MANUAL

# ON-LINE PROCESS STREAM ANALYSIS - ANALYSERS

DEP 32.31.50.12-Gen.

October 1995
(DEP Circular 45/99 has been incorporated)

**DESIGN AND ENGINEERING PRACTICE**

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## APPENDICES

# 1. INTRODUCTION

## 1.1 SCOPE

This new DEP gives recommendations and requirements for the selection, specification and installation of Quality Measuring Instruments. It also outlines the principles for their protection against the hazards caused by internal and/or external releases of flammable substances and, if applicable, against the hazards presented by an external flammable gas atmosphere.

This DEP gives recommendations and requirements for the

- selection of analysers and ancillary apparatus
- installation of analysers and ancillary electrical apparatus, and
- conditions in which the above should be used and operated.

This DEP also describes the verification and testing necessary to prove that the installation conforms to these requirements.

This DEP is one of a series of on-line process stream analysis DEPs.

The other publications are:

| | |
|---|---|
| DEP 32.31.50.10-Gen. | Sample take-off and transportation |
| DEP 32.31.50.11-Gen. | Sample conditioning |
| DEP 32.31.50.13-Gen. | Analyser Houses |

Instruments for the detection of fire, smoke and gas are outside the scope of this DEP; for this subject, refer to DEP 32.30.20.11-Gen.

## 1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by SIOP and SIEP, the distribution of this DEP is confined to companies forming part of or managed by the Royal Dutch/Shell Group, and to Contractors nominated by them (i.e. the distribution code is "C", as defined in DEP 00.00.05.05-Gen.).

This DEP is intended for use in oil refineries, chemical plants, gas plants, oil and gas production facilities, and in supply/marketing installations.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this document which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned with the object of obtaining agreement to follow this document as closely as possible.

## 1.3 DEFINITIONS

### 1.3.1 General definitions

The **Contractor** is the party which carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party which manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party which initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

### 1.3.2 Specific definitions

| | |
|---|---|
| **Across-stack measurement** | An in-situ measurement for flue gas analyses. |
| **Alarm** | An audible and/or visible signal to warn that appropriate action is necessary. |
| **Analyser house** | A building with a specific closed room containing one or more analysers, which may be connected to a process installation, together with associated electrical equipment and auxiliary devices.<br>NOTE: Laboratories are not included in this definition. |
| **Artificial ventilation** | A method of mechanical movement of air to reduce the concentration of flammable gases or vapours in the analyser house. Such ventilation may also be used to maintain the pressure inside the analyser house above or below the external ambient pressure. |
| **Compressibility** | The ratio of the real volume of a given mass of gas at a specified temperature and pressure to its volume under the same conditions as calculated from the ideal gas law. |
| **Density** | The mass of a fluid divided by its volume under specified conditions. |
| **Extractive measurement** | The method whereby the sample is extracted from the process and subsequently transported to the analyser. |
| **Extractive with pre-dilution** | Extractive measurement where the sample is diluted with a controlled amount of solvent (if the sample is a liquid) or carrier gas (if the sample is a gas). |
| **Forced ventilation** | Artificial ventilation effected by blowing air into the analyser house. |
| **Induced ventilation** | Artificial ventilation effected by the withdrawal of air from the analyser house. |
| **In-situ measurement** | Intrusive measurement where the analyser or its sensor is placed in or very close to the process. |
| **Lower Explosive Limit (LEL)** | The volume ratio of flammable gas or vapour in air below which an explosive gas atmosphere will not be formed. |
| **Precision** | The closeness of agreement between mutually independent test results under stipulated conditions.<br>NOTE: Precision depends only on the distribution of random errors and does not relate to the true value, conventional true value or specified value. |
| **Purging** | The operation of passing a quantity of a protective gas through a room and its associated ducts in order to reduce to a safe level any concentration of flammable gas or vapour which may be present. |
| **Quality Measuring Instrument (QMI)** | An instrument, suitable for use in a refinery environment, measuring either the empirical or absolute properties of a product. |

| | |
|---|---|
| **Relative density** | The ratio of the density of a fluid to the density of air (if the fluid is a gas) or to the density of water (if the fluid is a liquid) under the same stated conditions of temperature and pressure. |
| **Requisition** | A vehicle for information exchange prior to order placement, using the data/requisition sheets or requisition sheets for the particular instrument to be purchased. The various sheets are contained in the requisitioning binder (DEP 30.10.01.10-Gen.). |
| **Upper Explosive Limit (UEL)** | The volume ratio of flammable gas or vapour in air above which an explosive gas atmosphere will not be formed. |
| **Ventilation failure** | A situation where the required air flow and, if applicable, the required pressure cannot be maintained. |
| **Ventilation system** | The complete installation required to produce artificial ventilation. |

## 1.4 ABBREVIATIONS

| | |
|---|---|
| **AH** | Analyser House |
| **PGC** | Process Gas Chromatograph |
| **QMI** | Quality Measuring Instruments |
| **TOC** | Total Organic Carbon |

## 1.5 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets. Other documents referenced by this DEP are listed in (8).

# 2. SELECTION OF QMI

## 2.1 GENERAL

QMI shall be selected from the "List of selected vendors" supplied by the Principal. In the absence of a specific QMI on that list or in the absence of the list itself, the Contractor shall consult the Principal for advice.

The "List of selected vendors" is prepared by the Principal based on satisfactory information regarding the following:

- The Manufacturer should have submitted to the Principal
  - -) the company profile
  - -) the QA/QC (Quality Assurance and Quality Control) procedures and his progress with compliance to ISO 9001
  - -) sales references
  - -) part of the documentation (2.2) as required by the Principal
  - -) certification of the instrument for use in flammable gas hazardous areas, if applicable
  - -) test reports on mechanical/electronic and functional performance
- Construction of the instruments (2.3)
- Functional performance of the instruments (2.4)
- The Manufacturer/Supplier should have a procedure in place to brief the Principal at regular intervals on improvements or obsolescence of instruments in his supply
- Favourable experience with the instruments in the Shell Group.

## 2.2 MANUFACTURER'S DOCUMENTATION

The Manufacturer's documentation on QMI shall consist of

- Instruction manual with installation practices
- Operating manual
- Service manual.

The manuals shall include the following information

- Data sheets on the application
- Instructions for start-up
- Instructions for trouble-shooting
- Instructions for scheduled maintenance
- Instructions for validation/calibration
- Drawings for
  - -) layout
  - -) flow scheme
  - -) wiring
  - -) circuit diagrams
  - -) termination
- Parts list
- List of consumables
- List of fragile spares
- List of initial spares
- List of spares for one year's operation
- Electrical safety certificates and supporting documentation.

## 2.3 CONSTRUCTION

The Ingress Protection (IP) coding as per IEC-529 shall be specified by the Principal and confirmed by the Manufacturer.

