MANUAL

INSTRUMENTS FOR MEASUREMENT AND CONTROL

DEP 32.31.00.32-Gen.

July 1999

DESIGN AND ENGINEERING PRACTICE

PREFACE

DEP (Design and Engineering Practice) publications reflect the views, at the time of publication, of:

Shell International Oil Products B.V. (SIOP)
and
Shell International Exploration and Production B.V. (SIEP)
and
Shell International Chemicals B.V. (SIC)

The Hague, The Netherlands,

and other Service Companies.

They are based on the experience acquired during their involvement with the design, construction, operation and maintenance of processing units and facilities, and they are supplemented with the experience of Group Operating companies. Where appropriate they are based on, or reference is made to, national and international standards and codes of practice.

The objective is to set the recommended standard for good design and engineering practice applied by Group companies operating an oil refinery, gas handling installation, chemical plant, oil and gas production facility, or any other such facility, and thereby to achieve maximum technical and economic benefit from standardization.

The information set forth in these publications is provided to users for their consideration and decision to implement. This is of particular importance where DEPs may not cover every requirement or diversity of condition at each locality. The system of DEPs is expected to be sufficiently flexible to allow individual operating companies to adapt the information set forth in DEPs to their own environment and requirements.

When Contractors or Manufacturers/Suppliers use DEPs they shall be solely responsible for the quality of work and the attainment of the required design and engineering standards. In particular, for those requirements not specifically covered, the Principal will expect them to follow those design and engineering practices which will achieve the same level of integrity as reflected in the DEPs. If in doubt, the Contractor or Manufacturer/Supplier shall, without detracting from his own responsibility, consult the Principal or its technical advisor.

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NOTE: In addition to DEP publications there are Standard Specifications and Draft DEPs for Development (DDDs). DDDs generally introduce new procedures or techniques that will probably need updating as further experience develops during their use. The above requirements for distribution and use of DEPs are also applicable to Standard Specifications and DDDs. Standard Specifications and DDDs will gradually be replaced by DEPs.

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APPENDICES

1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for the selection and specification of instruments used for measurement and control of process variables.

This DEP is a revision of an earlier publication of the same number dated December 1996.

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 the Royal Dutch/Shell Group or managed by a Group company, 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 and, where applicable, in exploration and production facilities and 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, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations.

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

Analyser systems integrator	is a company that has the expertise to engineer, design, construct, test and commission complete analyser systems and provide other related services such as software support, on-site installation, maintenance and prefabricated analyser house installation where needed.
Instrumented protective function	is a function comprising the initiator function, logic solver function and final element function for the purpose of preventing or mitigating hazardous situations.
Instrumented protective system	is the electromechanical, electronic and/or programmable electronic Logic Solver component of the Instrumented Protective Function, complete with input and output equipment.
Modbus-RTU	is an industrial networking system that uses serial master-slave communication links at data transfer rates up to 19.2 Kbaud, in combination with a RS 232C physical link. NOTE: MODBUS-RTU is a generic phrase and the Contractor shall be more specific when quoting this communication system.
Piping class	An assembly of piping components, suitable for a defined service and design limits, in a piping system. The piping classes are contained in DEP 31.38.01.12-Gen. (primarily for SIOP applications) and DEP 31.38.01.15-Gen. (primarily for SIEP applications)
The **price** of an item	is the amount paid to the supplier of the item in question.
The **project specification**	is a technical contract document forming part of the agreement between the Principal and the Contractor. It contains all basic information on the project and all instructions and specifications as are required to enable the Contractor to prepare detailed design and engineering work. It furthermore contains all procedures and requirements for the execution of the work and services to be performed by the Contractor for the realisation of the project.
Reliability	is the ability of an instrument or system to perform a specified function under stated conditions for a stated period of time.
Total cost of ownership (TCoO)	is the total cost of owning an asset over its entire life, from conception of the need through to ultimate disposal. The TCoO is made up of the following cost elements: specification, price, purchasing, introduction/ installation, execution/ operation and termination/ disposal. A method for calculating the TCoO is given in DEP 32.31.09.31-Gen.
The **tolerance class**	is an identification code of measuring instruments which meets certain requirements that are intended to keep errors within specified limits.
Variety control	is the process of selecting an optimum number of different types and vendors, of products, processes or services to meet prevailing needs.

1.3.3 Abbreviations

DCS	Distributed control system
EMC	Electromagnetic compatibility
HART	Highway addressable remote transducer
IPF	Instrumented protective function
IPS	Instrumented protective system
PEFS	Process engineering flow scheme

PLC	Programmable logic controller
RTU	Remote terminal unit
SCADA	Supervisory control and data acquisition
TCoO	Total cost of ownership

1.4 CROSS-REFERENCES

Where cross-references are made, the number of the section or sub-section referred to is shown in brackets.

All publications referred to in this DEP are listed in section (12).

2. GENERAL REQUIREMENTS

2.1 SELECTION OF INSTRUMENTS

The selection of an instrument for a specific application is an iterative process, carried out as a joint effort of a process technologist and an instrument engineer. It is important to record the selection process for auditing purposes and future reference.

The selection process should involve the following steps:

1) Identify all operating cases, such as normal operation at minimum, normal and maximum flow, alternative operating modes, start-up, commissioning and emergency operation.

2) Determine the operating window by collecting all relevant process data for each operating case, including:
   - Fluid data such as fluid name and phase, physical properties, special fluid aspects such as corrosiveness, erosiveness, toxicity and presence of solids or contaminants, special risks such as foaming, decomposition, fouling, plugging, depositing, solidification and chemical reaction.
   - Operating data such as flow rate, pressure, temperature, density and viscosity.
   - Application aspects, such as continuous/batch operation, pulsating flow, uni-directional or bi-directional flow, backflow risk, mechanical integrity, vibration and hydraulic noise.

3) Collect data regarding the operating environment of the instrument. This should include the following aspects:
   - Accessibility and physical location in relation to equipment and piping.
   - Mechanical integrity.
   - Electrical safety and EMC requirements.
   - Health, safety and environmental conditions.
   - Requirements of the plant organisation regarding maintenance, data collection and retrieval, self-diagnostic and documenting features, expertise and training, stock keeping etc.
   - Authority requirements: Instruments, instrument systems and components for installation in certain European countries shall conform with the applicable EU (European Union) directives and shall be supplied with the required CE (European Community) certification and markings in accordance with legislation in the European Union. In other areas, equivalent local regulations and certification requirements may apply.

4) Select the adjusted range (2.4) and accuracy (2.8) to suit the process requirements.

5) Select measurement options and gather additional data required for the particular measurement principle.

6) Select suitable instrument makes and types for each measurement option from the ‘List of Selected Instrument Vendors’ as prepared for each project. The types of instruments already installed at the Principal's site should be taken into consideration, for the sake of variety control.

7) Evaluate the pros and cons of each measurement option and select the optimum solution, considering the following aspects:
   - Coverage of and performance under the process conditions, listed above.
   - Compliance with the aspects listed above under point 3.
   - The total cost of ownership (TCoO) over a period of 10 years. (A method for calculating the TCoO is given in DEP 32.31.09.31-Gen.)
   - Additional hardware required for proper operation, such as calibration facilities or disposal systems.
   - Specific maintenance aspects such as accessibility requirements, calibration aspects, self-diagnostic features, purging/flushing/disposal aspects.

Specific aspects for the selection of instruments per process variable are covered by the relevant sections of this document.

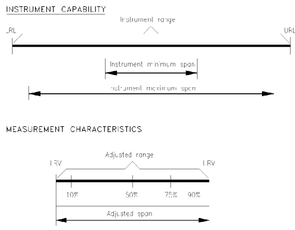
Specific fields of application are covered by the following DEP publications:

- Instrumentation in equipment packages	DEP 32.31.09.31-Gen.
- On-line process stream analysis	DEP 32.31.50.10-Gen. DEP 32.31.50.11-Gen. DEP 32.31.50.12-Gen. DEP 32.31.50.13-Gen.
- Instrumentation of fire, gas and smoke detection systems	DEP 32.30.20.11-Gen.
- Control valves, actuators, solenoid valves and valve accessories, including guidance for sizing and selection	DEP 32.36.01.17-Gen.
- Depressuring systems	DEP 32.45.10.10-Gen.

2.2 UNITS OF MEASUREMENT

The ranges and scales shall be in SI units unless otherwise specified, see DEP 00.00.20.10-Gen.

2.3 DEFINITION OF INSTRUMENT RANGE AND SPAN



Legend:

Range	Defined in IEC 60902 as follows: The region of values between the lower and upper limits of the quantity under consideration. It is expressed by stating the lower and upper limits (e.g. minus 1 to 10 bar (ga)).
Span	Defined in IEC 60902 as follows: The algebraic difference between the upper and lower limit values of a given range. It is expressed as a figure and unit of measurement (e.g. 8 bar).
LRL	Lower Range Limit; the lowest quantity that a device is designed to measure.
URL	Upper Range Limit; the highest quantity that a device is designed to measure.
Instrument range	The region in which the instrument is designed to operate. It is a physical capability of the device. The region limits are expressed by stating the LRL and URL.
Instrument minimum span	The minimum distance between the URV and LRV for which the instrument is designed. It is a physical limitation of the device.
Instrument maximum span	The maximum distance between the URV and LRV for which the instrument is designed. It is a physical limitation of the device.
LRV	Lower Range Value; the lowest quantity that a device is adjusted to measure.
URV	Upper Range Value; the highest quantity that a device is adjusted to measure.
Adjusted range	The measurement region. It is expressed by stating the

LRV and URV.

Adjusted span — The distance between the URV and LRV.

Example: A differential pressure transmitter is used to measure the level in a vessel, using a wet reference leg. 0% level corresponds with a differential pressure of -800 mbar and 100% level with - 100 mbar. The catalogue of the selected transmitter lists -1800/+1800 mbar for LRL/URL respectively and span limits of 300 to 1800 mbar, so:

Instrument range	=	-1800 to +1800 mbar
Instrument minimum/maximum span	=	300 / 1800 mbar respectively;
LRV / URV	=	-800 / -100 mbar respectively;
Adjusted range	=	-800 to -100 mbar.
Adjusted span	=	700 mbar.

NOTE: ‘Adjusted’ range and ‘adjusted’ span are frequently referred to as ‘calibrated’ range and ‘calibrated’ span. This term is however only correct, if a calibration facility is used to set the LRV and URV. For ‘intelligent’ measuring devices, the supplier is usually calibrating the device at the LRL/URL and the user is setting the required LRV and URV by remote communication.

2.4 SELECTION OF RANGES

The accuracy (2.8) and adjusted range of an instrument should be selected to cover the operating window (2.1), which includes applicable abnormal operation and alternative operating modes. Unless otherwise stated, the normal design value should lie between 50% and 75% of the adjusted range

NOTE: For certain applications it might not be possible to combine all normal and abnormal operating conditions in one measurement at the required accuracy. In such cases, a case-by-case analysis should disclose whether additional instruments are required or the accuracy requirements and/or operating window may be relaxed. It might be acceptable to present measured values during some of the abnormal operating cases at a lower accuracy or it might be justifiable for the measurement not to produce a sensible signal under some of the abnormal process conditions during start-up, commissioning, regeneration, emergency conditions and the like.

IPF transmitters should have the same instrument range, adjusted range and accuracy as corresponding process transmitters in order to facilitate measurement comparison. For details and exceptions, see DEP 32.80.10.10-Gen. Trip settings should lie between 10% and 90% of the adjusted range.

The LRV should be selected so that the displayed result represents the zero or sub-zero value of the process variable (e.g. 0-150 tons/day, 0-100% level, 0-10 bar (ga), -1/+3 bar (ga), 0-500 °C, -50/+50 °C etc.). Elevated zero’s (100-300 tons/day, 100-200 °C) should be avoided.

2.5 SIGNAL TRANSMISSION AND POWER SUPPLY

2.5.1 Electric signal transmission

Signal transmission requirements for IPF are covered by DEP 32.80.10.10-Gen.

'Intelligent' analogue communication (at 4-20 mA) should be considered between field transmitters and DCS. This can be achieved via a hand-held terminal/PC and/or a terminal in the control room. The 'HART' protocol is preferred as it is the most widely available, common, open protocol, supported by the majority of the instrumentation vendors.

Until a fieldbus is fully developed and internationally standardised, proprietary digital protocols from approved DCS vendors are acceptable. Often this means that only digital transmitters from the selected DCS supplier can be used.

Pending an internationally standardised fieldbus, Modbus-RTU serial communication protocol is the preferred communication between DCS and other digital sub-systems, including analyser systems. 'HART', being the most widely available common, open protocol and supported by the majority of the instrumentation vendors, should be considered in the TCoO estimates.

Transmission from DCS to the field mounted final elements shall be 4 to 20 mA DC.

Instrumentation such as for machine monitoring, fire and gas detection, tank gauging, sub-systems for motor operated valves, etc. may have other signal transmission requirements according to Manufacturers' standards.

2.5.2 Pneumatic signal transmission

Pneumatic signal transmission shall only be applied with the approval of the Principal, and where it is used the transmission signal shall be 0.2 to 1.0 bar (ga).

2.5.3 Power supply

The criticality of the application shall determine whether or not an instrument shall be powered from an uninterruptible power supply source at 24 VDC or 115/230 VAC. The normal operation of AC powered instruments shall not be adversely affected by power dips caused by load transfer operations of UPS systems.

2.6 ELECTRICAL SAFETY IN EXPLOSIVE ATMOSPHERES

2.6.1 General

In order to prevent electrical apparatus, including electronic process instrumentation, from becoming a source of ignition in potentially explosive atmospheres, protective measures shall be taken, based on the hazardous area classification of the particular area in which the electrical apparatus is being installed. For such electrical apparatus the appropriate safety documentation shall be available.

NOTES: 1. For protective measures of electrical apparatus used in dust hazardous areas, refer to BS 6467.

2. Area classification drawings should be available for the particular areas, prepared in line with the guidelines given in IEC 60079-10. Local guidelines on area classification may overrule IEC 60079-10.

2.6.2 Selection of type of protection

The selection of type of protection shall be in accordance with IEC 60079-14.

NOTE: Local rules may overrule IEC 60079-14.

The following is the order of preference for the selection of type of protection:

For Zone 0 areas: Ex 'ia' only

For Zone 1 areas: Ex ‘d’

Ex 'ia' ,or Ex 'ib'

For Zone 2 areas, consult IEC 60079-14, especially clauses 5.2.3/5.2.4. Apart from protection types according to IEC standards, some freedom is allowed with regard to the selection of protection types according to recognised non-IEC standards (clause 5.2.3) or national standards or codes of practice (clause 5.2.4).The order of preference is Ex ‘n’, Ex ‘e’, Ex ‘d’, Ex ‘ia’ or Ex ‘ib, ‘other’. The selection of type of protection shall be subject to TCoO evaluation, taking into consideration local legislation, site practices, etc.

NOTE: For zones 1 and 2, protection type Ex ‘m’ (encapsulation) in accordance with EN 50028 may be used, for instance for solenoid operators.

2.6.3 Safety documentation

Safety documentation for the selected type of protection for the installed electrical apparatus shall be available as follows:

- For Zone 0 areas Certificates shall be available.
- For Zone 1 areas Certificates shall be available.
- For Zone 2 areas If the selected type of protection is according to an IEC standard, certificates shall be available.

