking and maintenance procedures.

8.2 Reference measurements

As part of the plant commissioning procedure, it will be necessary to prove whether the flow at the sample station is homogeneous or stratified. If traverses are required (see 6.5), the sample station shall be chosen, or plant arranged, such that there be no air ingress, i.e. the gas turbine exhaust is undiluted.

Extra sample ports may be provided to allow system and reference measurements to be made concurrently, preferably at stable plant operation.

The analytical system used to make reference measurements may be that as specified in ISO 11042-1. Alternatively other techniques may be used as agreed by the parties involved.

Consideration should be given to making independent reference measurements a part of the plant commissioning procedure.