Any finish shall be suitable for local environmental conditions.

The enclosure as well as other mechanical, electric, electronic and optical components shall be suitably protected, e.g. tropicalised.

Generally, the tropicalising standard(s) shall be as specified by the Manufacturer. Additional requirements may be specified by the Principal or Contractor depending on the type of project and location.

All sample wetted parts shall be suitable for the fluid and the conditions to be analysed, e.g. made from AISI-316, Poly-Fluoro Chlorinated plastics or glass, etc.

Accessibility of components in the instrument shall allow component to be removed for servicing with a minimum of disturbance to other components.

Adjustments for calibration or validation should be possible from the front.

Hermetically sealed relays, switches and potentiometers should be used. Other electrical contacts, such as for switches and unsealed relays, shall be gold-plated.

Use of asbestos or Poly-Chloro-Biphenyl (PCB) compounds is not allowed.

Electrical terminations shall be compatibly labelled at the wire and the terminal or, in case of system cabling, at the cable connector and the cable socket.

## 2.4 FUNCTIONAL PERFORMANCE

The functional performance shall be to the satisfaction of the Principal and may be judged from the whole or part of the following:

- Manufacturer's in-house tests witnessed by the Principal
- Shell Group experience
- Evaluations/tests carried out by an independent testing authority on behalf of user organisations, e.g. SIREP (GB), WIB (NL) or EXERA (FR)

  NOTE: A positive evaluation or test as referred to above does not automatically mean that the instrument qualifies for acceptance for use in the Shell Group.

- Experience reported by third parties.

## 2.5 TYPICAL CHARACTERISTICS OF SPECIFIED QMI

### 2.5.1 General

Appendix 1 and subsections 2.5.2 to 2.5.15 give recommendations to assist in making the proper selection with respect to measuring techniques, but the "List of selected vendors" (2.1) has priority.

Key characteristics which are important to the service are for:

### 2.5.2 Composition

Multiple-component analysis can be best carried out with PGC. Mass spectrometers have advantages for fast response times and sometimes for selective trace component analysis in gaseous products. A typical response time is 6 seconds per component.

NOTES: 1) The calibration matrix of a mass spectrometer is often adversely affected by components which were not included in the initial calibration mixture or which were either under or over-represented in the initial calibration mixture. Calibration results may therefore have limited validity.

2) Certain mixtures may be difficult to analyse with a mass spectrometer.

Infrared and ultraviolet spectroscopic techniques are typically suitable for single-component analysis of gaseous products, but have limited application for liquid products. Infrared and ultraviolet spectroscopic techniques, more specifically Fourier Transform Infrared and Ultraviolet Diode Array techniques, are also suitable for multi-component analysis for a limited number of applications.

Microprocessor-based composition analysers usually offer the advantage of calculating derived physical properties such as heating value, density, distillation properties, and even octane numbers.

### 2.5.3 Density / Relative density

Density meters should be of the vibrating type.

### 2.5.4 Dissolved oxygen

Dissolved oxygen is normally measured with a polarographic cell. The output value is dependent on the temperature due to the change in permeability of the membrane at different temperatures.

Metal-electrode-type dissolved oxygen meters often have robust self-cleaning features. The output is dependent on oxidation-reduction potentials (REDOX) of the water. Heavy metals and free oil may impede the application.

### 2.5.5 Flammable gas detection

Refer to DEP 32.30.20.11-Gen.

### 2.5.6 Flashpoint analysers

Flashpoint analysers which detect the flash on explosion should be used.

NOTE: The response of flashpoint analysers using semi-conductors or pellistor type detectors is product (i.e. feedstock) dependent.

### 2.5.7 $H_2S$ gas detection

Refer to DEP 32.30.20.11-Gen.

### 2.5.8 Moisture measurements in gaseous products

a) Dewpoint mirror techniques are absolute measurements. They are costly and are specifically suitable for higher moisture concentrations (0.05% and higher). The technique shall not be used to measure water in natural gas, due to the difficulty in obtaining consistent results.

NOTE: High hydrocarbon concentrations may interfere. Typically, the hydrocarbon dewpoint should not be higher than 10 °C above the water dewpoint.

b) Karl-Fischer-type titration is an absolute measurement. Output shall be expressed in $mg/m^3$.

c) Metal-oxide-type sensor measurements are relative measurements. The output shall be calibrated against a test gas mixture or against an absolute measurement. The output calibration is dependent on temperature and pressure. For accurate measurements the flow cell shall be kept at constant pressure and temperature. The characteristics of aluminium-oxide-type sensors are in general not stable and regular verification of the calibration factors is therefore required (a typical requirement is once per year, but this may vary depending on the application).

d) $P_2O_5$ (phosphorus pentoxide) sensors are theoretically absolute measurements. However, they shall be treated as a relative-type measurement and calibrated with a test mixture or against an absolute measurement. This analyser type shall not be used in process streams containing double-bonded hydrocarbons or those rich in hydrogen. The analyser is flow-sensitive.

e) LiCl (lithium chloride) type sensors are applicable for Relative Humidity measurements. The main application is in buildings, for use as a tool for climatic conditioning.

f) Hygroscopically coated vibrating crystal-type moisture meters have the best accuracy. This type of meter should not be used for prolonged measurements of moisture concentrations in excess of 2000 $cm^3/m^3$.

NOTE: At moisture concentrations in excess of 2000 $cm^3/m^3$ the hygroscopic layer on the crystal may be washed off.

g) Conductivity of a hygroscopic salt-glycerol solution. This is fairly suitable for natural gas application as the sensor is relatively easy to rejuvenate, although this requires specialist attention.

### 2.5.9 Oil in/on water

For oil in/on water measurements the following applications should be considered.

a) Oil on water. This is a qualitative detection only. Reflectance-type measurements are applicable.

b) Oil emulsified/dispersed in water.

Infrared-type meters, e.g. measuring hydrocarbons dissolved in an extraction fluid, such as freon, have a reduced response for naphthenic hydrocarbons and do not respond to the aromatic hydrocarbon content of the oil.

Ultraviolet-type meters do not respond to the naphthenic and the paraffinic content of the oil. Instead they rely on the co-presence of aromatics in oil.

NOTE: Typical solubility rate for paraffinic hydrocarbons is in the order of 20 mg/litre and 80 mg/litre for aromatic hydrocarbons.

c) Total Organic Carbon - TOC (2.5.14). Any oil or hydrocarbon entering the measuring cell will be detected.

### 2.5.10 Oxygen

a) Zirconium-oxide-type meters are applicable for measuring oxygen in flue gas to stack. These meters shall not be used for gases containing flammable gas or unburned material (e.g. soot). The sensor, which is kept at a temperature of typically 800 °C, should be of an Ex-d construction in accordance with IEC 79 by means of a flame arrestor.