  If the selected type of protection is not based on an IEC standard, follow the guidelines of IEC 60079-14, especially clause 5.2.3/5.2.4 and the guidelines of the applied standard or code of practice.

NOTE: In certain European countries, Cenelec certificates are mandatory.

The Contractor shall:

- investigate whether local requirements overrule the requirements and recommendations defined in this section and propose alternatives for approval by the Principal.
- arrange for the required safety documentation as defined above.

2.7 INSTRUMENT NAME PLATES AND WARNING PLATES

2.7.1 General

All instruments, junction boxes, cabinets, panels and ancillary equipment shall be provided with nameplates indicating the tag number only or the tag number and the service. For details, see standard drawing S 37.601.

In addition to the above, the text on nameplates for manual selector switches shall repeat the switch position markings and shall unambiguously describe what each switch position represents. Similarly, the text on nameplates for push buttons shall describe what action is taken when the push button is activated.

The language or languages to be used on nameplates at the Principal’s site will be advised by the Principal. Licenser or local requirements may dictate special nameplate and/or language requirements, in particular for safety related instruments and instrument systems.

For nameplate requirements associated with impulse lines, see DEP 32.37.10.11-Gen.

2.7.2 Field-mounted nameplates

All plant-mounted instruments, e.g. inline instruments, transmitters, local indicators, converters, control valves, limit switches, solenoid valves etc., and junction boxes shall be provided with nameplates. The nameplate shall be properly secured, for instance to the instrument support. The preferred method is by means of screws; the use of alternative methods such as adhesives subject to the approval by the Principal. No holes shall be tapped into instruments for fixing nameplates, as this will affect the integrity and guarantee of the instrument.

The material of the nameplate should be laminated plastic. The colour shall be as specified by the Principal.

IPF initiators of SIL 1 and higher shall have a red nameplate with black lettering, as per DEP 32.80.10.10-Gen.

For control valves, additional identification requirements apply, see DEP 32.36.01.17-Gen.

For valves and instruments in gaseous oxygen service, additional marking and identification requirements apply as per DEP 31.10.11.31-Gen.

NOTE: Any medium containing more than 21% oxygen by volume or a system with air at a pressure above 50 bar (ga) is to be considered oxygen service.

Thermocouples used for furnace coil balancing services require special markings as specified in (7.3).

2.7.3 Nameplates for indoor use

All panel-mounted instruments shall be provided with nameplates in accordance with the Manufacturer's standard.

Cabinets and distribution frames shall be provided with nameplates, carrying at least the tag number. The material of the nameplates should be laminated plastic and the colour should be as specified by the Principal.

Labels and marking methods used inside instrumentation cabinets shall be to Manufacturers' standards provided they are secure and permanent.

2.7.4 Titles on nameplates

Where abbreviations are necessary, these shall be standardised and consistent for all titles as specified in the Project Specification or the Principal's site standards.

2.8 MEASUREMENT ACCURACY

The required accuracy of a measurement depends on the duty and service and shall be defined by parties responsible for process control. The tolerance classes and accuracy figures listed below are indicative only and are only to be used after confirmation by the Principal.

Process variable	Tolerance Class A	Tolerance Class B	Tolerance Class C	Tolerance Class D
Application	– Custody transfer. – Critical reactor (ratio) feed control.	– Enhanced monitoring and control. – Internal accounting.	– Regular monitoring and control.	– Coarse monitoring and control.
Flow (see note below)	– Liquid: better than 0.25% of reading. – Gas/steam: better than 0.5% of reading.	– Liquid: better than 2% of reading. – Gas/steam: better than 3% of reading.	Better than 6% of reading.	Better than 10% of reading.
Level (see note below)	Better than 2 mm (absolute).	Better than 10 mm (absolute).	Better than 5% of adjusted span.	Better than 10% of adjusted span.
Pressure	To be assessed on a case-by-case basis to suit specific requirements.	Better than 0.25% of adjusted span.	Better than 1% of adjusted span.	-
Temperature	– TC type K/J: tolerance class 1 as per IEC 60584-2. – TC type T/B: tolerance class 2 as per IEC 60584-2. – RTD: see (7.4) – Others: To be assessed on a case-by-case basis to suit specific requirements.	-	– TC type K/J: tolerance class 2 as per IEC 60584-2. – TC type T/B: tolerance class 3 as per IEC 60584-2. – RTD: see (7.4) – Others: Better than 1% of adjusted span.	-

The accuracy figures include linearity, hysterisis, repeatability, static pressure and temperature effects.

The accuracy requirements apply under all normal design conditions, including alternative operating modes. If the accuracy figures cannot be met during abnormal process conditions, such as start-up, commissioning, regeneration and emergency operation, the Principal's approval is required; see also (2.4).

NOTE: The above accuracy requirements for flow and level measurements do NOT apply to the accuracy of the installed sensor, but to the 'presented' result of the measurement in the relevant units of measurement. If for example a liquid flow measurement of tolerance class B is to be presented in mass flow units, the 'overall' accuracy of the presented mass flow figure should be better than 2% of the reading. If in such a case a flow sensor is used that measures a volumetric flow, pressure/temperature and/or density measurements might be required to meet the 2% 'overall' accuracy requirement on the 'presented' mass flow figure.

2.9 REQUIREMENTS FOR MATERIAL INSPECTION, CERTIFICATION AND MARKING OF INSTRUMENTS AND RELATED COMPONENTS

2.9.1 In-line instruments

In-line instruments are considered to be all instruments and components direct-mounted in or on process and utility lines or equipment and which are subjected to the pressures and temperatures of the piping systems or equipment in or on which they are installed.

Typical examples:

Measurement	Types of Instrument
Flow	Turbine and PD meters with their accessories, orifice and restriction orifice plates, venturi, vortex flow meters, Coriolis mass flow meters, ultrasonic flow meters, magnetic flow meters, thermal mass flow meters.
Level	Displacer type level instruments, capacitance level instruments, tank gauges, radar gauges.
Quality	Analyser sample probes
-	Control valves, including IPF valves, depressuring valves, deluge valves.

For in-line instruments, the traceability and associated material certification for pressure retaining parts (including bolting of pressure retaining parts) shall be in accordance with the requirements of the piping class or equipment in or on which the instruments are installed.

2.9.2 On-line instruments

On-line instruments are all instruments and components connected to process and utility lines or equipment via small (maximum DN 50) block valves. They are subjected to the pressures of the piping systems or equipment on which they are installed.

Typical examples are impulse line components, transmitters, pressure gauges, analyser sampling systems, etc. Pressure or differential pressure instruments that require diaphragm seals are not considered to be on-line instruments unless the size of the diaphragm seal makes it necessary to use a line class shut-off valve. Unless otherwise specified by the Principal, no material certification is required for on-line instruments and their connections to process systems, provided that facilities are present to isolate these instruments and connections from the process. As an exception to this rule, material certification is required for the following:

- All impulse line tubing.
- Pressure retaining parts of instruments and impulse line components in ‘Sour’ or ‘Wet H_2S’ service (as defined in DEP 31.38.01.11-Gen.), see NACE MR0175 and DEP 31.38.01.11-Gen.

2.9.3 Off-line instruments

Off-line instruments are considered to be all instruments and components which are not in direct contact with any process medium or which are not connected to any process/utility line or equipment.

Typical examples are thermocouples, resistance elements and bi-metallic thermometers in thermowells, signal converters, local receiving indicators, etc.

Unless otherwise specified by the Principal, no material certification is required for off-line instruments.

2.10 LAMP TEST FACILITIES

All indication lamps shall be provided with test facilities in the vicinity of the lamp, so that one man can execute the test. The test logic should be located in the DCS or IPS.

2.11 CRIPPLED MODE OF ANALOGUE TRANSMITTERS

‘Crippled mode’ is an abnormal situation caused by a faulty transmitter, a line break, short circuit and the like. Modern transmitters and instrument systems have features to detect such abnormal situations and to reduce (shed) the resulting adverse effects. It is recommended to make optimum use of such features as it will result in increased plant availability, well defined and controlled scenarios for (partial) shutdowns and major improvements in failure analysis.

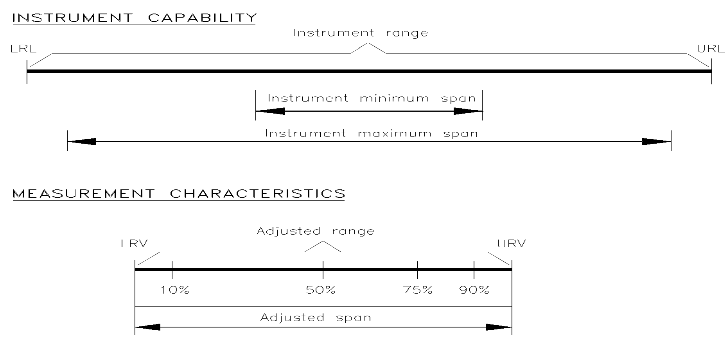
2.11.1 Crippled mode detection

If a crippled measurement is to be detected, it is important to distinguish between a real fault, i.e. a transmitter fault and/or a line break/short circuit situation, and a process underrange or overrange situation. Most modern transmitters have clamping and failure mode features intended to make such a discrimination.

An underrange or overrange situation of an analogue transmitter can occur during normal or abnormal process operating conditions. Since the measurement is healthy, no fault alarms should be triggered.
Clamping features on transmitters operating in the analogue mode (4-20 mA nominal signal) restrict the upper and lower output values, as long as the measurement is healthy.
If the measured value drops below the lower range value, the clamping feature will freeze the output at its lower clamping limit. A similar situation exists for measured values exceeding the upper range value, resulting in output freezing at the upper band value.

Upon failure of the analogue transmitter, the transmitter failure mode feature drives the output signal beyond the clamping limit in the upscale or downscale direction. Upon line break or a short circuit, the measured signal will also exceed the clamping limits. Receiving systems such as DCS and IPS have functions to detect a crippled measurement on the basis of signal levels beyond the clamping limits. A crippled measurement shall trigger an alarm.

NAMUR recommendation NE 43 defines normal and abnormal signal levels for 4-20 mA type output signals and should be followed to the maximum possible extent. The NAMUR recommendations can be depicted as follows:



2.11.2 Crippled mode shedding

It is recommended to develop crippled mode shedding strategies in an early project phase, after the makes and models of DCS, IPS, in-line meters and transmitters have been selected. The crippled mode shedding strategy may include controller mode switching, output value selection/freezing and process alarm suppression, and sets the rules for failure mode selection of analogue transmitters (upscale or downscale).

Due to the variety of transmitters and systems, it is recommended to assess whether the crippled mode detection capabilities and limitations of each transmitter type employed in a project matches the crippled mode detection and shedding capabilities of the receiving system, such as DCS and IPS. Experience shows that the following aspects need special attention:

- Transmitters operating in digital mode are usually provided with elaborate diagnostic features for crippled mode detection. However, no uniformity exists in methodology and reporting.
- If transmitters and systems are of different makes, crippled mode detection might be limited or absent or might require parameter or software adjustments at the transmission and/or receiving side of the loop.
- Transient behaviour during the powering up or down of the transmitter circuit may affect the detection. Some transmitters and systems have (optional) features to prevent these problems.
- For each transmitter / system combination, the assessment should disclose whether the combination has the ability to detect a crippled transmitter and/or a line break and/or a short-circuit. Furthermore, the relevant parameter settings for the transmitter and the system shall be defined.
- In specific cases, compliance with Namur recommendation NE 43 might be restricted by transmitter loop powering demands or by Zener barrier current limitations.
- If the transmission distance is long, the loop resistance might be so high that a short circuit near the transmitter will not cause the loop current to exceed the 21 mA specified by Namur standard NE 43.

2.12 ENVIRONMENTAL PROTECTIONS

All instruments, systems and related components shall comply with the environmental conditions as specified in the Project specification.

Plant-mounted instruments shall be suitable for operation in industrial, humid, saliferous and corrosive atmospheres and shall be adequately protected according to the electrical area classification.

For outdoor locations, the climatic conditions of location class D2 of IEC 60654-1 apply.

The minimum degree of protection of plant instruments shall be IP 65 as defined in IEC 60529.

For mechanical influences, classification in accordance with IEC 60654-3 shall apply.

For corrosive influences, classification in accordance with IEC 60654-4 shall apply.
The corrosive influence class shall comply with the requirements of Class 1 (Industrial clean air) or Class 2 (moderate contamination), as specified by the Principal.

For tropical areas more stringent requirements, such as anti-corrosion coatings or tropicalisation of printed circuit boards, may be applicable and advice shall be obtained from the Principal. Special attention shall be paid to factors relating to insects, animals, etc.

Special attention shall be paid to instruments and ancillary equipment which will be used in marine (e.g. jetty) services and/or installed in coastal or offshore environments. In such cases hermetical sealing of the electronic circuitry may be required.

Depending on site conditions, the contacts of switches/relays may require protection against traces of H_2S and SO_2 in the indoor and outdoor atmospheres by gold coating (at least 10 μm) or by locating them in hermetically sealed housings.

2.13 ELECTROMAGNETIC COMPATIBILITY (EMC)

Unless otherwise specified by the Principal, EMC of instruments, instrument systems and instrument installations shall be in accordance with the latest SIOP/SIEP policies. The Principal will inform the Contractor on the applicable requirements.

Metal cable glands shall be fitted where instrument signal cables enter the housings of field instruments, with a low impedance earthing connection between the cable armouring/braiding and the instrument housing via the metal gland being ensured by a robust, circumferential (360 degrees) connection. Glands constructed in accordance with BS 6121-1 types C/D/E or BS 6121-3 types CK/EK provide such an earthing connection. For details, see DEP 32.37.20.10-Gen. The use of plastic cable glands is not allowed for instrument signal cabling.

3. PLANT INSTRUMENTS

3.1 GENERAL

Instruments with 4-20 mA output signals are preferred to discrete, direct mounted, field switches (e.g. pressure switches) for their lower failure rates, better accuracy and better stability, and allow instrument signal analysis and measurement comparison. Discrete, direct mounted field switches shall not be used unless specified or approved by the Principal.

IPF trip initiators of SIL 1 and higher should have a red colour and the finish of plant-mounted instruments in oxygen service should be yellow. The finish of all other plant-mounted instruments may be in the Manufacturer's standard colour (but not red or yellow).

In-line instruments shall comply with the requirements of the piping class or equipment in or on which the instruments are installed.

3.2 INTEGRAL AND RECEIVING INDICATORS

Integral or receiving indicators should be considered as an alternative to pressure and temperature gauges.

Where a local indicator is required to support operating personnel, the physical location of the indicator should be selected so that it can be read from the intended operator position. If this requirement cannot be met by an integral indicator, a receiving indicator shall be applied.

Integral and receiving indicators required for operational reasons shall be shown on PEFS and shall present measurement information in engineering units.

Blind transmitters are preferred for all applications where an integral indicator is not required for operational reasons.

NOTE: Some transmitter designs are only available with an integral indicator. Such an indicator is acceptable and where local indication is not a requirement, these indicators shall not be shown on PEFS and no size/display/location requirements apply.