NOTE: The start-up of fired equipment may pose conditions of increased hazard due to the likelihood of unburned fuel being present in an cold environment, e.g. upon misfiring. The application design therefore requires careful assessment of the risks involved. Equipment selection shall take into consideration the suitability of the sensor with respect to the gas group and temperature class. E.g.: the application of a high concentration of hydrogen in fuel gas requires an electrical certification of the sensor that allows the instrument to operate in such an environment, while the temperature class shall be related to the auto-ignition temperature of the fuel.

b) Para-magnetic type oxygen meters are applicable for oxygen concentrations higher than 0.5% mol and requiring a precision of 1% relative or 0.1% absolute, whichever is better.

c) Polarographic (Electrochemical) type sensors are applicable for trace oxygen analyses or for applications where a precision of 5% relative or worse is acceptable.

### 2.5.11 pH measurements

a) Electrode-type pH meters should be used only for pH measurements $4 < pH < 10$.

NOTE: Below a pH of 4 precision is reduced, and above a pH of 10 precision and electrode life are reduced.

Electrode-type pH meters shall not be used for $pH > 12$.

Dual junction reference electrodes should be considered for fouling conditions. Severe services may require additional (automated) features to maintain clean electrodes, i.e. mechanical (ultrasonic, brushes, flushing) and/or chemical cleaning.

Fluids of low conductivity, e.g. demineralised water, require a liquid-earthing electrode. The construction of the reference electrode should ensure an unimpeded delivery of electrolyte from the reference electrode to the process. Pressure compensated constructions or sleeve (fritt) type reference electrodes may provide that condition.

b) Titrator-type analysers should be used for $pH < 4$, and $pH > 10$.

When a fast-response system is required, it should be considered to install a titrator in combination with an electrode-type pH meter for improved response.

c) For a fast-response pH measuring system for $pH > 12$, a Flow Injection Analysis QMI may be considered.

NOTE: Systems b) and c) may require a skilled maintenance pool. Reagent consumption rate is relatively high. Possibility of frequent breakdown should be anticipated in the process design.

### 2.5.12 Phenol in water

Colorimetric type water quality analysers should be used.

NOTE: PGC shall not be used for this purpose because phenol can be adsorbed and desorbed on the column material, thus causing low output values when concentrations are high and high output values when concentrations are low.

### 2.5.13 Stack gas composition analysers

Typically, the following measurements are applicable for stack gas composition analysers, e.g. (in order of most common measurements):

- Oxygen ($ZrO_2$-type oxygen meter) by
  - -) in-situ type measurements, or
  - -) extractive with analyser mounted against duct/stack wall.
- Opacity (particulates)
  - -) across stack with visible light optical type instrument.
- $SO_2$, $NO_x$
  - -) across stack with infrared or UV light type instrument
  - -) extractive with pre-dilution and chemo-luminescence type analysers
  - -) extractive with infrared or UV light type instrument.
- CO
  - -) across stack with infrared or UV light type instrument
  - -) extractive with infrared or UV light type instrument.
- Dust
  - -) across stack with visible light optical type instrument.

Electronic equipment associated with stack measurements should be located at ground level.

### 2.5.14 TOC in water

TOC (Total Organic Carbon) should be measured by the UV oxidation technique.

Because of the high combustion temperature and the relatively slow cool-down of the oven section, hot catalytic type analysers shall not be used in hazardous areas, and should not be used in analyser houses (even though they are ventilated).

The typical usable range for TOC measurements is 0 to 50 mg/l or less. The lowest practicable reading is limited to the background signal, which could be typically 2 mg/l in case of tap water or even higher in systems where corrosion inhibitors are being applied.

NOTE: Compounds which have a reduced oxidation efficiency with the UV oxidation technique do not normally occur in petrochemical processes. They would normally occur in minor concentrations compared to the bulk of hydrocarbons. Typical reduced efficiencies are in general better than 80%. The overall error in measuring organic carbon is normally better than 2% of the measured value.

### 2.5.15 Viscosity

For optimum precision, capillary-type viscometers shall be used.

Other measuring principles, e.g. the tuning fork principle, may be considered for measurements on binary mixtures or on applications requiring only a rough precision (5% of the range or worse) such as in assessing the pumpability of heavy fuel oil.

# 3. SPECIFICATION OF QMI

## 3.1 GENERAL

A successful analyser application depends on a good understanding of the analyser requirements and knowledge of the prevailing process conditions, both by the Principal and the Manufacturer/Supplier. Application details shall be thoroughly discussed between the Principal and Manufacturer/Supplier. Prior to detailed engineering and the subsequent selection of analysers, the Manufacturer/Supplier analyser data sheet shall be completed and agreed upon by all engineering disciplines involved.

The aspects of sample transport and sample conditioning shall be duly covered and agreed upon.

## 3.2 TYPICAL REQUIREMENTS

Typical requirements that should form part of a requisition as a minimum, are:

- The type of QMI
- The composition, quality and/or physical property to be measured
- The measuring range
- The required precision and maximum bias
- Technical data concerning the parts of the QMI (e.g. analytical part, control module, power supply, etc.)
- Speed of response (after consulting the Manufacturer/Supplier (3.3))
- The construction type with respect to:
  - electrical certification;
  - enclosure;
  - mounting facilities

The electrical construction shall be in compliance with IEC 79.

The following is a typical selection chart:

| | |
|---|---|
| a) Area classification | Non-Haz., Zone 2, Zone 1, Zone 0 |
| b) Gas group | IIA, IIB, IIC |
| c) Temperature class | T1, T2, T3, T4, T5, T6 |
| d) Construction | Ex-ia, Ex-ib, Ex-d, Ex-e, Ex-m, Ex-n, Ex-p |
| e) Protection | IP classification (IEC 529) |
| f) Mounting | WM = Wall mounted, FM = Flush panel mounted, RM = Rack mounted, BM = Bracket, PO = Portable |
| g) Location | AH = Analyser House, F = Field, AR = Auxiliary Room,<br>CR = Control Room, FAR = Field Aux. Room, SHA = Sample Handling Area of AH |

In applications where gas group IIC is required due to the presence of only hydrogen but where acetylene is not present, equipment may be certified as "IIB including hydrogen" (IIB + H2).

## 3.3 ADDITIONAL INFORMATION TO BE SUPPLIED TO MANUFACTURER/SUPPLIER

Typical information that shall be supplied to the Manufacturer/Supplier as a minimum, is as follows:

- The area classification for which the analyser shall be suitable.
- The environmental conditions for which the analyser shall be suitable.
- The service, e.g. top reactor, etc.
- The product, e.g. kerosene, distillate fuel oil, residual fuel oil, etc.