3.3 PRESSURE AND TEMPERATURE LIMITS OF PRESSURE-CONTAINING PARTS

For in-line instruments, the upper and lower pressure and temperature limits of the pressure containing parts shall meet at least the requirements of the piping class.
For in-line instruments associated with equipment where no piping class applies (e.g. vessels/package units), the upper and lower pressure and temperature limits of the pressure containing parts shall meet at least the upper and lower design pressure and temperature of the related equipment.

For on-line instruments, the upper and lower pressure limits of the pressure containing parts shall meet at least the requirements of the piping class. For on-line instruments associated with equipment where no piping class applies, the upper and lower pressure limits of pressure containing parts shall meet at least the upper and lower design pressure of the equipment.

In addition to the above, differential pressure type instruments shall be capable of withstanding the upper and lower pressure limit requirements of the piping class in either direction (positive and negative).

NOTES:
1. The lower pressure limit is relevant for an instrument if its value is below atmospheric pressure. In such cases it is important to realise that the instrument should be capable of functioning under (full or partial) vacuum conditions.

2. The lower temperature limit is relevant for an instrument if its value is below zero degrees Celsius.

3.4 SELECTION OF MATERIALS

This section provides an overview on the selection of materials. In all cases not clearly covered by this overview, advice from the responsible materials and corrosion engineer shall be sought. In cases where special materials are used, this shall be clearly marked on the respective items (according to a colour marking scheme).

The selection of materials shall be based on the process conditions and the selected materials shall be corrosion resistant. The material selection is in general related to the material of the equipment and piping. Precise requirements cannot be given in this DEP because of the large variety in products handled in that equipment and piping.

As a general rule, AISI 316(L) will be suitable in systems with austenitic stainless steel or carbon steel equipment and piping, but 316(L) stainless steel may be unsuitable in carbon steel systems containing water with chlorides. The stainless steel shall be resistant to intergranular corrosion as per ASTM A262 Practice E. Further guidance on materials selection is given in the following sections of this DEP, related standard drawings and where applicable, MESC descriptions.

For wetted parts of in-line instruments subject to pressure, temperature, erosion and corrosion, the selection of materials shall meet the minimum requirements of the piping class.

NOTE: All materials for piping connections such as gaskets, bolts etc. for mounting of the in-line instruments are part of the scope of mechanical engineering.

For instrument impulse line material selection, refer to DEP 32.37.10.11-Gen.

For material selection of control valves, see DEP 32.36.01.17-Gen.

For further guidance on the selection of materials, see DEP 30.10.02.11-Gen. and DEP 30.10.02.13-Gen.

Specific materials selection requirements apply to the following categories:

a) ‘Sour’ or ‘Wet H_2S’ service:

   ‘Sour’ or ‘Wet H_2S’ services are defined in DEP 31.38.01.11-Gen. The materials selection of parts of instruments and components which under any process condition are in contact with process water or aqueous condensate shall comply with the requirements of NACE MR0175 and the relevant piping class.

b) Hydrogen fluoride (HF) alkylation service:

   The material selection for wetted parts of instruments and components shall comply with the requirements of DEP 31.38.01.11-Gen. The measuring element diaphragm material shall be Hastelloy C-276.

   NOTE: It should be noted that only a small section of an HF alkylation plant will be classified as HF service. For the other sections of the plant in which the concentration of HF is sufficiently low, AISI 316(L) should be selected.

c) Chemical plants:

   As a general rule, AISI 316(L) will be suitable in systems with stainless steel and carbon steel equipment and piping. Where special stainless steel with increased Mo content, Incoloy 825 and/or Hastelloy C-276 are used for the equipment and/or piping, the selected material for pressure transmitters and differential pressure transmitters and manifolds, etc. should be Hastelloy C-276. In all cases not clearly covered by this rule, advice from the responsible materials and corrosion engineer shall be sought.

d) Services with strong reducing acids:

   In services (e.g. demineralisation plants) where strong reducing acids such as pure hydrochloric and sulphuric acid are used, all wetted parts (excluding the diaphragms of pressure transmitters, differential pressure transmitters and diaphragm seals) shall be of Hastelloy B-2. The measuring element diaphragm material shall be tantalum (Ta). For contaminated acids and less severe reducing conditions the responsible materials and corrosion engineer shall be consulted.

e) Oxygen service:

All instrumentation in oxygen service shall meet the requirements of DEP 31.10.11.31-Gen.

NOTE: Any medium containing more than 21% oxygen by volume or a system with air at a pressure above 50 bar (ga) is to be considered oxygen service.

The measuring element diaphragm material shall be selected in accordance with the above mentioned requirements. The following additional requirements apply:

a) Stainless steel 316(L) and cobalt base alloys are the preferred diaphragm materials and should be selected, if suitable for the application.

b) If a cobalt base alloy such as Elgilloy is selected, the Manufacturer shall guarantee that the alloy is not sensitive to weld decay by restricting the carbon content.

c) Services containing hydrogen and 'Sour' or 'Wet H_2S' services require special attention to be paid to instrument diaphragms to prevent hydrogen penetration. These diaphragms shall be gold-coated in the following cases:

   - Dry hydrogen service, if the partial pressure of hydrogen is above 7 bar (abs) and the temperature above 30 °C.

   - All 'Sour' or 'Wet H_2S' services.

   The Principal's approval is required if diaphragms of instruments operate above 100 °C in the above services.

3.5 DIAPHRAGM SEALS

Instruments may be provided with integral or remote diaphragm seals.

Diaphragm seals are typically employed in the following applications:

- As an alternative for impulse line purging or flushing in viscous, waxy, sticky or plugging (e.g. coke forming) services. The viscosity in impulse lines should be below 200 cSt under all normal and abnormal operating conditions.

- If the fluid temperature under any normal or abnormal operating condition exceeds the maximum allowable temperature of the sensing element.

The diaphragm seal size shall be selected to obtain the required instrument accuracy. Typically, DN 80 or DN 100 diaphragm seals should be used for level measurement.

Diaphragm seals shall be ordered as an integral part of the instrument.

The complete diaphragm seal assembly shall be of welded construction. Screwed connections shall not be used. For transmitters, the capillary tubing shall be welded directly onto both ends of the sensor.

For instruments with remote seals, the capillary material shall be stainless steel AISI 316(L) and shall be mechanically protected by flexible stainless steel armouring.

The length of the capillary tubing shall suit the application but shall be at least 1 metre. For differential pressure applications with two remote seals, the two parts of the capillary tubing shall be of the same length. The process connections shall be on the same side of the equipment.

If capillary tubing is exposed to direct sun radiation or to extreme temperature fluctuations (e.g. arctic environments), thermal insulation and, if required, tracing of the capillary tubing should be considered, to reduce measurement errors as a result of varying ambient temperatures and exposure to solar radiation. Thermal insulation shall be of a solar radiation reflecting nature (black coloured insulation shall not be used).

Filling liquids shall be selected in consultation with the party responsible for the process design and with the Manufacturer. The seal filling liquid shall be suitable for the upper and lower pressure and temperature limits of the process and shall not harm the process upon rupture of the diaphragm. Filling fluids for capsules and diaphragm seals shall not present a hazard to the environment in the event of a diaphragm failure.

Special attention shall be paid to diaphragm seals used in vacuum service, i.e. services with a sub-atmospheric lower design pressure. Filling liquids and connections shall be suitable for vacuum service. Transmitters with diaphragm seals in vacuum service shall be mounted at least 50 cm below the bottom equipment tapping.

NOTE: The above figure is based on the fact that most differential transmitters start functioning properly at a static pressure above 35 mbar (abs). With a transmitter mounted 50 cm below the bottom process tapping, sufficient static pressure is created at the transmitter under full vacuum conditions at the bottom equipment tapping.

Special attention shall be paid to the use of diaphragm seals handling small ranges (typically 50 mbar or smaller) and interface level measurement.

Facilities shall be provided to test and calibrate the diaphragm seal type transmitters under operating conditions. For details refer to DEP 32.37.10.11-Gen.

Particular care shall be taken while handling diaphragm seals. Diaphragm seal transmitters are heavy and shall be properly supported. Installation and gasket selection shall follow the recommendations of the Supplier. Proper mechanical protection of the vulnerable diaphragm by means of a suitable protection plate during transportation and prior to final installation is essential.

3.6 ACCESSIBILITY LEVELS

Accessibility identifies the effort required for a healthy human being to reach devices such as an instrument, measuring element, instrument process connection, instrument utility connection, block valve or sampling point for the purpose of operational attention or regular maintenance. It includes the ability to reach such a device with all tools required to perform such operational attention or maintenance. In the context of this DEP, four accessibility levels are defined as follows:

- Permanent accessibility
  A device is considered permanently accessible if it is located not more than 0.5 m horizontally away from and not more than 1.7 m vertically above grade, platform or walkway, if no obstructions are in place and if such locations can be safely reached from those levels during plant operation.
- Limited accessibility
  A device has a limited accessibility if it is located not more than 1.0 m horizontally away from and at a height between 1.7 m and 4.0 meter above grade, platform or walkway, if no obstructions are in place and if such locations can be safely reached during plant operation by means of a mobile platform or ladder.
- Poor accessibility
  A device has a poor accessibility if it is located more than 4.0 m above grade, platform or walkway or at any other location that can only be safely reached during plant operation by installing temporary facilities such as scaffolding or cranes.
- A device is also considered to have a poor accessibility if it can only be reached after removal or disassembly of other devices or components, such as thermal insulation or equipment noise hoods.
- Inaccessibility
  A device is considered inaccessible if it cannot be safely reached during plant operation for the purpose of operational attention and maintenance.

3.7 LOCATION AND ACCESSIBILITY

Apart from the requirements for specific types of instruments as given in the relevant sections, field-mounted instruments shall be installed considering the following aspects:

- On-line instruments are to be mounted on or in the direct vicinity of the instrument process connection(s).
- The location shall guarantee a good representative measurement of the process

condition.

– Limited accessibility is acceptable for indicating instruments, providing that they can be properly read from a permanently accessible location.

– Instruments shall not be subjected to excessive vibration (e.g. on suction or discharge lines of pumps or compressors, etc.) or to mechanical stresses, and are not to be exposed to temperatures which will influence the measurement.

– Heavy equipment such as control valves and inline flow meters of DN 100 and larger and all positive displacement meters and turbine meters should be accessible by mobile hoisting equipment. Where this is not possible, permanent hoisting facilities shall be considered.

– Instruments and their impulse lines shall be surrounded by sufficient free space to allow rodding-out of process connections and the removal of:

  - bolts, nuts and gaskets etc;
  - covers and enclosures;
  - orifice plates from the orifice flanges;
  - removable parts from in-line flow meters;
  - internals from the control valve;
  - displacers from the displacer chambers;
  - thermometer elements from the thermowells.

– Special requirements for safe handling of toxic substances, as dictated by the relevant piping class.

Permanent and easy access for maintenance purposes used to be the dominant factor in selecting the physical location of plant mounted instruments. This resulted in long impulse lines and additional ladders/platforms.

Major improvements in mean time between failure (MTBF) and remote diagnostics via ‘intelligent’ communication has drastically reduced the need for on-the-spot maintenance of modern field instruments.

Appendix 3 provides the minimum accessibility requirements. However, local situations such as labour cost may justify deviating from these requirements.

NOTE: Irrespective of the minimum accessibility level given in Appendix 3, one should aim for an optimum accessibility if this can be achieved at acceptable cost. It may, for instance, be feasible to relocate the piping take-off point during the engineering stage so as to change the accessibility level of a pressure transmitter from ‘limited’ to ‘permanent’ at no additional cost.

3.8 PROTECTIVE SHADES

If electronic instruments in tropical and sub-tropical areas are exposed to direct sun radiation, a protective shade should be applied to limit zero/span shifts resulting from temperature changes/one-sided heating and to reduce instrument housing temperature variations between day and night.

In such tropical and sub-tropical areas, shades might also be applied to serve as an umbrella, protecting electronic instruments from the adverse effects of condensation during heavy tropical rains.

Where instruments require shades which are not available as standard equipment or require specially made supports and brackets (e.g. in-line flow meters, displacer level instruments, tank gauges), these shall be shown on detailed construction drawings.

3.9 LOCAL PANELS AND CUBICLES

Local panels shall be avoided wherever possible and in any case require the approval of the Principal.

The Contractor shall specify materials and an appropriate paint system suitable for the intended location and atmosphere. Where the local panel or cubicle requires openings for ventilation, these openings shall be provided with screens to prevent the entry of animals or insects.

There shall be no direct process connections between process fluids and enclosed instrument panels. Wherever necessary transmitters shall be applied.

Whenever possible, instruments shall be mounted at eye level, but in any case not lower than 750 mm from the base.

Local panels shall be located well away from steam outlets and constant drizzles of water.

3.10 GENERAL INSTALLATION NOTES

In-line instruments (such as in-line flow meters, control valves, orifice plates), strainers and heavy off-line equipment (such as displacer level instruments and tank gauges) shall generally be installed by the mechanical engineering discipline, under the supervision of the instrument engineering discipline.

4. FLOW INSTRUMENTS

4.1 GENERAL

In-line flow meters are preferred for flow rate measurements if the benefits of initial investment, wide turn down, high accuracy and low maintenance requirements outweigh the extra effort and risk associated with proper sizing and selection. Furthermore, the availability of expertise must be guaranteed during engineering, initial start-up and operation.

Vortex flow meters (4.2) are preferred for flow rate measurements, unless special considerations such as required size, pressure rating, accuracy, turn-down, low Reynolds Number, avoidance of obstructions in the piping, etc., make it necessary to apply other in-line flow measuring techniques such as:

- Ultrasonic flow meters (4.3)
- Electromagnetic flow meters (4.4)
- Coriolis mass flow meters (4.5)
- Thermal dispersion mass flow meters (4.6)

Where in-line meters are not justifiable, pressure differential type flow meters shall be considered. The use of positive displacement meters and turbine meters should be restricted to cases where local rules dictate their use (e.g. for custody transfer applications).

To ensure proper flow meter selection, correct process data such as fluid phase, flow rate, pressure, temperature, density and viscosity shall be provided for minimum, normal and maximum design conditions as well as for alternative operating modes and abnormal operating conditions such as start-up, commissioning, regeneration, emergency and the like.

The required accuracy and the allowable pressure loss under all process conditions shall also be available before the proper flow meter can be selected. Furthermore, special service aspects (e.g. multi-phase fluid, varying fluid composition, corrosion, erosion, presence of solids, fouling risk) during normal or abnormal conditions are important factors for proper flow meter selection.

For liquid custody transfer applications, multi-path ultrasonic flow meters and Coriolis mass flow meters should be selected in preference to other types of meters. The use of these meters may require approval of the local authorities and agreement between the involved parties.

For gas custody transfer applications, multi-path, ultrasonic flow meters should be considered as an alternative to pressure differential and turbine meters, if local authorities allow their use.

NOTE: In-line flow meters are part of piping systems and should therefore comply with the relevant requirements of the applicable piping class.

Ultrasonic, electromagnetic and Coriolis flow meters can be used in uni-directional and bi-directional service. The other measurement devices discussed in (4) are uni-directional only. Uni-directional meters will present a forward flow output under backflow conditions. This makes them less suitable for backflow detection.

Coriolis and thermal dispersion flow meters measure mass flows, while all other measurement devices discussed in (4) are ‘actual volume’ flow meters.

The measured flow rate is usually presented in mass flow units on the basis of an assumed (reference) density. With pressure differential type measurements, deviations between actual and assumed (reference) density have a smaller impact on the accuracy of the presented mass flow figure than in all other volume flow meters discussed.

Coriolis mass flow meters and positive displacement meters are independent of velocity profile, whereas all other measurement devices discussed are dependent on velocity profile and therefore require straight upstream and downstream pipe lengths.

The following general installation requirements apply:

1) The installation requirements (including the minimum straight length requirements) of pressure differential devices such as orifice plates and venturi tubes shall be in accordance with ISO 5167-1. For other types of flow measurement the Manufacturer's guidelines with regard to installation, commissioning and maintenance requirements shall be followed carefully. The straight length shall be free of protrusions from gaskets, welds etc.

2) Eccentric pipe reducers have proven to severely disrupt the velocity profile and should therefore not be used in the vicinity of velocity profile dependent flow meters.

   NOTE: Concentric reducers with sufficient constriction ($D_{downstream}/D_{upstream} \leq 0.7$) have a strong remedial effect on asymmetry and uniformity of velocity profile, but not on swirls.

3) To avoid extremely long upstream straight lengths, control valves should be located downstream of the velocity profile dependent measuring elements wherever possible. Where isolating valves are located upstream of the measuring element, they should be located outside the required straight length, of the 'straight-through' type (e.g. gate valves or ball valves) and fully open under normal plant operation.

4) Flow metering devices should preferably be installed in vertical lines, with the flow in the upwards direction. Exceptions: for steam and wet gas applications or for gas containing particles, the flow direction shall be downwards.

5) Liquid meters in horizontal lines shall not be installed at the highest piping point where gases are likely to collect and hard to remove.

6) For liquid services, the horizontal or vertical flow line must remain full under all operating conditions.

7) Gas meters in horizontal lines shall not be installed at the lowest piping point where liquids are likely to collect and hard to remove.

8) Choose a location with minimum pipe vibration. If necessary, support the pipe at either end of the meter to prevent excessive movement.

9) The inner diameter of the gasket shall exceed the inner diameter of the meter/meterrun. Select a gasket type that is centred by its outer ring. An inner ring should prevent soft material from protruding into the pipe, causing flow pattern disturbance.

10) If pressure and/or temperature measurements are required for density compensation, the pressure tapping and thermowell should be located at one pipe diameter upstream and five pipe diameters downstream of the uni-directional meter respectively.

11) The vendor may or may not allow the electronic parts (e.g. sensors) to be enclosed by heat-insulation materials. Extensions meant to keep electronics at a moderate temperature shall not be thermally insulated or traced. Vendor's recommendations shall be complied with.

4.2 VORTEX FLOW METERS

4.2.1 General

A fluid passing a fixed solid obstruction ('bluff body' or 'shedder bar') supported diametrically across a pipe generates a succession of vortices. The vortices are generated alternately on opposite flanks of the shedder bar. They then separate from the flow element and progress downstream. The separation of the vortices from the flow element is called 'vortex shedding'. The shedding frequency is a linear function of the fluid velocity and hence of the volumetric flow rate.

Various methods of sensing the frequency generated by the vortex formation have been developed, such as differential pressure, thermistor, piezo electrical and variable capacitance sensors. The electronics of the meter can be an integral part of the meter or mounted remotely (for instance for high temperature applications or to allow easy access to the electronics).

Although mass vortex flow meters are being developed, the present generation of vortex flow meters only produce a signal proportional to the volumetric flow rate.

Vortex flow meters are characterised by wide turn downs and can be used on a wide range of process fluids, i.e. liquids, gas and steam. Vortex meters are uni-directional, velocity profile dependent, volume flow meters.

Vortices only occur from a certain fluid velocity onwards, consequently they have an elevated zero the referred to as the 'cut-off' point. The minimum measurable flow is limited by any one of the following factors:

- a low Reynolds number, causing the vortex shedding phenomenon to cease;
- minimum fluid velocity;
- too low a signal/noise ratio (sensors cannot make a distinction between signal frequency and background noise).

To ensure proper operation of the meter at minimum flow conditions (e.g. during start-up), it shall be sized for those minimum conditions, which usually result in a meter that is one or two sizes smaller than the line size (e.g. a DN 80 or DN 50 vortex meter in a DN 100 pipe). If two sizes of vortex flow meters are both able to cover the minimum and maximum flow rate, the smaller size meter should be selected.

NOTE: 1 Many operational problems associated with vortex meters are related to oversizing. Oversizing increases the cut-off point, which might make the meter unsuitable for proper control.

The maximum flow to be measured should not be less than 35% of the maximum measurable flow rate (the capacity) of the chosen vortex meter and the settings for low flow switch functions should amply exceed the cut-off point.

As a properly sized vortex meter is usually one or two sizes smaller than the line size, this criterion may be used as a screening value during sizing reviews.

2 Selection of the lowest possible cut-off point is particularly critical for meters used in closed control loops, as vortex shedding introduces instability (hunting) at the cut-off point. If operation in the cut-off region cannot be prevented, the use of a 'flow rate estimator' on the basis of control valve position could be considered. Such an estimator requires Principal's approval.

3 The cut-off phenomenon and the fact that the meter does not make a distinction between forward and backflow makes the vortex meter less suitable for backflow detection.

Vortex meters will only function properly under truly single-phase fluid conditions. In liquid applications, the pressure profile across the vortex meter shall not result in cavitation under any operating condition. Cavitation will cause signal drop-out and might damage the meter and downstream piping.

Vortex meters are susceptible to oscillating flows and mechanical vibration. If the frequencies enter the vortex frequency range, major systematic or random errors are introduced.

The swirl flow meter is a special type of vortex flow meter. An additional swirl is added to the incoming process fluid via a set of helical blades installed in the inlet of the meter body. The advantage of this type of vortex flow meter is its relative insensitivity to the flow pattern of the incoming fluid, which means the straight length requirements are less stringent than those for standard vortex flow meters. Another advantage is its lower allowable Reynolds Number.

4.2.2 Selection of vortex flow meters

The following shall be considered in vortex flow meter selection:

1) Turndown requirements, taking into account all normal and abnormal operating conditions.
2) The Reynolds number shall be at least 20,000, but preferably above 40,000 under any normal or abnormal process condition. Furthermore, the minimum fluid velocity, specified by the Manufacturer, shall be met under any normal or abnormal process condition that requires a reliable measurement. The minimum flows to be measured shall amply exceed the minimum measurable flow of the selected meter, specified by the Manufacturer, in order to achieve reliable measurement. In selecting a vortex flow meter, the meter turn-down shall be balanced against the permanent pressure drop.
3) Vortex meters in liquid service should be selected so that cavitation does not occur during any normal or abnormal process condition.
4) Vortex meters should not be located downstream of positive displacement pumps/compressors without suction and discharge dampers.
5) Vortex flow meters should not be used in wet gas or wet steam applications or in any other two-phase application (e.g. liquids with gas bubbles or foam, flashing liquids, half-full lines).
6) Vortex flow meters should not be considered for very viscous, waxy or erosive services.
7) Vortex flow meters shall be provided with process flanges.
8) Non-wetted sensors are preferred. For critical applications, the sensors shall be replaceable during operation.

If there is a requirement for separate control and safeguarding functions, vortex flow meters shall be equipped with two independent sets of sensors and electronics.

4.2.3 Installation requirements

1) For general installation requirements, see (4.1).
2) In general, the orientation (horizontal or vertical) of the vortex flow meter is not critical. If mounted in horizontal pipes, it is recommended to mount vortex meters with the shedder bars in the horizontal plane in order to reduce the build-up from debris and other hard deposits.
   For gas measurements in horizontal lines, the meter should preferably not be located at the lowest point in order to avoid condensate impacting on the measuring element.
   For vortex meters in a vertical line, the flow shall be upwards.
   In liquid services, the horizontal or vertical flow line must remain full under all operating conditions.

   NOTES: 1. Where horizontal positioning of a shedder bar in horizontal lines causes interference with adjacent piping, the shedder bar may be mounted at a 45 degrees angle.

   2. For specific meter designs, the Manufacturer's recommendations may overrule the above recommendations.
3) If pressure measurement is required for density compensation, the reference pressure at which the Manufacturer has determined the meter is relevant. It is often assumed that this is the absolute pressure at the shedder bar.

   NOTE: The pressure at the shedder bar can be calculated from the measured upstream pressure and Manufacturer's data on permanent pressure loss and pressure gradient across the vortex meter.

4) Straight length requirements shall be as specified by the Manufacturer.

5) Upstream pipe or flange transitions shall be smooth and flush with the pipe wall, i.e. free from welding roughness and burrs. Otherwise, vortices may be created which may adversely affect the performance of the flow meter.

6) For services where condensable gases during abnormal operation will convert into liquid, draining facilities have to be provided to prevent damage of the shedder bar by liquid slugs at plant (re)start.

7) Install the vortex flow meter only after flushing or air blowing activities have been completed.

8) A welded vortex flow meter body may be considered depending on the application and make. The use of welded vortex flow meters is subject to the approval of the Principal.

4.3 ULTRASONIC FLOW METERS

4.3.1 General

Only ultrasonic flow meters based on the 'transit-time' ('time-of-flight') method shall be used. Meters based on the 'Doppler' principle are less accurate and shall not be used.

In operation, two ultrasonic transducers transmit and receive at an angle to the flow in the pipe. The fluid flow adds velocity to the signal in the flow direction and subtracts velocity from the signal in the opposite direction. By using digital correlation and filtering techniques, a signal is produced which is proportional to the fluid velocity and hence to the volumetric flow rate. These methods give highly accurate results and have proven to be reliable.

Ultrasonic flow meters can be used for a wide range of process fluids, i.e. liquids, gas and steam. Ultrasonic flow meters are velocity profile dependent, volume flow meters, suitable for uni-directional and bi-directional flow measurements.

Additional outputs can be added, such as an output for velocity-of-sound. This velocity-of-sound output can be used as a measure/indication of actual flowing density, concentration (e.g. for fluids consisting of two distinctive components) and molecular weight (if pressure, temperature, Cp/Cv ratio and compressibility are known). The additional velocity-of-sound output is frequently used for mass flow measurements in flare stacks or in fuel gas supply lines to furnaces.

The electronics of the meter can be an integral part of the meter or mounted remotely at a short distance (for instance for high temperature applications or to allow easy access to the electronics).

If 'non-intelligent' meters are used and the velocity-of-sound output is not required for measurement purposes, the signal should be made available in the Field Auxiliary Room (FAR) or control room, as this provides useful information on plant/unit operation and for trouble shooting and testing.

AGA-9 technical report provides guidelines for the use of ultrasonic flow meters in gas custody transfer applications.

4.3.2 Selection of ultrasonic flow meters

The following shall be considered in the selection of ultrasonic flow meters:

1) The service conditions are an important factor in the selection of the ultrasonic flow meter. Transit-time ultrasonic flow meters are designed to be used for clean liquids or gases and steam. Some Manufacturers, however, have specifications that allow some solid particles in liquid or gas measurements or gas entrainment in liquid measurements.
2) The minimum and maximum measurable fluid velocity, specified by the Manufacturer.
3) Ultrasonic flow meters shall be considered for use on large lines and for large turndowns, if the TCoO of a vortex flow meter is higher.
4) Ultrasonic flow meters shall be considered where pressure drop is not permitted.
5) On critical services (such as control, safeguarding or mass/energy balance), ultrasonic flow meters with insertion probes shall have retraction mechanisms to allow onstream probe maintenance.
6) Clamp-on ultrasonic flow meters may only be used for liquid metering. Clamp-on ultrasonic flow meters are suitable for use on all piping materials and on glass-lined pipes. Measurements on PTFE or rubber lined piping is not possible. For testing purposes or other temporary measurements, portable clamp-on flow meters are available.
7) Ultrasonic meters are by their nature dependent on the velocity profile they are exposed to. Especially, single beam ultrasonic meters, having their beam axis intersecting the centre line of the pipe, are vulnerable to changes in the velocity profile. Dual beam meters with symmetrical parallel beams, located at a distance of ½ radius from the centre line, are less sensitive to velocity profile variations.

8) Multipath flow meters should be considered if high accuracy is required or if the straight length requirements cannot be met for a single path meter. Multipath flow meters should also be considered for applications with low Reynolds Numbers (typically < 5000). The Supplier of the ultrasonic flow meter shall be consulted in these cases.

4.3.3 Installation requirements

1) For general installation requirements, see (4.1).

2) Ultrasonic flow meters can be installed at any point in the pipe run. In horizontal lines, nozzles shall be in the horizontal plane to avoid the collection of debris. Locations having high noise, such as cavitating or noisy control valves, should be avoided. The meter shall not be installed directly downstream of sources of aeration, such as cavitating pumps, throttling valves or an aerating mixing tank.

   NOTE: Where horizontal positioning of nozzles in horizontal lines causes interference with adjacent piping, the nozzles may be mounted at a 45 degrees angle.

3) Care shall be taken if an ultrasonic flow meter and a low noise control valve are installed in the same pipe. Certain high frequencies produced by a low noise control valve may interfere with the measuring signals of the ultrasonic flow meter. A special silencer may have to be installed between the meter and this type of control valve. This silencer will filter out the high frequency signal produced by the low noise valve which interferes with the signal produced by the ultrasonic flow meter. If sufficient distance is available between the flow meter and the low noise valve, this special silencer may not be necessary.

4) Bending of the ultrasonic probes or torque acting on the probes will affect their measuring accuracy. The probes shall be aligned towards each other. This is particularly important if the probes have to be installed in existing pipe work (e.g. flare stacks).

5) Upstream and downstream straight lengths shall be as specified by the Supplier.

6) If a clamp-on ultrasonic flow meter is used, it shall be safeguarded against shifting of the sensors. A rigid sensor mounting construction shall be used and the sonic coupling compound shall be selected in accordance with the pipe design temperatures. The pipe surface shall be smoothened prior to installation of the sensors. On horizontal process lines the longitudinal axis of sensors shall be in the horizontal plane. If clamp-on meters are installed on existing pipe runs, measurements will be inaccurate if scaling or deposits are present on the inner wall of the pipe.

4.4 ELECTROMAGNETIC FLOW METERS

4.4.1 General

Electromagnetic flow meters, often referred to as 'magmeters', are based on the principle that an electromagnetic force (emf) is generated when a conductive fluid moves in a magnetic field. If the field is perpendicular to a pipe which contains a moving fluid and if the conductivity of the fluid is above a certain minimum value, a voltage can be measured between the two electrodes in the pipe wall. As this voltage is proportional to the strength of the magnetic field, the average velocity of the moving fluid and the distance between the electrodes, the volumetric flow rate is derived.

The flow tube of an electromagnetic flow meter is made of a non-magnetic material and the electrodes which generate the electric field are insulated from the body. The flow tube is lined with a non-conductive material.

With most electromagnetic flow meters, the signal is picked up by the two metal electrodes which are in contact with the process fluid. These electrodes can become coated with non-conductive deposits, which impairs the electrical contact between the electrodes and the process fluid. To overcome this potential problem, certain electromagnetic flow meters have the electrodes embedded in the insulating material of the liner and electrical contact with the process fluid is made via capacitive coupling.