- The composition of the product or the component(s), physical property, etc. of interest.

NOTE: Normal, minimum and maximum values shall be reported

- Alarm settings, if any
- Sample properties at sample take-off and as well as at return, e.g.
  - Pressure
  - Temperature
  - Absolute viscosity
  - Density
  - Molar mass
  - Gas in liquid
  - Liquid in gas
  - Water in sample
  - Solids in sample
  - Solids particle size
  - Cloudpoint
  - Pourpoint
  - Dewpoint of gaseous sample
  - Bubble point of liquid sample

NOTE: For sample take-off the normal, minimum and maximum conditions apply.
For sample return the normal and maximum conditions apply.

- Available utilities, as mentioned below, i.e.
  - voltage, V (ac), single phase
  - voltage, V (ac), 3-phase
  - Frequency
  - Instrument air (dewpoint and minimum/maximum pressures and temperatures)
  - Tool air
  - Demineralized water
  - Potable water
  - Cooling water supply (pressure and minimum/maximum temperature)
  - Cooling water return (minimum and maximum pressures)

## 3.4 TYPICAL INFORMATION TO BE REQUESTED FROM MANUFACTURER/SUPPLIER

Manufacturer/Supplier shall be requested to advise the

- precision and bias for the typical application
- speed of response
- nominal, minimum and maximum inlet and outlet conditions for his QMI
- response/cycle time
- safety precautions to be taken in the case of a failure
- required ambient conditions
- maintenance requirements of his QMI
- deviations, if any, from the requisition.

## 3.5 DOCUMENTATION

The language used in the documentation shall be English, unless otherwise specified by the Principal.

The documentation is intended for the purchasing department, the start-up team, the service team in the field (one document per QMI) and the maintenance workshop library. Type of documentation and their numbers shall be specified with the order.

## 3.6 PURCHASE REQUIREMENTS

### 3.6.1 General

Specific details of the required QMI shall be specified in the requisition.

### 3.6.2 Calibration and testing facilities

Where special test equipment is specified to facilitate calibration, testing and checking the QMI, such test equipment shall be made part of the order. Calibration gas cylinders with the appropriate calibration gases and all necessary equipment such as pressure regulators, sensor head connections, fittings, etc. should be part of the main order. Cylinder connections shall be compatible with the local standards.

A certificate shall be supplied with every cylinder, stating composition of the gas contained, the date of filling and the expiry date. Refer also to (6.).

# 4. DESIGN, ENGINEERING AND INSTALLATION OF QMI

## 4.1 DESIGN STUDY - LOCATION OF QMI

The first objective of the design study shall be to install QMI in an Analyser House with artificial ventilation. Control units, e.g. micro-processors for Process Gas Chromatographs (PGC), may be remotely installed in other suitable premises such as the auxiliary room of the central control room (CCR) or the field auxiliary room (FAR) nearest to the analyser equipment.

## 4.2 ENGINEERING OF THE QMI SYSTEM

### 4.2.1 General

**Amended per Circular 45/99**

For instrument installation practices, DEP 32.31.00.32-Gen. shall apply.

The standards of protection are not necessarily limited to the following:

| Options | | |
|---|---|---|
| (a) | intrinsically safe | (Ex-ia or Ex-ib as appropriate) |
| (b) | pressurised | (Ex-p) with type certification |
| (c) | flame-proof | (Ex-d) |
| (d) | pressurised | (Ex-p) with item certification |
| (e) | non-incendive | (Ex-N) |

NOTES:
1. Option (c) is preferred to option b) if the apparatus is without an internal source of release.
2. Option (e) is suitable only for apparatus without an internal flammable source of release installed in Zone 2 areas

Electrical installation shall be in compliance with DEP 33.64.10.10-Gen.

### 4.2.2 Location of QMI

QMI should be located close to the sample take-off point if this can be done without adversely affecting the perfomance or maintainability of the analyser.

If performance or maintainability cannot otherwise be assured, the QMI should be located in a walk-in shelter or an analyser house.

The required environment (e.g. humidity, temperature, area classification, etc.) may require the analyser to be located in an analyser house.

Walk-in shelters shall have the same area classification as the surrounding area.

The following analysers are normally suitable for location in a walk-in shelter:

- Oxygen meters on flue gas in stacks or ducts

  NOTE: $ZrO_2$ type oxygen meters may be installed with sunshade and rain protection only.

- pH (electrode-type) meters
- Electrical conductivity meters
- Dissolved oxygen analysers
- Density meters for "absolute density" measurements (i.e. density under process conditions).

  NOTE: pH-meters, electrical conductivity, dissolved oxygen and density meters may be installed in a small cabinet dimensioned to contain the control units only. The transducer element may need protection against direct solar radiation and rain.

- moisture analysers
- $H_2S/SO_2$ ratio (Air Demand) analysers on sulphur recovery (Claus) units
- QMI handling very viscous products (e.g. bituminous products) which may solidify at ambient temperatures.

### 4.2.3 QMI monitoring gaseous products

QMI for monitoring the composition of gaseous products and requiring the best possible precision and bias shall have:

- either the outlet of the measuring cell vented to a vent system at constant absolute pressure (3.2.10).
- or electronic compensation for barometric pressure changes.

### 4.2.4 QMI with thermostatic baths

Samples entering these analysers shall be at a temperature not more than 10 °C higher or lower than the thermostatic bath/oven temperature, or less if so specified by the Manufacturer.

### 4.2.5 Electrical protection

The inside of an analyser house with artificial ventilation should be classified as Non-hazardous. However, the following recommendations shall be followed without exception:

All electric and electronic enclosures which are installed inside an analyser house and which may not be switched off on ventilation failure, shall be suitable for installation in Zone 1 hazardous areas.

All electric and electronic enclosures with an internal flammable source of release, whether they are installed inside an analyser house or in any area of the process plot, shall be suitable for installation in Zone 1 hazardous areas, irrespective of the area classification.

Gas group and temperature class shall be as follows:

a) For apparatus without an internal flammable source of release, the gas group and temperature class shall be the same as that of the process area in which the QMI or the analyser house is located.

NOTE: The fact that hydrogen is brought to the analyser house for operation of e.g. Process Gas Chromatographs should not affect the outside gas group classification. This is because due to the design conditions of an analyser house (DEP 32.31.50.13-Gen.) the maximum amount of hydrogen that will be released under worst conditions is far below the quantities that affect area classification.

b) For apparatus containing an internal flammable source of release, the gas group and temperature class shall meet one of the following requirements, whichever offers the highest degree of protection:
   (i) the same as that of the process area in which the QMI or the analyser house is located,
   or
   (ii) as applicable for the type of internal flammable source of release in the apparatus.