Electromagnetic flow meters are suitable for most liquids, providing that they are electrically conductive. Electromagnetic flow meters are not suitable for gas and steam applications.

Electromagnetic flow meters are suitable for dirty, greasy and gaseous fluids, untreated sewage and fluids containing solids.

EM-meters are velocity profile dependent volume flow meters, suitable for uni-directional and bi-directional flow measurements.

4.4.2 Selection of electromagnetic flow meters

The following shall be considered in the selection of electromagnetic flow meters:

1) Electromagnetic flow meters require a process liquid with a minimum conductivity.

NOTES: 1. Since most hydrocarbons have a very low conductivity, electromagnetic flow meters are mainly used in utility services and chemical plants.

2. The minimum required electric conductivity shall be advised by the vendor. It depends on the method of the magnetic field excitation (alternating or pulsed DC voltage) and on the electrode used (wetted/non wetted type) and varies typically from 0.05 to 20 μS/cm.

2) Select the liner materials based on services.

a) **PTFE**
PTFE is the most frequently used liner material. As this liner cannot be glued to the inside of the housing, it is NOT suitable for vacuum service. Furthermore certain liquids can penetrate through PTFE, which then may cause short circuiting and/or corrosion of the meter parts.

b) **PFA**
Liquid penetration is less than for PTFE, but PFA does not retain its original shape once this has changed under pressure and temperature. This problem can be overcome by reinforcing the liner with a steel wiring mat. Reinforced PFA is suitable for vacuum service.

c) **Ceramic**
Liners are suitable for most applications, but the material is sensitive to temperature shock, and stresses in the piping may crack the liner.

Electromagnetic flow meters with a ceramic liner, in conjunction with capacitive sensors, can be used for conductivities as low as 0.05 μS/cm. Ceramic is an expensive liner which requires careful handling and installation.

d) **Rubber**
Neoprene or natural rubber is the cheapest of all liners. It is mainly used for water services.

3) Electromagnetic flow meters are insensitive to low amounts (0 - 5 vol. %) of entrained gases, as long as it is equally distributed. The meter will read ‘high’ with larger quantities of gases in the liquid. Furthermore, gas bubbles can cause problems when they accumulate around the electrodes. If gases are entrained in the liquid, the meter shall be installed in a vertical process line.

4) A minimum fluid velocity is required (typically 0.3 - 0.5 m/sec). For abrasive service, the maximum velocity should not exceed 3.5 m/sec.

4.4.3 Installation requirements

1) For general installation requirements, see (4.1).

2) An electromagnetic flow meter can be installed at any point in the pipe run, provided the straight length requirements are met. It shall be ensured that the flow tube is always completely filled with liquid.

NOTE: Special electromagnetic flow meters are available for measuring flow in partially filled lines.

3) The electrode axis shall be horizontal in order to prevent contamination of the electrodes and to prevent contact loss due to gas bubbles around the electrodes.

4) Earthing of electromagnetic flow meters (including earthing rings) requires special attention. The recommendations of the flow meter Manufacturer shall be followed.

5) Avoid installation of electromagnetic flow meters close to large conducting surfaces such as metal supports. These large metal objects will interfere with the magnetic field of the flow meter and hence influence its accuracy and behaviour.

6) For abrasive liquids, the inlet part of the liner is easily damaged. For protection of the liner inlet, earthing rings with edge protection shall be considered.

7) PTFE envelope packing shall be used. When tightening the process bolts, the torque specifications of the flow meter Manufacturer shall be followed.

NOTE: To prevent liner damage, spiral wound metal gaskets shall not be used for magnetic flow meters. Graphic gaskets shall not be used either, as they may result in a conductive, graphic layer on the meter’s inside wall, which may adversely affect the measurement.

8) Short spool pieces may be installed upstream and downstream of the meter to protect the liner during removal from the pipe (the meter and the spool pieces can then be removed together).

4.5 CORIOLIS MASS FLOW METERS

4.5.1 General

The flow tube of a Coriolis mass flow meter is vibrated at its natural frequency by means of a strategically located magnetic device. Due to the ‘Coriolis’ or ‘gyroscopic’ effect, a fluid flowing through the vibrating tube forces this specially shaped tube to twist. The amount of phase difference between the leading and the lagging part of the vibrating tube is proportional to the mass flow rate. The construction and shape of the metering tube and the number of measuring tubes varies from one Supplier to another.

Several Manufacturers offer an optional output for actual density.

The electronics of the meter can be an integral part of the meter or mounted remotely (for instance for high temperature applications or for easy access to electronics).

Coriolis meters are suitable for a wide range of liquids and gases, but not for steam service. They are unaffected by the fluid viscosity variations, which makes them suitable for slurries and emulsions. Within the instrument density boundaries, the Coriolis meter is not affected by density variations.

Coriolis meters are susceptible to oscillating flows and mechanical vibration. If the frequencies enter the natural frequency range of the vibrating tube, random errors are introduced.

Coriolis mass flow meters are independent of velocity profile and suitable for uni-directional and bi-directional mass flow measurements.

4.5.2 Selection of Coriolis mass flow meters

The following shall be considered in the selection of Coriolis mass flow meters:

1) Coriolis mass flow meters are restricted in size and rating but if the required flow rate cannot be handled by one meter, two or more meters can be installed in parallel.
2) Coriolis mass flow meters shall be considered for custody transfer, chemical injection and in-line blending applications. For custody transfer, approval of the Authority is required.
3) The type of process fluid and other components that are present are important factors in the selection of the material of the metering tube. The tubes are available in a variety of materials, including stainless steel 316/304, Hastelloy, Inconel, Monel, titanium and tantalum. Stainless steel metering tubes shall **not** be used for fluids containing halogens, even if present only in minute concentrations, as the vibration of the tube will induce stress corrosion. Hastelloy tubes shall be specified for **all** applications containing halogens.
4) The pressure drop across the meter under normal and abnormal conditions is an important factor in the selection of Coriolis mass flow meters. Care shall be taken to ensure that cavitation does not occur under any process condition, as this will seriously damage the meter.
5) Coriolis mass flow meters are also suitable for gas applications. For all gas applications, the Supplier shall be consulted to confirm suitability, especially regarding the minimum required gas density.

   NOTE: In the past, Suppliers’ application guidelines called for a minimum gas density of 4.5 kg/m^3. Tests have however shown that this figure is too restrictive and that no hard density limit is known. The size of the meter and loss of accuracy may become prohibitive as the flowing density becomes lower.

6) Avoid the use of Coriolis mass flow meters in two-phase fluids. The presence of a small amount of gas in liquids or liquid in gas will create erratic measurements.
7) As Coriolis mass flow meters have no moving parts and in general do not require accessories like strainers, gas eliminators or flow straighteners, they should be used in preference to positive displacement meters and turbine meters.

4.5.3 Installation requirements

1) For general installation requirements, see (4.1).
2) Coriolis mass flow meters can be mounted in any position, although sometimes it may be preferred to install the meter tube as self-draining.
3) There are no straight length requirements for Coriolis mass flow meters.
4) A downstream tight shut-off valve should be installed to ensure actual zero flow before setting the meter's primary zero.
5) The flow meter shall be properly supported as specified by the Supplier. The meter will only measure properly if it is installed vibration and stress free in the pipe work. Bellows are sometimes applied, for instance for Custody transfer skids, to achieve a stress free installation.

   The following piping practices are essential for proper meter performance:

   - Meter process connections shall not be used as pipe supports.
   - Support bypass loops and valves separately.
   - Do not use pressure gauges and pulsation dampers around Coriolis meters in pulsating services.
6) To avoid corrosion, hermetically sealed sensors should be used in humid or saliferous climates.

4.6 THERMAL DISPERSION MASS FLOW METERS

4.6.1 General

Thermal dispersion mass flow meters, often called thermal mass flow meters, rely on the transmission of heat from a body to a gas flow. Inside the flow meter sensor head, a heated resistance thermometer (RTD) is electronically compared with an unheated RTD sensor. As a gas passes the heated RTD, heat is transferred from this sensor to the gas, and hence the RTD is cooled, thereby reducing the temperature difference between the two sensors. Heat transfer from the RTD to the process gas depends on the composition of the gas, hence the temperature difference between the two RTDs is a function of the mass flow rate of the gas.

The electronics of the meter can be an integral part of the meter or mounted remotely (for instance for easy access to electronics).

This measuring principle is limited to low-accuracy gas applications with the gas or gas mixture being clean, homogeneous and of fairly constant composition.

Thermal dispersion mass flow meters are uni-directional, velocity profile dependent mass flow meters.

4.6.2 Selection of thermal dispersion mass flow meters

The following shall be considered in the selection of thermal mass flow meters:

1) Thermal mass flow meters are mainly used for air measurements, such as ventilation air to analyser houses, purge air flow measurements and combustion air flow to furnaces.
   NOTE: Experience has taught that intake of foggy air does not adversely affect the performance of thermal mass flow meters.

2) Thermal mass flow meters can also be used on gases other than air, but the composition of the process gas must be known. The variations in composition shall be small, as thermal mass flow meters perform best when the composition of the gas remains constant.

3) The gas to be measured shall be dry or saturated. Free liquid in the gas, when in contact with the heated RTD, seriously affects the performance of the flow meter.

4) Some thermal mass flow meters have a very slow response time. The required response time shall be specified.

   NOTE: Thermal mass flow meters on the basis of the ‘Constant Power Anemometer’ measuring principle have a response time of 20-60 seconds against 1-3 seconds for those based on the ‘Constant Temperature Anemometer’ measuring principle.

4.6.3 Installation requirements

1) For general installation requirements, see (4.1).

2) The sensor assembly shall be placed with the sensing elements across the cross sectional centre of the process pipe or duct.

3) In large pipes or ducts the sensing elements shall extend at least 60 mm into the process gas. It is important for the sensor head not to touch the wall of the pipe or duct. For large ducting or disturbed velocity profiles, multiple sensors should be used.

4) Thermal mass flow meters should be calibrated on the gas to be measured, as conversion factors are usually inaccurate.

5) Thermal mass flow meters should be provided with a retractable sensor to allow cleaning and testing during operation.

6) The probes of thermal mass flow meters shall be removed prior to flushing or air blowing.

4.7 DIFFERENTIAL PRESSURE TYPE FLOW METERS

4.7.1 Selection

Flow meter selection and calculations for non-pulsating services should be based on ISO 5167-1. Measurements in pulsating services should be prevented.

4.7.2 Selection of flow scale reading

For the scale reading, a round figure should be selected that is 1-5% above the maximum flow to be measured under normal or abnormal operating conditions and 15-20% above the normal design flow. The scale reading is usually expressed in mass flow units. One differential pressure transmitter is adequate, if the following criteria are met:

- the accuracy requirements (2.8) are met;
- the minimum design flow is above 67% of the maximum flow reading for tolerance classes A and B (2.8) and above 55% of the maximum flow reading for tolerance classes C and D (2.8) measurements. These figures correspond with a differential pressure/transmitter output signal of 45% and 30% respectively.

Two or ultimately three differential pressure transmitters with overlapping ranges should be considered, if the above criteria are not met.

4.7.3 Selection of bore and dP range

On the basis of the required scale reading (4.7.2) and a preferred differential pressure (dP) range of around 250 mbar, a standard bore will be selected. The exact dP-range will be calculated and used for transmitter range adjustment.

NOTE: The practice of using standard dP-ranges and non-standard bores is no longer advocated.

To limit the static pressure loss, the calculated dP-range should preferably be approximately 0-250 mbar. Ranges lower than 0-12.5 mbar and higher than 0-1000 mbar should be avoided.

4.7.4 Flow meter orifice plates

Square edge orifice plates with flange tappings, shall be used wherever possible. Only for special applications, e.g. due to low pipe Reynolds Number, should a quarter circle or a conical entrance plate be used.

Depending on line size and site preference, the orifice bore should be rounded off to the nearest 0.1 or 1 mm. For variety control, standard orifice bores are to be defined at site or project level.

Orifice plates for flow measurements shall be in accordance with the following Standard Drawings:

- S 32.102, for square-edge orifice plates;
- S 32.104, for quarter-circle orifice plates;
- S 32.112, for conical entrance orifice plates.

NOTES:
1. Orifice plates in accordance with the above drawings (for nominal pipe sizes of DN 15, DN 20, DN 25 or DN 40) are intended for installation between flanges in meter runs prefabricated in accordance with Standard Drawing S 38.134.
2. Orifice plates for nominal pipe sizes of DN 50 and larger are intended for installation between flanges in accordance with Standard Drawings S 38.130 (flange tappings) or S 38.131 (corner tappings).

Stainless steel orifice plates in accordance with the above Standard Drawings may be used for a differential pressure of 2 bar maximum and, if mounted between carbon steel flanges, for a temperature of 450 °C maximum.

Bleed or vent holes shall only be specified for orifice plates in horizontal piping of DN 50 or larger and with a orifice throat diameter (bore) of at least 19 mm.

NOTE: Standard ISO 5167-1 does not cater for drain and vent holes, so the calculated bore must be corrected for the vent or drain hole area.

Installation requirements:

1) For general installation requirements, see (4.1).

2) The straight length and other installation requirements of orifice plates and venturi tubes shall be in accordance with ISO 5167-1.

3) Impulse lines are the weak components of differential pressure type flow meters. Incorrect installations will lead to additional errors in the measurement. The impulse line hook-up shall follow the requirements of DEP 32.37.10.11-Gen. and standard forms DEP 32.37.02.81-Gen. (Metric version) or DEP 32.37.02.82-Gen. (Imperial version).

4) To ensure proper operation of the instruments, normal and abnormal process conditions and climatic conditions shall be considered in deciding whether to apply purging, liquid sealing, diaphragm seals, heating and insulation, etc.
DEP 32.37.10.11-Gen. shall apply.

5) Differential pressure transmitters for gas services should be mounted such that they are self draining. For details, see DEP 32.37.10.11-Gen.

6) Ample space shall be provided to allow rodding out of process connections and removal of orifice plate, nuts and bolts.

7) If one flow measuring element is used for two independent measurements, four tappings are required to obtain segregation. This is, for instance, the case if a control and IPF transmitter share the same measuring element.

   NOTE: If high and low range transmitters are required to measure a flow accurately, these are not considered as independent measurements, so they can share the same set of tappings.

8) Small diameter orifice meter runs as per drawing S 38.134 and orifice meter runs having orifice flanges with corner tappings shall always be located in horizontal pipes. Other flow measuring elements should be located in vertical pipes, the flow being preferably downwards for wet gases and saturated steam, and upwards for liquid containing vapour. Where this is impossible, e.g. because of requirements for straight length or accessibility, the measuring elements may be located in horizontal pipes.

9) Downwards pointing tappings in horizontal lines are vulnerable to fouling. Such applications (e.g. four tappings in horizontal line) require the Principal's approval.

10) When not supplied in prefabricated form, orifice meter runs shall be fabricated at the construction site in accordance with DEP 61.38.10.10-Gen.

4.7.5 Restriction orifice plates

Restriction orifice plates are devices for creating a certain pressure drop or for limiting a flow rate. They are not intended for flow measurement but are similar to flow metering orifice plates, in construction and sizing method.

The construction of restriction orifice plates shall be in accordance with Standard Drawing S 32.114. Stainless steel restriction orifice plates made in accordance with this drawing may be used for a differential pressure of:

- 50 bar maximum for line sizes DN 15-150;
- 10 bar maximum for line sizes DN 200-300;
- 6 bar maximum for line sizes DN 350-600;
- when mounted between carbon steel flanges, for a temperature of 450 °C maximum.

If these limits are exceeded (or other materials are used for the orifice plate), the relevant dimensions shall be adjusted to suit the application.

The specification of restriction orifice plates shall take into account:

1) the nominal size (normally equal to line size);
2) the pressure rating of the flanges;
3) the material (which shall be stainless steel to AISI 316 unless other materials are specified for the intended application);
4) for high pressure drops, consideration should be given to hard-facing the orifice or to selecting of a material which can be hardened throughout;
5) the orifice diameter resulting from the sizing. The required dimension shall be the calculated dimension rounded off to the nearest 0.1 mm;
6) bleed or vent holes shall only be specified for plates in horizontal piping of DN 50 or larger.

NOTE: Standard ISO 5167-1 does not cater for drain and vent holes, so the calculated bore must be corrected for the vent or drain hole area.

Restriction orifice plates do not normally require straight lengths in upstream and downstream piping, but where the fluid flow has to be accurately set, the straight lengths shall be in accordance with the bracketed values given in ISO 5167-1.

4.7.6 Construction of other measuring elements

Venturi tubes and flow nozzles of circular cross section shall be in accordance with ISO 5167-1. Unless otherwise specified, only one pressure tapping shall be provided for upstream and one for downstream pressure measurement. Prior to fabrication, the Manufacturer shall submit the mechanical construction drawings of these measuring elements for approval.

4.7.7 Differential pressure instruments

Diaphragm-type transmitters with a continuously adjustable range shall be used as a standard. Electronic differential pressure transmitters may be selected on the basis of MESC specification 60.30/069.

4.7.8 Meter runs for pipe sizes DN 15 to DN 40

For pipe sizes DN 15 to DN 40, meter runs shall be used. These meter runs shall be fabricated in accordance with Standard Drawing S 38.134.

The length of meter runs according to this standard drawing will usually satisfy the minimum straight length requirements. Where this is not the case, the straight length should be achieved by applying the adjacent piping with the same internal diameter as the meter run.

4.7.9 Meter runs for pipe sizes DN 50 and larger

Meter runs for pipe sizes DN 50 and larger shall only be applied for custody transfer requirement or where a high accuracy is required. Meter runs (DN 50 to DN 300) shall be fabricated in accordance with Standard Drawing S 38.132.

The fabrication of meter runs in pipe sizes greater than DN 300 shall be in accordance with DEP 61.38.10.10-Gen.

The length of meter runs according to this standard drawing will usually satisfy the minimum straight length requirements. Where this is not the case, the straight length should be achieved by applying the adjacent piping with the same internal diameter as the meter run.

4.7.10 Integral orifice transmitters

The use of transmitters with integral orifice, for flow metering in line sizes smaller than DN 15, requires the approval of the Principal. For these types of measurement, small Coriolis mass flow meters should be considered as a first option.

4.8 VARIABLE AREA FLOW METERS

The use of ‘variable area’ flow meters, often called ‘rotameters’, shall be restricted to simple applications such as measurement of purge, bubble-type level measurements, cooling or sealing fluids, or in sample conditioning systems for analysers.

Variable area flow meters shall be of the all-metal type.

4.9 TURBINE METERS

Turbine meters shall have flanged connections and the body material shall be carbon steel with stainless steel internals, unless the application requires other materials as specified by the Principal.

On non-lubricating services such as LPG or gasoline, the turbine meter bearings shall be specially hardened, e.g. tungsten carbide. Bearing dimensions shall be such that a permanent liquid film is maintained (e.g. by having a longer axis and/or a larger diameter). For these applications ultrasonic flow meters or Coriolis mass flow meters, having a better performance and rangeability, should be considered.

The meters shall be protected against damage due to overspeeding or hydraulic shock, e.g. caused by the quick opening and closing of valves. In liquid service, adequate filtering and degassing shall be provided.

Viscosity fluctuations affect the accuracy. The use of turbine meters is normally limited to products with relatively low viscosities, typically maximum 10 mm^2/s (10 cS).

For the requirements of turbine meters for custody transfer, see DEP 32.32.00.11-Gen.

Flow straighteners shall be used with turbine meters if specified by the vendor to meet the required flow meter performance (4.11.4).

4.10 POSITIVE DISPLACEMENT METERS

Positive displacement meters (PD meters) shall have flanged connections. The body material shall be carbon steel unless the application requires other materials as specified by the Principal.

PD meters shall not be selected for use with non-lubricating liquids such as LPG or gasoline. Flow limiting devices shall be considered to prevent over-ranging of PD meters. Certain types of PD meters have their maximum capacity limited not only by flow but also by the maximum allowable pressure drop across the meter. Consideration should be given to limiting the maximum pressure drop, especially when the meter is used with liquids having a high viscosity when starting from cold.

PD meters shall have a direct-coupled pulse generator and shall be provided with signal amplifiers mounted close to the meter. If used for toxic products, the meters shall have magnetic couplings to counters.

The meters shall be protected against damage due to overspeeding or hydraulic shock, e.g. caused by the quick opening and closing of valves. In liquid service, adequate filtering and degassing shall be provided.

In view of their considerable mass, especially for large sizes, positive displacement meters and their ancillary equipment such as filters and vapour eliminators shall be installed so that they are well supported, and can easily be reached by hoisting equipment. Adjacent piping shall not exert any stress on the meter body.

Where only a local indication is required mechanically-coupled single (ticket) counters may be used. The use of multiple (ticket) counters shall be avoided.

For typical arrangements of positive displacement meters, see Appendix 4.

4.11 FLOW METER ACCESSORIES

For turbine fiscal metering systems for liquid hydrocarbons, see DEP 32.32.00.11-Gen. For systems outside the scope of DEP 32.32.00.11-Gen., the following applies:

4.11.1 Strainers

Strainers shall be provided for PD and turbine meters. In the clean condition, the strainer shall have a pressure drop of not more than 0.2 bar, and in a dirty condition the strainer internals shall be capable of withstanding a pressure drop of at least 3 bar.

NOTE: The latter requirement is more stringent than that specified by most Suppliers, but is considered necessary to prevent the collapse of a dirty strainer.

A differential pressure indicator shall be installed across the strainer.

A differential pressure alarm shall be provided:

- on all applications for blending and custody transfer;
- where frequent fouling of the strainer is expected.

The strainer enclosure shall be of the quick-opening type with valve vent and drain connections. The strainer shall have replaceable stainless steel inserts.

The mesh size for the screen shall be as recommended by the meter Supplier and the screen shall be supported by a strainer basket having much larger openings than those of the screen (they may be from 3 - 20 mm, depending on the size and construction).

NOTE: In general, turbine meters and PD meters should have the same mesh size for the screen. Typical is a 0.1 mm opening mesh size (10 mesh).

4.11.2 Gas eliminators

For liquid applications, turbine meters and PD meters should have gas eliminating facilities upstream of the meters. For heavy products, this may be achieved by a vent valve on the strainer, venting being done manually from time to time. Automatic gas eliminators shall be provided where the separation of entrained air or other gases can be expected more frequently. They should be of the tangential type.

In addition to the automatic vent valve, the gas eliminator shall have facilities for manual draining and venting. The float operation of the automatic vent valve shall be capable of opening this valve at the maximum allowable operating pressure of the gas eliminator, as proved by testing or by a design calculation.

In the evaluation of the TCoO of turbine or PD meters, the cost of gas eliminators shall be included.

4.11.3 Flow limiters

Flow limiters shall be specified where meters are liable to damage by overspeeding or where meter accuracy would be seriously affected by over-ranging due to excess pump capacity.

4.11.4 Flow straighteners

Flow straighteners should be considered for reducing the required upstream straight length for turbine meters, especially where strong swirls are expected. The required straightener length depends on the pitch of the swirl.

NOTE: Flow straighteners should not be installed in the upstream piping of differential pressure-type flow meters, e.g. orifice plates or Venturi tubes, unless agreed by the Principal.

4.12 METER PROVING FACILITIES

For turbine fiscal metering systems for liquid hydrocarbons, see DEP 32.32.00.11-Gen. For systems outside the scope of DEP 32.32.00.11-Gen., the following applies: Meter proving facilities shall be available for all flow meters used for custody transfer unless otherwise agreed by the Principal. Where valves are used to redirect the flow through the meter prover, these should be tight shut-off (Class V or Class VI as per IEC 60534-4), arranged as 'double block and bleed' type and, if feasible, provided with facilities to check their tightness.

Depending on the location, the meter proving facilities may be owned and operated by the Principal, a body recognised by the Principal, the local authorities, or the customer who will purchase the measured product. Where such facilities are not already available, they shall be provided as part of the project.

NOTE: Local regulations or the nature of the application may require that meter proving is carried out or witnessed by the local authorities or an independent third party.

The PEFS and the instrument data sheets shall indicate:

1) where meter proving facilities / provisions are required;
2) whether these facilities are master meters, compact provers, ball provers or prover tanks;
3) whether these facilities shall be mobile or permanently installed.

Permanent installation (including manifolding) of the proving facilities shall be fully detailed in the PEFS.

Where mobile facilities are specified, the piping shall have provisions for the insertion of a master meter, a compact prover or a mechanical displacement prover into the line in which the meter is installed. The meters shall be accessible to the mobile prover.

Where master meters are used, calibration facilities shall be available either at the Principal's site or from an authorised third party.

For meter provers, preference should be given to compact provers or mechanical displacement provers. Where compact provers or mechanical displacement provers cannot be used or are not allowed by the local authorities, meter prover tanks shall be provided.

Interfaces between the custody transfer flow meter vendor and the proving facility vendor should be eliminated by integrating these custody transfer applications into one package so as to create single vendor responsibility.

5. LEVEL INSTRUMENTS

5.1 GENERAL

To measure the level inside equipment over a particular range, various types of instruments are available.

Depending on the process conditions, the following techniques may be applied:

- differential pressure type instruments (with or without remote diaphragm seals);
- capacitance and admittance type instruments;
- radar, microwave and ultrasonic type instruments;
- radioactive type instruments;
- displacer type instruments.

Level instruments without moving parts are preferred.

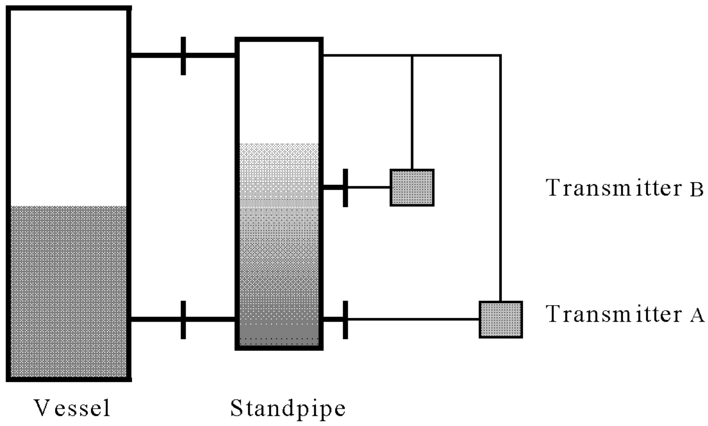
NOTE: For level gauge glasses, see DEP 31.38.01.11-Gen.

Level instruments shall have connections to the equipment. The connections shall be located so that impingement from process streams flowing into the equipment is prevented. Where necessary, this shall be achieved by installing deflection plates in the equipment.

NOTE: Connections to process piping may be considered in exceptional cases, providing that the dynamic pressure loss in the piping has a negligible effect on the measurement accuracy and that the tapping cannot be isolated from the equipment by an isolation valve in the process pipe. Such applications require approval by the Principal.

The use of stand pipes in level applications requires approval by the Principal, since it may introduce systematic measurement errors as a result of density variations.
If too many instrument nozzles are fitted on one piece of equipment, multiple instrument process connections should be branched off from one equipment nozzle. Each instrument process connection shall be provided with a dedicated process isolation valve.

NOTES: 1 The use of stand pipes is based on the law of communicating vessels. The assumption that the level/interface in the vessel and stand pipe will be identical is only valid if the densities are the same and remain the same. In practice this is frequently not the case: Density changes may occur during normal operation or shifts from one operating mode (e.g. start-up) to another mode (e.g. normal operation), causing light liquid to get ‘trapped’ in the standpipe. Under these conditions, the level/interface instruments are only measuring correctly if the process connections of the instruments are at the same elevations as the stand pipe connections on the equipment. Hence, the stand pipe serves no purpose and the instruments should be directly connected to the vessel. This is illustrated in the figure below: transmitter A is measuring correctly, transmitter B is not. Although the illustration shows level measurements on the basis of differential pressure instruments, similar measurement errors can be expected for other level measurement principles.



2 The decision whether or not standpipes are allowed to be used needs to be taken in the early project stage, as it might affect equipment design.

5.2 SELECTION OF LEVEL INSTRUMENTS

The selection process for instruments in discussed in general terms in (2.1). For level instruments, the following specific aspects apply:

1) The measurement principle shall be selected on the basis of service conditions, accuracy requirements, maintenance aspects and site preferences.
2) For level measurement in highly viscous, waxy or fouling service and for emulsive interface level measurements, differential pressure and displacer type instruments are less suitable. Ultrasonic, capacitance, admittance, radar, microwave, radioactive, laser or bubble type measurements should be considered.
3) The possible variations in liquid densities during normal or abnormal operating conditions shall be investigated and recorded when level measurement configurations using differential pressure or displacer type transmitters are designed. The following aspects should be addressed:

   - to ensure safety, high level alarm and high trip settings should be based on the lowest density of the liquid;
   - to ensure safety, low level alarm and low trip settings should be based on the highest density of the liquid;
   - the above requirements will result in a reduction of operating window and available time for operator action.

   NOTE: In applications with high pressure or temperature variations, variations in the vapour/gas density shall also be addressed. In liquid/liquid interface applications, variations in both liquid phases have to be taken into account.

   If the above results in an unacceptable reduction of operating window or available operator response time, the following alternatives should be considered:

   - applying another measurement technique;
   - density compensation;
   - selection of a smaller measuring range for high level trip initiators (reduced range).

4) Purging or heating should be considered to ensure proper operation of level instruments for highly viscous liquids and for liquids containing water or solids, especially if the latter tend to form sediments.
5) For instruments in high-pressure or high temperature service, the difference in density between liquid and vapour during normal operation is usually smaller than during plant commissioning. In such cases, to obtain satisfactory measurements of the actual level under all operating conditions, consideration should be given to correcting the level transmitter output in the DCS/IPS for pressure or temperature variations.
6) For proper level measurements with externally mounted instruments (such as side mounted displacer type instruments), the liquid in the level chamber shall be kept at the process temperature.
7) For all applications, the difference between liquid density and gas/vapour density should be taken into account when specifying displacer instruments or calculating the range for differential-pressure instruments.
8) For liquid/liquid interface service, special attention shall be paid to the dimensions of the displacer or float to achieve a satisfactory sensitivity, especially when the difference in densities is small. For measuring level interfaces with density differences of 100 kg/m^3 or less, capacitance type instruments should be considered.
9) The performance of ultrasonic-type level measurements is adversely affected by varying gas/vapour phase composition. Consult the vendor for limitations.
10) Internal level instruments shall not be applied for applications where instrument removal requires shutdown of the process.