For example,

| | | Gas group | | Temperature class |
|---|---|---|---|---|
| IF | the process area has been classified as: | IIA | and | T3 |
| AND | the QMI is analysing or using hydrogen, i.e. has the classification: | IIC | and | T1 |
| THEN | the electrical protection of that QMI part containing an internal flammable source of release shall be: | IIC | and | T3 |

### 4.2.6 Power supply

AC powered apparatus should have the same voltage as the site power supply. Separate step-down transformers shall not be used.

### 4.2.7 Output signal

Refer to Appendix 3.

The preferred way of data transfer to Distributed Control System (DCS) is via serial link. The serial link shall provide either single loop integrity or be redundant. The configuration is subject to the approval of the DCS design engineer.

Digital data transfer between equipment of different makes shall comply with the Modbus RTU protocol.

### 4.2.8 Measuring range

#### 4.2.8.1 General

The measuring range (span) should be selected such that it
- provides optimum precision, and
- prevents false sense of accuracy (span too narrow)

The measuring ranges quoted below are guidelines.

#### 4.2.8.2 (Electrode-type) pH meter

The typical range for electrode-type pH meters is 4 - 10.

#### 4.2.8.3 Electrical conductivity meter

The optimum range of electrical conductivity meters is 2 decades, e.g. 1 - 100 microsiemens or 0.1 to 10 microsiemens, etc.

A larger range results in reduced precision and should not be applied unless reduced precision is acceptable.

#### 4.2.8.4 Spectrometric analysers, Infrared and Ultraviolet type

The optimum range of light absorption spectrometers is 2 decades.

A larger range results in reduced precision and should not be applied unless reduced precision is acceptable.

#### 4.2.8.5 Process Gas Chromatographs (PGC)

The range for a single component on a PGC with thermal conductivity detection (TCD) shall not exceed 1-to-1000, and should not exceed 1-to-100.

The range for a single component on a PGC with flame ionization detection (FID) shall not exceed 1-to-10 000, and should not exceed 1-to-1000.

#### 4.2.8.6 Pump driven capillary and rotating type viscometers

The range shall be expressed in absolute viscosity units. Kinematic viscosity can be calculated by dividing by the absolute density.

The output shall not be expressed in kinematic viscosity units, unless it has been compensated with the density signal from a density meter on the same fast loop.

#### 4.2.8.7 Moisture measurements

a) Mirror-type dewpoint meters
The output shall be expressed in temperature units.

b) Karl Fischer measurements shall be expressed in mg/m$^3$.

c) Metal-oxide type moisture meters
The output shall be expressed in cm$^3$/m$^3$.

d) $P_2O_5$ (phosphorus pentoxide) output should be expressed in cm$^3$/m$^3$.

e) Absorption-type moisture meters, e.g. LiCl type
The output shall be expressed in % RH (Relative Humidity).

f) Hygroscopically coated vibrating crystal type moisture meters
The output shall be expressed in mg/m$^3$.

### 4.2.9 Utilities

All utilities except instrument air shall enter the QMI via the sample conditioning system.

NOTE: Utilities should only enter closed Sample Conditioning Cabinets when this is strictly required. If not located inside, associated isolation valves, flow limiting devices, etc., shall be placed at accessible locations adjacent to the Sample Conditioning Cabinet.

Instrument air may be brought to the QMI via the sample conditioning system or directly from the Analyser House instrument air header.

### 4.2.10 Vent and drain outlets

Vent and drain outlets should be routed via the sample conditioning system rack.

NOTE: For additional information on vent and drain procedures refer to DEP 32.31.50.11-Gen.

Gases and vapours from products, of any type and in any quantity, shall not be vented to atmosphere unless approved by the Principal.

NOTES: a) Certain analysers, PGCs and spectrometric type QMI, require an outlet at near-atmospheric pressures and at very constant back-pressure. In that case the measuring cell outlets shall be vented via a gas recovery system (at constant absolute pressure or at a pressure slightly above ambient pressure) to process or flare (4.2.3).

b) For further information on how to deal with vents and outlets refer to DEP 32.31.50.11-Gen.

The measuring cell outlet and the sample valve outlet of PGC with Thermal Conductivity Detection measuring gaseous products shall be vented to the same vent system.

The sample valve outlet of PGC with Flame Ionization or Photo Ionization Detection and measuring gaseous products shall be vented to a system at constant absolute pressure.

### 4.2.11 Computer-assisted functions

Analyser equipment should be microprocessor based, aiming at a high degree of self diagnostics and supporting on-line statistical control of the validation and calibration procedures. Priority should be given to arrangements compatible with the AMADAS functionality as per Report MF 93-1410.

# 5. INSPECTION AND TESTING

## 5.1 FACTORY INSPECTION AND TESTING

### 5.1.1 General

Inspection and testing at the Manufacturer/Supplier's works shall be carried out in accordance with DEP 62.10.09.11-Gen. and the Manufacturer's own procedures.

### 5.1.2 Acceptance test

The QMI shall be tested at the Manufacturer/Supplier's works to demonstrate proper functioning of the system prior to shipment to site. The Principal shall be invited to witness the Factory Acceptance Test (FAT).

Testing shall comprise a full check on the operational requirements and on proper functioning of all hardware and, where applicable, software in the system.

Testing shall include a full functional check, including fault diagnostics, and a test run with a sample with properties close to the process sample to prove the precision of the QMI as requisitioned.

## 5.2 SITE INSPECTION AND TESTING

Site inspection and testing shall be carried out in accordance with DEP 62.10.08.11-Gen. and the Manufacturer's own procedures.

# 6. CALIBRATION AND TESTING DURING START-UP AND COMMISSIONING

## 6.1 GENERAL

At initial start-up QMI need to be calibrated to match the output signal to the reference value.

## 6.2 CALIBRATION AND TEST RECORDS

For record purposes a specific calibration sheet shall be completed after each calibration and a test sheet after each test. These sheets shall clearly indicate the date, the name of the technician, and the type of calibration or test.

## 6.3 TEST MIXTURES

### 6.3.1 Gravimetrically prepared standards:

Gravimetrically prepared standards are traceable to mass standards and weighing procedures and to the sources of their constituents. This standard shall be used for calibration of QMI measuring the composition of a product when a maximum accuracy is required.

The supplier of the mixture shall be requested to submit the results of the gravimetric procedures. These results shall be referred to as the true value.

NOTE: The Manufacturer often verifies the test mixture by laboratory analysis for which he usually issues a "Certificate of Analysis". The accuracy of gravimetrical standards are, however, considered as superior to the methods of analysis. Therefore this "Certificate of Analysis" shall not be used for calibration.

### 6.3.2 Traceable standards:

Traceable standards are products which by analysis have been compared with samples obtained from an official standardization centre. The precision cannot be better than the precision of the analytical method.