For special requirements for level measurement in LPG storage vessels, refer to DEP 30.06.10.12-Gen.

5.3 DIFFERENTIAL-PRESSURE LEVEL INSTRUMENTS

5.3.1 General

The make and type of differential-pressure level instruments shall be the same as those of flow transmitters of the differential pressure type.

Electronic differential pressure transmitters may be selected on the basis of MESC specification 60.30/069.

For differential pressure transmitters having diaphragm seals with capillary extensions, see (3.5).

Where it is necessary to avoid plugging of the nozzle, the instrument shall have an extended diaphragm flush with the inside of the equipment. The extended diaphragm shall not be specified for instruments on equipment requiring mechanical cleaning. For instruments with an extended diaphragm, the diameter of the extension shall allow free passage in the nozzle. The use of extended diaphragm type instruments requires the approval of the Principal.

5.3.2 Process connections

Equipment sketches shall be prepared by the party responsible for process design to determine operating levels and nozzle sizes/locations and to match the different types of measurements with each other (transmitters/level gauges etc.).
Frequently-used arrangements of differential pressure level instruments are shown in Appendix 1. With the exception of flange mounted instruments and instruments with seals, differential-pressure level instruments shall be mounted at or below the lowest connection or above the highest connection. The equipment connections for such instruments should terminate in a DN 15 lap joint flange.

The process connection size for flange-mounted differential-pressure level instruments shall have a size of DN 80, DN 100 or DN 150, dependent on the type of instrument and flanged to the required ASME class. The connection shall be internally free from burrs.

NOTES:

1. The equipment connection including the lap joint flange forms part of the mechanical engineering scope of work. For heavy wall piping (class XXS), the internal pipe bore shall be sufficiently wide to prevent plugging and fouling of the nozzles.

2. For instruments with diaphragm seals, see (3.5).

3. The practice of basing the centre-to-centre distances of nozzles on standard displacer sizes to allow for future replacement of the differential pressure type instrument by a displacer type instrument is no longer advocated.
   If the Principal decides to stick to this practice, the centre-to-centre distances of nozzles shall be 356, 813, 1219, 1524, 1829, 2134, 2438, 2743 or 3048 mm and each pair of equipment nozzles shall be adequately sized and positioned perfectly vertical above each other.

5.3.3 Selection of hook-up arrangement

For the measurement of liquid level in equipment in which the vapour space is truly at the ambient atmospheric pressure, the low-pressure connection of the instrument can be left open to atmosphere.

In all other cases, the low-pressure connection shall be connected to the vapour space by means of a reference leg. Depending on the arrangement, this reference leg is ‘dry’ (filled with gas) or ‘wet’ (filled with a liquid).

A dry reference leg can be used where:

- self-purging occurs in equipment which is always at temperatures below ambient temperature and contains liquids which will still fully evaporate under all normal and abnormal operating pressures at the lowest ambient temperature.

- external gas purging is allowed and a reliable source of suitable non-condensing purge gas of sufficient pressure is available (purging through the dry leg). This arrangement is vulnerable and maintenance intensive and should only be used if alternatives are less attractive.

A wet reference leg shall be used where the reference leg will fill with process liquid when it condenses at the lowest ambient temperature.

Two options are available for filling the wet reference leg:

- the process liquid: This method should be applied if the process liquid is non-viscous, non-corrosive and non-toxic and is self-condensing under any normal and abnormal operating pressure at the highest ambient temperature.
- a sealing liquid: This method shall be applied in all other cases.

NOTES:
1. The density of process liquids in wet legs may gradually drift away from the density in the associated equipment as a result of 'stripping' of the liquid in the wet leg. The use of a sealing liquid is therefore preferred.
2. If water is used in the reference leg, freezing under sub-zero ambient temperatures (if relevant) shall be prevented, e.g. by winterising.
3. For further details, see DEP 32.37.10.11-Gen. and Standard Forms DEP 32.37.02.81-Gen. (metric version) or DEP 32.37.02.82-Gen. (Imperial version).
4. The viscosity of liquids in the measurement and reference legs should not exceed 200 cSt to obtain an acceptable response time.

If the operating pressure is relatively low, the level can also be determined by subtracting the pressure measured in the vapour space from the pressure measured at the equipment bottom. Such level measurements on the basis of two pressure measurements may be considered as an alternative option in the following cases.

- A reference leg would require long impulse lines, i.e. in relatively tall equipment.
- Special and 'difficult' services, requiring remote seals, expensive sealing liquids, purging and/or heating.

This alternative requires approval by the Principal. A calculation shall be presented to demonstrate acceptable accuracy and resolution of the calculated level measurement under all normal and abnormal operating conditions.

5.3.4 Adjusted range

The adjusted range should be based on the minimum and maximum liquid levels for which the subject equipment is designed.

The adjusted range shall be calculated and specified in mbar, e.g. 0 to 197 mbar, 18 to 197 mbar, -18 to 197 mbar. For range calculations, see Appendix 1. The calculations apply to measurements with or without remote diaphragm seals.

5.3.5 Seal liquid selection

For the selection of seal liquids for use in integral or remote diaphragm seal systems, see (3.5).

For a reliable and low maintenance level measurement, using a differential pressure transmitter, the appropriate choice of the seal liquid is of paramount importance. The seal liquid shall be selected to suit the process application. Seal liquids shall be selected in consultation with the party responsible for the process design, considering the following aspects:

- chemical resistance in contact with the process fluids (polymerisation, disintegration, solubility of process fluid).
- effect on process (contamination, poisoning of catalyst).
- seal fluid properties (temperature expansion coefficient, freezing point, viscosity,

handling safety, cost of purchase/tracing/disposal etc.).

Frequently used low-cost seal liquids are water, glycol, glycerine and silicon oil (used silicon oil, drained from transformers).

NOTE: The density of some seal liquids (e.g. silicon oil) varies considerably with temperature. To limit the effect of changing densities, it should be considered to use tracing and insulation to keep seal liquids in wet legs at a constant temperature.

5.3.6 Seal liquid refill pump unit

The Principal should be contacted about his policy on the removal of contaminated seal liquids: draining is one option, disposal into the process is a widespread alternative.

For personal protection of the instrument mechanic and for environmental reasons, facilities should be provided to pump seal liquid into the impulse lines during operation. The impulse line hook up should include the necessary connections for such a pump unit. The design of the mobile seal liquid refill pump unit requires the approval of the Principal.

5.4 DISPLACER LEVEL INSTRUMENTS

Displacer level instruments shall normally be mounted on external displacer chambers.

They may only be mounted internally in equipment in simple applications such as storage tanks and process vessels at atmospheric pressure, providing that removal of the instrument does not require a shutdown of the process. A stilling well might be required. Such arrangements require the written approval of the Principal.

Chambers for displacer level instruments shall have connections at the side of the equipment, in such a position that the mid-point of the displacer coincides with normal operating level. Each pair of connections shall be perfectly in line, and exactly vertically above each other thus ensuring that the displacer chamber is positioned vertically without exerting stress thereon.

Ranges for displacer instruments shall be 356, 813, 1219, 1524, 1829, 2134, 2438, 2743, 3048, 3200, 3300, 3400 mm etc.

NOTES: 1. Displacer chambers for external displacer instruments shall be in accordance with Standard Drawing S 38.056.
The hanger extension length of the displacer instrument shall be:
- 185 mm for rating ASME class 150/300;
- 215 mm for rating ASME class 600;
- 230 mm for rating ASME class 900;
- 255 mm for rating ASME class 1500.

2. For liquid/liquid interface service with small differences in densities, a large displacer or float may be required to achieve a satisfactory sensitivity. A displacer chamber with a size DN 150 body and top flange may be required.

All displacer instruments shall be specified with left-hand or right-hand mounting of the instrument with respect to the mechanism chamber, depending on the relative position of process equipment and displacer chamber, access from platforms, etc.

For high temperature as well as low temperature and cryogenic services, torque tube heat insulation extensions or torque tube extensions shall be fitted. The instrument Supplier shall be consulted for details.

Displacer level instruments shall initially be installed without the displacer, if the displacer is not designed for the equipment test pressure.

NOTE: Low cost radar instruments may be considered as replacements of displacer instruments in existing installations, providing that the radar measurement principle and process fluid(s) are compatible, see (5.6).

5.5 CAPACITANCE LEVEL PROBES

Capacitance-type level probes are particularly suitable for the following applications:

1) liquids with varying density;
2) liquid/liquid interface;
3) level switches;
4) corrosive services.

For liquid services which tend to foul an admittance probe should be considered.

5.6 RADAR TYPE INSTRUMENTS

High accuracy radar instruments have a resolution in millimetres and low accuracy radar instruments have a resolution in centimetres. Radar instruments used in custody transfer applications shall be of the high accuracy type and are subject to Authority approval.

Radar type level instruments are suitable for a wide range of applications. The suitability is determined by the dielectric constant of the process medium. Consult the vendor for application limits.

The instrument has no moving parts, so minimum maintenance is required.

Radar type level instruments may be considered as a replacement for displacer type level instruments in existing installations.

5.7 LEVEL SWITCHES

Mechanical-type level switches (float switches) should be avoided and may be used only with the approval of the Principal.

Displacer type level switches shall not be used.

Other types of level switches (e.g. vibration type switches etc.) may only be used with the approval of the Principal.

5.8 TANK GAUGING SYSTEMS FOR PRODUCT AND STORAGE TANKS

The use of a stilling well is recommended for all tanks with level measurements of accuracy tolerance classes A and B, see (2.8).

Unless otherwise specified by the Principal, tank gauges for custody transfer shall be of the radar type (5.6) or the servo-motor operated (surface seeking) type, with remote checking facilities.

Tank gauges for custody transfer shall have an approval certificate from an independent body which is recognised by the authorities involved.

Servo-motor operated type tank gauges for custody transfer shall be installed in the gauge pole. Construction of the gauge pole shall be in accordance with Standard Drawings S 51.114 (fixed roof tank, custody transfer) or S 51.115 (floating roof tank, custody transfer) or S 51.154 (fixed roof tank, non-custody transfer). The gauge pole shall be installed in a perfectly vertical position.

For additional requirements for tank gauges for LPG storage vessels, see DEP 30.06.10.12-Gen.

Where the storage tanks require an averaging temperature detector, this shall form part of, and be connected to, the tank gauging system. The average temperature detectors shall be fixed multiple elements (resistance or thermocouple).

Where spot reading temperature detection is required, this shall be provided in the lower part of the tank. The temperature measuring device shall be a thermocouple or resistance element.

6. PRESSURE INSTRUMENTS

6.1 PRESSURE GAUGES

If local pressure indication is regularly needed to support field operator actions, a pressure gauge or receiving pressure indicator is needed. If pressure transmission is also required for control room indication, a local (integral or remote) receiving indicator has preference over a pressure gauge. A pressure point shall be considered if a pressure measurement is only occasionally required for non-operational activities.

Bourdon tube pressure gauges should be of the safety-pattern type in accordance with EN 837-1. Where such gauges are not suitable due to corrosion, plugging, etc., pressure gauges with a diaphragm seal shall be used, see also (3.5).

Pressure gauges may be selected on the basis of MESC Specification 60.35/001 and diaphragm seals for pressure gauges on the basis of MESC Specification 60.36/001. The diaphragm seal and pressure gauge combination shall be supplied as an integral unit.

For environmental and maintenance reasons, oil-filled pressure gauges shall be avoided and may only be used with the approval of the Principal. Pressure gauges shall have a nominal diameter of 100 mm unless otherwise specified by the Principal.

Pressure gauge ranges shall be selected from the following series so that the normal operating pressure is between 50 to 75% of scale, and the gauge is suitable for the lower design pressure (e.g. full vacuum) and covers the upper design pressure (relief valve set pressure should not exceed the range):

1) For pressures above atmospheric pressure, in bar (ga):

0 to 1,	0 to 1.6,	0 to 2.5,	0 to 4,	0 to 6,	0 to 10,
0 to 16,	0 to 25,	0 to 40,	0 to 60,	0 to 100,	0 to 160,
0 to 250,	0 to 400,	0 to 600,	0 to 1000,	0-1600.	

2) For vacuum services, in bar (ga):
-1 to 0.

3) For combined pressure/vacuum services, in bar (ga):
-1 to +0.6, -1 to +1.5, -1 to +3, -1 to +5, -1 to +9.

NOTES:
1. For reasons of variety control, it may be necessary to reduce the number of different ranges.
2. The ranges mentioned above are a selection of the ranges defined in standard EN 837-1.
3. If the normal operating pressure is considerable lower than half of the system's upper design pressure, the use of gauge savers should be considered.

6.2 OTHER PRESSURE INSTRUMENTS

For pressure measurements, electronic transmitters shall be used, switching in either the DCS or in the IPS. The use of direct-mounted pressure switches requires approval of the Principal.

The ranges for pressure instruments should be selected from the series as given for pressure gauges (6.1), but where narrow-span instruments are required the adjusted range shall cover the minimum and maximum operating pressure.

For pressure transmitters having a diaphragm seal, see (3.5).

Electronic pressure transmitters may be selected on the basis of MESC specification 60.32/069.

For the measurement of absolute pressure, the instrument shall have an absolute vacuum reference chamber.

If a pressure measurement is used as input for a calculation utilising the absolute pressure (e.g. flow compensations, surge parameter calculations), a pressure instrument with an absolute vacuum reference chamber should be considered as a means to improve the accuracy of the calculated result.

Electronic differential pressure transmitters may be selected on the basis of MESC specification 60.30/069.

For direct-operating pressure regulating devices, see DEP 32.36.01.17-Gen.

7. TEMPERATURE INSTRUMENTS

7.1 GENERAL

Filled thermal systems, such as those with alcohol, may be used only with the approval of the Principal. Mercury-filled systems shall not be used.

For remote temperature indication, thermocouples (7.3) should be used. Resistance thermometers (7.4) should be used if the required accuracy cannot be met by thermocouples (e.g. for custody transfer).

The temperature sensors, except skin-mounted elements, shall be installed inside thermowells.

Thermowells are part of the Mechanical Engineering scope of work and are covered by DEP 31.38.01.11-Gen. The type, length and material of the required thermowell are dictated by the appropriate Piping Class. For dimensions of standard thermowells see Standard Drawings S 38.103, S 38.104, S 38.106, S 38.107, S 38.110 and S 38.112. Flanged thermowells are generally used. Welded thermowells according to S 38.112 shall only be installed if, due to high velocity and density of the fluid, the bending forces are too high for flanged thermowells or if they are subject to vortex vibration.

Thermowell cover flanges shall be in accordance with:
S 38.046 (for thermowells in accordance with S 38.103/104/110);
S 38.060 (for thermowells in accordance with S 38.106/107).

The length of the thermowell shall be selected in accordance with DEP 31.38.01.12-Gen. or DEP 31.38.01.15-Gen. so that:

- the measuring element is fully immersed, see Appendix 5;
- excessive vibration due to fluid velocity does not occur.

Screwed thermowells shall not be employed.