Certain QMI, e.g. cloudpoint analysers and flashpoint analysers, can be calibrated against traceable standards obtained from the Principal's main laboratory or from a Quality Surveyor, in which case the "Certificate of Analysis" shall be used for calibration.

### 6.3.3 Secondary standards:

Secondary standards are traceable to either a gravimetrically prepared standard or a traceable standard.

A secondary standard may be used for checking or testing purposes. A secondary standard is typically derived from material collected from a suitable location in the process.

## 6.4 PROCEDURES FOR CALIBRATION/VERIFICATION OF QMI

### 6.4.1 General

The normal method for calibration and verification of QMI is to introduce a suitable test mixture to the QMI.

When more than one party has an interest in the integrity of the analyser, e.g. in case of custody transfer, the method and its procedural coverage shall be subject to mutual agreement between the parties.

NOTE: Contractual conditions may impose constraints on the selection of analysers and the associated equipment and facilities.

### 6.4.2 Composition

PGC, infrared and ultraviolet spectrometers and mass spectrometers shall be calibrated with test mixtures. In addition mass spectrometers require gravimetrically prepared binary mixtures for each component analysed and/or interfering components.

### 6.4.3 Density, Relative density (vibrating type)

Absolute density meters shall be calibrated in accordance with the Manufacturer's instructions. Calibration shall only be performed under laboratory conditions.

Verification may be performed by checking the inherent frequency of the vibrating spool of the sensor at near-vacuum conditions. Grab sampling may be an alternative for gas density analysers, provided that temperature and pressure during sampling can be measured to an acceptable degree of accuracy. The density can then be calculated on the basis of compositional data and the measured temperature and pressure, taking into account the compressibility of the gas (e.g. for natural gas following the AGA NX19 or the GERG standard). Uncertainties of the method shall be carefully evaluated so as to provide judgement on the criteria for adjustment.

Relative density meters should be calibrated with pure gases of different molecular weight. Calibration may be performed in situ.

NOTE: When pure gases do not facilitate the required narrow span for calibration, either one or both test gases may be gravimetrically prepared binary mixtures. The relative density can then be calculated on the basis of compositional data, taking into account the compressibility of the mixture and air, both at the defined reference conditions.

### 6.4.4 Dissolved oxygen

The normal method for calibration of a dissolved oxygen meter is by exposing it to air. The Manufacturer's instruction manual should be followed for detailed procedure. Zero checks should be performed by passing the sample through an oxygen scavenger.

### 6.4.5 Flammable gas detection

Refer to DEP 32.30.20.11-Gen.

### 6.4.6 Flashpoint analysers

These shall be calibrated with a traceable standard. The range of calibration should not exceed 20 °C.

### 6.4.7 $H_2S$ gas detection

Refer to DEP 32.30.20.11-Gen.

### 6.4.8 Moisture measurements

Refer to (2.5.8).

### 6.4.9 Oxygen

a) Initial calibration of zirconium-oxide-type meters shall be carried out with three test gases, low-span, mid-span and high-span. Subsequent re-calibrations may be carried out with low-span and high-span test gas only.

b) Para-magnetic-type oxygen meters shall be calibrated with zero gas and air as span gas. The composition of the zero gas should reflect the background gas at process conditions.

c) Polarographic-type oxygen meters shall be calibrated with zero gas and span gas. If the measuring span exceeds more than one decade, mid-span gas may be required. The composition of the test gases should reflect the background gas at process conditions.

### 6.4.10 pH measurements

a) Calibration of electrode-type pH meters shall be carried out with buffer solutions with a wide temperature range.

On-line pH meters may be verified with a portable pH meter that has been certified by the Principal's main laboratory. Comparing pH values from on-line pH meters with samples analysed elsewhere is not reliable. Similarly, testing on-line pH meters with pH paper is not reliable.

b) Titration-type pH meters shall be calibrated by using gravimetrically prepared samples of known pH.

# 7. MAINTENANCE, CALIBRATION AND TESTING DURING NORMAL OPERATION

## 7.1 GENERAL

Maintenance, testing and calibration of QMI are usually carried out by the Principal's site service organisation or by a third party under service contract.

Initial readings (output values versus reference values and response times) should be recorded in the relevant part of the site "Instrument / QMI Maintenance Management System".

## 7.2 MAINTENANCE

Scheduled maintenance on QMI includes visual inspection at specified intervals. Any deviation from observed conditions (i.e. flow, pressure, temperature etc.) shall be corrected and recorded.

## 7.3 TEST/CALIBRATION FREQUENCIES

Initial calibration and test frequencies shall be selected taking the Manufacturer's recommendations into account. As system performance is recorded with time, test frequencies should be adapted to such a level where optimum performance is ensured.

At times that the QMI is tested for its performance, adjustments to match the output signal to the reference value should be carried out only when the difference exceeds the specified tolerance limits. These tolerances should be subject to statistical control and should depend on historic verification data.

NOTES:

1) For record purposes, a specific calibration record should be completed after each calibration, and a test sheet after each test. These sheets should include the date, the name of the technician, and the type of calibration or test. Hard copy (paper) or electronic (from the site Instrument Analyser Maintenance Data Acquisition System) records can be used.

2) QMI may be considered to have an acceptable performance when the Mean Time Between Adjustments is equal to or greater than one month. This period can sometimes not be met due to limitations of the measuring technique of the QMI.

For calibration under operating conditions, the same procedures apply as described in (7).

## 8. REFERENCES

In this DEP reference is made to the following publications:

NOTE: Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments/supplements/revisions thereto.

**Amended per Circular 45/99**

### SHELL STANDARDS

| | |
|---|---|
| Index to DEP publications and standard specifications | DEP 00.00.05.05-Gen. |
| Requisitioning Binder (containing data/requisition and requisition sheets) | DEP 30.10.01.10-Gen. |
| The instrumentation of fire and gas detection systems | DEP 32.30.20.11-Gen. |
| Instruments for measurement and control | DEP 32.31.00.32-Gen. |
| On-line process stream analysis<br>- Sample take-off and transportation | DEP 32.31.50.10-Gen. |
| On-line process stream analysis<br>- Sample conditioning | DEP 32.31.50.11-Gen. |
| On-line process stream analysis<br>- Analyser Houses | DEP 32.31.50.13-Gen. |
| Electrical engineering guidelines | DEP 33.64.10.10-Gen. |
| Field inspection and testing of instruments and instrument systems | DEP 62.10.08.11-Gen. |
| Factory inspection and testing of instruments and instrument systems | DEP 62.10.09.11-Gen. |
| Analyser Maintenance And Data Acquisition Systems (AMADAS) | MF Report 93-1410 |

### INTERNATIONAL STANDARDS

| | |
|---|---|
| Electrical apparatus for explosive gas atmospheres | IEC 79 |
| Degrees of protection provided by enclosures (IP code) | IEC 529 |