The pipe nozzle used for installation of the thermowell shall be adequately insulated, irrespective of the operating temperature.

NOTE: It is recommended to take suitable measures to prevent (rain) water ingress into the thermowell prior to installation of the temperature sensor. If such measures are not taken, the thermowells should be dried prior to installation of the sensors to prevent erratic measurements (i.e. the temperature of boiling water is measured at operating temperatures above 100 °C).

For the measurement of a fluid temperature below 0 °C, the length of the head extension shall suit the insulation thickness, and the head shall extend at least 200 mm outside the insulation.

Where the fitting of a thermowell is not practical, thermocouples and resistance thermometers may be located on the surface (‘skin’) of pipes or vessels. For details, see Standard Drawings S 10.109, S 24.604, S 24.615 and S 35.411. The measuring location shall be adequately insulated, irrespective of the operating temperature.

To prevent water ingress into the assembly head, the thermo-element assembly shall be mounted in the horizontal position or in a tilted position with the head facing upwards.

Special attention shall be given to the location of temperature points in mixing applications. Proper mixing and proper heat exchange between the fluid components should have been accomplished before those components reach the temperature sensor.

Temperature points shall never be installed directly downstream of flashing or cavitating valves, due to the risk of breakage as a result of excessive vibration, nor directly upstream of flow meters requiring a straight length.

In fluidized catalytic cracking units, the connections for thermowells in catalyst service shall be suitably protected against wear. They shall not extend more than 0.6 m inside the equipment or line.

Where long multiple thermocouples are fitted in reactor vessels, etc., the vessel design and equipment lay-out shall be critically examined to ensure that the multiple assemblies and their associated protective wells can be installed in and removed from the vessel without being obstructed by adjacent equipment.

The use of thermowells having a 90° directional change inside the vessel, in order to simplify vessel design, is not allowed.
Only when it is completely impossible to use a straight well should curved wells be considered. The radius of curvature shall then be at least 1.5 m and the total angular displacement shall not exceed 45°. The location of the nozzles on the vessels shall be calculated to rationalise the number of multiple element types required.

For the measurement of tray temperatures in distilling columns, special attention shall be paid to the thermowell length and nozzle location.

The use of optical pyrometers should be considered for monitoring furnace tubes at very high temperatures.

For self acting temperature regulators, see DEP 32.36.01.17-Gen.

7.2 DIAL THERMOMETERS

Local temperature indication should be installed at locations where operator actions are needed, otherwise just a temperature point (plugged-off thermowell) will suffice.

For local indication of temperatures up to 400 °C, bi-metal thermometers shall be used and they shall be in accordance with Standard Drawing S 35.410 They may be selected on the basis of MESC specification 60.48.12/001.

Dial thermometer ranges shall be selected from the following series so that the normal operating temperature is between 50 to 75% of scale:

- 30 to +60°C, 0 to 160 °C, 0 to 250 °C, 0 to 400 °C.

For reasons of variety control, dial thermometers of the ‘every-angle’ type should be used, instead of the fixed axial and co-axial types.

7.3 THERMOCOUPLES

For the arrangement of thermocouple assemblies mounted inside thermowells, see Standard Drawing S 35.409. For surface mounting thermocouples, see Standard Drawing S 35.411.

Thermocouples shall be of the mineral-insulated metal-sheathed type, with the measuring junction free from earth. They may be selected on the basis of MESC specification 60.42.04/001.

Reference tables for thermo-electric voltage in relation to temperature are based upon IEC 60584-1.

Thermocouples for standard applications shall be selected from the following types:

Type	Temperature Ranges
K	- 20 °C to 1000 °C
J	0 °C to 550 °C
T	below 0 °C
B	above 1000 °C

For use of other thermocouple types requires the approval of the Principal.

For thermocouple type letter designations, refer to IEC 60584-1.

Thermocouple heads may be selected in accordance with MESC Specification 60.49.04/001, having a cable entry of M20 x 1.5 and accessories covered by MESC Specification 60.49.04/002. The use of ‘duplex’ thermocouples shall be avoided except where special thermowell constructions are required or where process conditions demand exotic materials. A ‘duplex’ thermocouple shall not be used to serve control/indication with one channel and an IPF of SIL 1 or higher with the second channel.

Where type K thermocouples operate in temperature services above 800 C and where hydrogen diffusion may be expected, magnesium-oxide insulated thermocouples with Inconel protective sheathing shall be used; alternatively a titanium ‘getter’ wire shall be specified, in addition to the normal execution.

Thermocouples for measuring the skin temperature of furnace tubes shall be in accordance with standard drawings S 35.405 and S 24.615. They may be selected in accordance with MESC specification 60.42.04/001.

All thermocouples used for furnace coil balancing shall be from the same batch and shall be calibrated and certified for the specified operating temperature. In addition to the Standard identification, these thermocouples shall each be provided with a batch and certificate number. The thermocouples shall furthermore be provided with warning plates, having black letters on a red background, stating:

‘CALIBRATED AND CERTIFIED THERMOCOUPLE’

NOTE: If one such thermocouple fails, all thermocouples in that set shall be replaced at the same time.

Where multiple thermocouple assemblies are required, e.g. for measuring temperature at several levels inside a reactor, they shall be assembled from thermocouple elements of the appropriate lengths in a flexible metal sheath or bound together with a metal wire or mesh to form a composite flexible assembly.

The outside diameter of the individual thermocouple assemblies shall be adequate for mechanical strength, but sufficiently small to be coiled to a radius of 0.75 metres for shipping and for flexibility during installation. Care shall be taken not to make the thermocouple wires for long elements too thin, as this will create an unacceptable wire resistance and the thermocouple elements may easily be damaged.

Thermocouple elements shall be supplied complete with flexible, insulated tails of thermocouple material. These tails shall normally end in a head mounted junction box, containing a terminal block suitable for connecting the tails to thermocouple signal cables having solid conductors of 1.2 mm diameter. Alternatively, the thermocouple tails may be directly connected to a head-mounted transmitter. See (7.5) for restrictions on the use of these types of transmitters.

7.4 RESISTANCE THERMOMETERS

Resistance thermometers should only be used for temperatures up to 650 °C.

Resistance thermometers shall normally be of the platinum type Pt 100 (100 ohm at 0 °C), resistance tolerance class A. They may be selected in accordance with MESC Specification 60.44.04/001.

Resistance tolerance classes and the relation between resistance and temperature shall be in accordance with IEC 60751.

For very high accuracy, special resistance elements such as Pt 400 and Pt 1000 should be considered. The use of such elements requires the approval of the Principal.

Resistance thermometers shall be used for applications where high accuracy is required, such as temperature compensation for custody transfer measurements, for narrow span applications and for differential temperature measurements.

Resistance thermometers shall not be used in vibrating services.

Resistance thermometers used for average temperature measurement in storage tanks may be made of other materials, such as nickel or copper. The characteristic shall be in accordance with the Manufacturer's standard.

For the arrangement of resistance thermometer assemblies mounted inside thermowells, see Standard drawing S 35.409. For surface-mounted assemblies, see standard Drawing S 35.411.

Resistance thermometer heads may be selected in accordance with MESC Specification 60.49.04/001, having a cable entry of M20 x 1.5 and accessories covered by MESC Specification 60.49.04/002.

7.5 INSTRUMENTS FOR THERMOCOUPLE AND RESISTANCE THERMOMETERS

Instruments connected to thermocouples shall have automatic compensation for temperature variations at the cold junction.

Temperature transmitters should be located in the field, whereby head-mounted ‘intelligent’ types are preferred (see also 2.5.1). The transmitter output signal shall be linear with the measured temperature. All temperature transmitters shall have galvanic separation between the sensor element and the output amplifier.

8. ELECTRICAL PARAMETERS

Where measurement of electrical parameters such as current, voltage, power consumption speed or temperatures in electrical equipment is required for IPF, signal converters shall be installed in the electrical switch house to provide either discrete analogue 4 to 20 mA DC signals (preferred) or potential free on/off signals to the IPS.

Where measurement of these electrical parameters are required for indication and recording in the DCS, the Contractor shall make a TCoO evaluation between the following two options:

- discrete analogue 4 to 20 mA DC signals, or
- integrated motor control system (IMCS) to communicate with DCS by serial communication. If the IMCS is used for control purposes, the serial communication shall be redundant.

9. SPEED INSTRUMENTS

Speed-measuring instruments are usually supplied as part of the rotating equipment, see DEP 32.31.09.31-Gen.

On critical and variable speed rotating equipment, the speed measurement should have a separate channel in the machine monitoring system, see (10).

For equipment such as forced-draught fans of boilers or furnaces, where the speed instruments are not supplied as part of the equipment, their make and type shall be as specified by the Principal.

10. MACHINE MONITORING

For monitoring the vibration and shaft position of rotating equipment, the probes and oscillator/demodulators are usually supplied with the equipment, see DEP 32.31.09.31-Gen. The make and type of these items shall therefore be agreed upon at an early stage of the project, to ensure compatibility with this permanent monitoring system and the portable test equipment used by the Principal.

This Section is based on the usual situation where each measured value (axial shaft position or radial vibration) will have independent probes and oscillator/demodulators, hereafter called ‘channels’.

Requirements for machine monitoring ensue from the IPF classification exercise, see DEP 32.80.10.10-Gen. and from API 670. In case of conflict, DEP 32.80.10.10-Gen. shall take precedence. Where permanent machine monitoring is required, the monitoring system:

- shall be in accordance with API 670 (unless otherwise stated);
- shall be suitable for an electricity supply of 24 V(dc), floating;
- shall be suitable for mounting in standard 483 mm (19 inch) racks;
- shall be installed in system cabinet(s) for machine protection in the respective auxiliary room or control cubicle;
- may require automatic suppression during equipment start and/or stop to prevent nuisance alarms or trips. API 670 provides recommendations and constraints for time delays and suppression;
- shall not be provided with maintenance override switches (MOS).
  This is a deviation from API 670. If a MOS is required, it shall be incorporated in the downstream IPS and not on the monitor. For restrictions on the use of a MOS, see DEP 32.80.10.10-Gen.

The key-phaser channel, if present, does not need a permanent monitor. This signal shall be available on a test socket for orbit analysis, etc.

A typical arrangement for a machine monitoring system is shown in Appendix 2.

11. FLAME DETECTION

The Principal shall specify the measuring principle to be applied (e.g. ultra violet, infra red, etc.). The Principal shall also specify the number of detectors per flame.

Special detectors are required for flames containing H_2S, such as in furnaces on sulphur recovery units (SRUs). The Principal shall advise suitable makes and models.

A positive air flow is usually required to keep the flame detector cool and clean.

Flame detectors shall be provided with self diagnostic capabilities.

12. 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.

SHELL STANDARDS

DEP publications and standard specifications	DEP 00.00.05.05-Gen.
Standard Drawings	DEP 00.00.06.06-Gen.
The use of SI quantities and units (Endorsement of ISO 31 and ISO 1000)	DEP 00.00.20.10-Gen.
Pressurised bulk storage installations for LPG	DEP 30.06.10.12-Gen.
Metallic materials - Selected standards	DEP 30.10.02.11-Gen.
Non-metallic materials - Selection and application	DEP 30.10.02.13-Gen.
Gaseous oxygen systems	DEP 31.10.11.31-Gen.
Piping - General requirements	DEP 31.38.01.11-Gen.
SIOP Piping classes	DEP 31.38.01.12-Gen.
SIEP Piping classes	DEP 31.38.01.15-Gen.
Fire, Gas and Smoke detection systems	DEP 32.30.20.11-Gen.
Instrumentation for equipment packages	DEP 32.31.09.31-Gen.
On-line process stream analysis -sample take-off and transportation	DEP 32.31.50.10-Gen.
On-line process stream analysis part 2: Sample conditioning	DEP 32.31.50.11-Gen.
On-line process stream analysis -Analysers	DEP 32.31.50.12-Gen.
On-line process stream analysis -Analyser houses	DEP 32.31.50.13-Gen.
Turbine fiscal metering systems for liquid hydrocarbon	DEP 32.32.00.11-Gen.
Control valves: Selection, sizing and specification	DEP 32.36.01.17-Gen.
Instrument impulse lines	DEP 32.37.10.11-Gen.
Instrument signal lines	DEP 32.37.20.10-Gen.
Instrumentation of depressuring systems	DEP 32.45.10.10-Gen.
Classification and implementation of instrumented protective functions	DEP 32.80.10.10-Gen.
Shop and field fabrication of orifice meter runs	DEP 61.38.10.10-Gen.

STANDARD FORMS

NOTE: Standard Forms are contained in a binder (DEP 00.00.10.05-Gen.)

Standard Forms binder	DEP 00.00.10.05-Gen.
Instrument impulse lines ‘Metric version’	DEP 32.37.02.81-Gen.
Instrument impulse lines ‘Imperial version’	DEP 32.37.02.82-Gen.

STANDARD DRAWINGS

NOTE: The latest edition of Standard Drawings can be found in DEP 00.00.06.06-Gen.

Cleat and sleeve for surface-mounted thermometer assembly	S 10.109
Connection for skin thermocouple	S 24.604
Installation of thermocouple on furnace tubes	S 24.615
Square edge flow metering orifice plates for ASME B 16.36 raised face orifice flanges	S 32.102
Quarter circle flow metering orifice plates for ASME B 16.36 raised face orifice flanges	S 32.104
Conical entrance flow metering orifice plates for ASME B 16.36 raised face orifice flanges	S 32.112
Restriction orifice plates for ASME B 16.5 raised face flanges	S 32.114
Furnace tube skin thermocouple assembly	S 35.405
Thermometer assemblies for mounting in thermowells	S 35.409
Bi-metal thermometer assembly	S 35.410
Thermometer assembly for surface mounting	S 35.411
Instrument name plates	S 37.601
Cover flanges for flanged thermowell nozzle	S 38.046
Displacer chambers	S 38.056
Cover flanges for flanged thermowell ring-joint	S 38.060
Flanged thermowell DN 40 ASME classes up to class 1500 incl.	S 38.103
Flanged thermowell DN 50 ASME flange classes up to Class 2500 incl.	S 38.104
Flanged thermowell, ring-joint DN 40 and 50, ASME classes 900 and 1500	S 38.106
Flanged thermowell, ring joint DN 50, ASME flange class 2500	S 38.107
Flanged thermowell DN 40 ASME classes up to class 900 incl.	S 38.110
High pressure welded thermowell for piping systems, DN 50	S 38.112
Orifice flanges, RF, with flange tappings, ASME class 300 to 2500 incl. nom. size DN 50 to 600 incl.	S 38.130
Orifice flanges, RF, with corner tappings, ASME class 300 and 600, nom. size DN 50 to 600 incl.	S 38.131
Orifice meter runs with flange tappings, ASME class 300 to 2500 incl., nom. size DN 50 to 300 incl.	S 38.132
Orifice meter runs with flanged ends, nom. size DN 15 to DN 40 incl., ASME class 150 to class 1500 incl.	S 38.134
Level gauge pole for fixed roof tanks (execution for custody transfer)	S 51.114
Combined guide pole/level gauge pole for floating roof tanks (for custody transfer)	S 51.115
Level gauge pole for fixed roof tanks (non custody transfer)	S 51.154

AMERICAN STANDARDS