*Issued by:*
*Central Office of IEC (Sales Dept.)*
*3, Rue de Varembé*
*1211 Geneva 20*
*Switzerland.*
*Copies can also be obtained from national standards organizations.*

| | |
|---|---|
| Quality systems - Model for quality assurance in design, development, production, installation and servicing | ISO 9001 |

*Issued by:*
*Central Office of ISO*
*1, Rue de Varembé*
*1211 Geneva 20*
*Switzerland.*

*Copies can also be obtained from national standards organizations.*

## APPENDIX 1 TYPES OF QMI

Cloudpoint analysers. Optical type -,

Colour Alarm
  Spectrometers. Visible light -,

Composition
  Spectrometers. Infrared -,
  ditto. Ultraviolet -,
  ditto. Mass -
  Process Gas Chromatographs

Conductivity meter
  Conductivity electrode system

Density. Gas/Liquid/Relative Density - ,
  Vibrating-type density meter

Dissolved oxygen
  Polarographic cell

Distillation. 95% recovered -
  Distillation analysers
  PGCs. Simulated distillation Process Gas Chromatographs

Distillation. Final boiling point - analysers
  Distillation analysers. 95% recovered
  PGCs. Simulated distillation Process Gas Chromatographs

Flammable gas detection
  Infrared-type detectors
  Pellistor-type detectors

Flashpoint analysers

$H_2S$ gas detection for area monitoring
  Electrochemical type sensors
  Semi-conductor type sensors

$H_2S$ in effluent water
  Water quality analyser - Titrator

KVP - Vapour Pressure. Kinetic - ,
  KVP analyser

Moisture
  Dewpoint mirror technique with capacitance detection
  Karl Fischer titration
  LiCl sensors
  Metal-oxide sensor
  $P_2O_5$ (phosphorus pentoxide) sensors

Oil in water
  Total Organic Carbon meters with UV-oxidation
  TOC meters with catalytic combustion

Opacity (Smoke Density) meters. Optical type -
  Spectrometers. Visible light -

Oxygen in flue gas
  $O_2$ meters. Zirconium-oxide type -,

pH
  pH electrode system for $4 \leq pH \leq 10$
  Titrators for $pH < 4$, and $pH > 10$

Phenol in water
  Water quality analyser
  PGC

  Colorimetric-type water quality analysers

TOC - Total Organic Carbon
  UV oxidation type

Viscosity
  Capillary type -

## APPENDIX 2 ON-LINE QUALITY MEASUREMENTS IN PETROCHEMICAL PROCESSES

This Appendix contains typical QMI for various plants.

### 1. OIL PROCESSES

### 1.1 ADIP TREATER

Composition
$H_2S$ in process gas
$H_2S$ gas detection for area monitoring

### 1.2 ALKYLATION UNIT

Composition
Density. Gas - ,
Electrical conductivity
Oxygen in furnace fluegas
pH

### 1.3 AROMATICS FRACTIONATOR

Composition

### 1.4 BUTANE DE-ASPHALTING

Colour alarms
Density. Liquid - ,
Viscosity

### 1.5 CATALYTIC CRACKING UNIT

Composition
Density. Gas - ,
Distillation. Final Boiling Point - ,
Flammable gas detection
Flashpoint
$H_2S$ area monitoring
KVP - Kinetic Vapour Pressure
Opacity (Smoke Density)
pH
Pourpoint
Regenerator gas. $O_2$ in - ,
Regenerator gas. CO in - ,
Regenerator gas. NOx in - ,
Regenerator gas. $SO_2$ in - ,
RSH - Mercaptans

### 1.6 CRUDE DISTILLATION UNIT

Cloudpoint
Composition
Distillation. Boiling range - ,
Distillation. 95% recovered -
Distillation. Final boiling point - ,
Electrical conductivity
Flammable gas detection
Flashpoint
Freezing point
$H_2S$ gas detection for area monitoring
Opacity meters

Oxygen in fluegas
pH in crude distiller overhead water
Salt in crude
Viscosity

## 1.7 FUEL GAS SYSTEM

Composition
Density. Gas - ,
Density. Relative -

## 1.8 HYDROCRACKING UNIT

### 1.8.1 Hydrocracking unit - Fractionator

Composition
Conductivity. Electrical - ,
Density. Gas -
Distillation. 95% recovered
Flashpoint
$H_2S$ area monitoring
KVP - Vapour Pressure. Kinetic - ,
Oxygen in furnace fluegas

### 1.8.2 Hydrocracking unit - Reactor section

Colour alarm
Conductivity. Electrical - ,
Density. Relative -
$H_2S$ area monitoring
Oxygen furnace fluegas

## 1.9 HYDRO-DESULPHURIZER

Electrical conductivity
$H_2S$ area monitoring
Opacity (Smoke Density)
Oxygen in furnace fluegas

## 1.10 HMU - HYDROGEN MANUFACTURING UNIT

Composition
CO
$CO_2$
Density. Gas - ,
Dissolved oxygen
Electrical conductivity
Hydrogen
Nitrogen
Oxygen in furnace fluegas
pH
Silicate
(Total) sulphur
Wobbe Index

## 1.11 HOT OIL SYSTEM

Oxygen in furnace fluegas

### 1.12 HVU - HIGH VACUUM UNIT

Cloudpoint
Colour alarm
Flammable gas detection
$H_2S$ area monitoring
Opacity (Smoke Density)
Oxygen in furnace fluegas
Oxygen. trace - ,
pH
Viscosity

### 1.13 HYCON

$CO_2$
Colour alarm
Composition
Density. Gas - ,
Density. Liquid - ,
Dissolved oxygen
Electrical conductivity
Flashpoint
Oxygen in gas in the presence of flammable vapours
Oxygen in furnace fluegas
pH
Silicate
TOC - Total Organic Carbon
Viscosity

### 1.14 HYDROTREATER

Composition
Distillation. 95% recovery - ,
Flashpoint
$H_2S$ area monitoring
KVP - Kinetic Vapour Pressure
Oxygen in furnace fluegas
Opacity

### 1.15 LPG PLANT

Composition
Density. Gas - ,
Density. Liquid - ,

### 1.16 PLATFORMING UNIT

Composition
Density. Liquid - ,
Density. Relative - ,
Electrical conductivity
$H_2S$ in process gas
HCl in process gas
KVP - Kinetic Vapour Pressure
Moisture in recycle gas
Octane Number
Opacity
Oxygen in furnace fluegas
PNA analysis. Paraffins / Naphthenes / Aromatics - ,

### 1.17 SULFINOL UNIT

CO - Carbon monoxide
Composition
Density. Gas - ,
Density. Relative - ,
Electrical conductivity
Oxygen in furnace fluegas
pH
RSH - Mercaptans

### 1.18 SRU - SULPHUR RECOVERY UNIT

Air demand - $H_2S:SO_2$ ratio
Flammable gas detection
$H_2S$ area monitoring
Hydrocarbons in feed
Oxygen in furnace fluegas

### 1.19 VISBREAKER

Colour alarm
Density. Liquid - ,
Flashpoint
$H_2S$ area monitoring
Oxygen in furnace fluegas
pH
Viscosity

### 1.20 STORAGE, TANK-FARM, MOVEMENTS

Benzene in naphtha
CFPP - Cold Filter Plugging Point
Cloudpoint
Composition
Density. Liquid - ,
Distillation. Boiling range - ,
Distillation. 95% recovered - ,
Distillation. E70 - ,
Distillation. E100 - ,
Distillation. E135 - ,
Flammable gas detection
Flashpoint
KVP - Kinetic Vapour Pressure
Moisture
Octane Number. RON and MON - ,
Pourpoint
(Total) sulphur in oil
Viscosity

## 2. GAS PROCESSES

Colour alarm
Composition
Density. Gas - ,
Density. Liquid (LPG) - ,
$H_2S$ in gas
Total sulphur
KVP - Kinetic Vapour Pressure
Moisture

## 3. CHEMICAL PROCESSES

### 3.1 DI-PHENYLOL PROPANE - DPP

Conductivity. Electrical -
Flammable gas detection
Moisture
pH
Phenol in water
Oxygen in fluegas

### 3.2 MEK - DE-WAXING UNIT

Pourpoint

Refractive Index

### 3.3 POLYPROPYLENE UNIT

CO - Carbon monoxide
$CO_2$
Composition
Density. Gas - ,
Hydrogen
Flammable gas detection
Moisture
Oxygen. Trace - ,
pH
SBA - Secondary Butyl Alcohol

## 4. UTILITIES, AIR

### 4.1 AIR DRIERS

Dewpoint of air

## 5. UTILITIES, WATER

### 5.1 BOILERS

Density. Gas - ,
Electrical conductivity
Oil in water
Oxygen in boiler fluegas
Opacity of stack gas
pH
Water quality. Hardness - ,
Water quality. Phosphate - ,
Water quality. Silicate - ,
Water quality. Sodium - ,
Water quality. TDS (Total Dissolved Solids) - ,

### 5.2 CONDENSATE SYSTEM

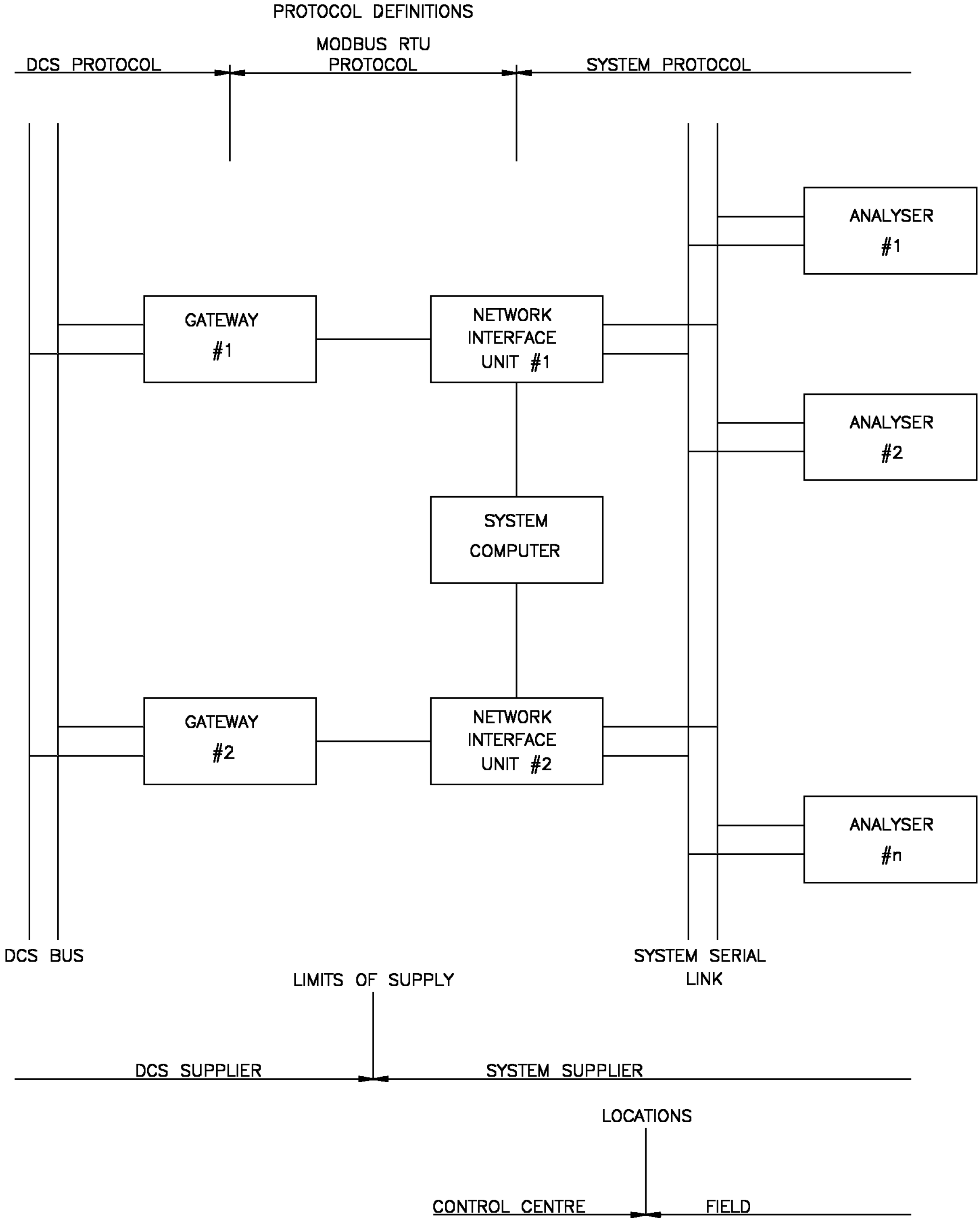
Chlorine
Conductivity. Electrical -
Dissolved oxygen
$H_2S$ in effluent water
Oil in water

pH

## 5.3 WATER TREATER

Chlorine in air
Chlorine in water
Dissolved oxygen
Electrical conductivity
$H_2S$ area monitoring
$H_2S$ in water
Oil in water
pH
TOC - Total Organic Carbon

## APPENDIX 3 TYPICAL EXAMPLE OF A REDUNDANT SERIAL LINK



## APPENDIX 4 TYPICAL EXAMPLE OF A SINGLE LOOP INTEGRITY DESIGN