
British Standard Code of practice for
**Instrumentation in process control systems:
installation design and practice**

Appareillage des systèmes de contrôle des processus — Conception et fonctionnement de l'installation —
Code de bonne pratique

Leitfaden für Meßgeräte in Prozeßsteuerungssystemen; Geräteanordnung

Foreword

This British Standard code of practice has been prepared under the direction of the Industrial-Process Measurement and Control Standards Committee. It is based on an initial draft provided by the Institute of Measurement and Control.

Acknowledgement is made to the Engineering Equipment and Materials Users' Association for permission to make use of its Handbook no. 34, published in 1973.

The code gives recommendations for achieving good design for the installation of instrumentation for measurement and control systems in the process industries and the implementation of this installation.

It is intended to be used as a manual of good practice by engineers at the site and also to assist those who design and draw up specifications for instrumentation and control systems. It is expected that companies not having their own established procedures will find it especially useful, but this code should also help the larger companies that have worldwide interests in instrument installation to maintain good engineering practices.

In the cases where special instruments are to be installed which are not covered in this code, many of the recommendations will generally apply but these should be supplemented by information obtained from the manufacturers.

The drawings given in this code are not necessarily to scale and are intended only to supplement the text and to illustrate the general principles where applicable. They are not the only possible examples and they are not intended as design examples or to be fully dimensioned working drawings.

NOTE. All pressures quoted are gauge unless otherwise stated.

The code is primarily intended for land based installations concerned with processing organic and inorganic materials and the generation of energy. It may also be applicable to some offshore installations although the nature of some of these plants is likely to require special considerations not necessarily dealt with in this code. These special considerations also apply to installations in the Mining Industry.

Appendix A gives information on certification. Appendices B to F give examples of calibration and check sheets and a test report. An example of test or calibration equipment which may be required for on-site instrument testing and pre-commissioning is given in appendix G. Miscellaneous regulations and recommendations are given in appendix H.

NOTE 2. Wherever the words 'specified in the original design' or 'at the original design stage' appear, these mean the drawing office design of the instrumentation.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Contents

	Page		Page
Foreword		Inside front cover	
Committees responsible		Back cover	
Code of practice			
Section one. General			
1.1 Scope	4	4.3 Pressure	18
1.2 Definitions	4	4.3.1 General	18
Section two. Personnel safety		4.3.2 Pressure connections	18
2.1 General	6	4.3.3 Differential pressure measurement	19
2.2 Statutory regulations	6	4.3.4 Direct reading instruments	19
2.3 Responsibility	6	4.3.5 Pressure transmitters and switches	19
2.4 Permit to work	6	4.4 Temperature	20
2.5 Protective equipment	7	4.4.1 General	20
2.6 Use of tools	7	4.4.2 Thermometer sheaths or pockets	20
2.7 Lifting gear and lifting appliances	7	4.4.3 Expansion thermometers	20
2.8 Ladders and scaffolding	7	4.4.4 Thermocouples	20
2.9 Safe access and egress	7	4.4.5 Resistance thermometers	22
2.10 Safety signs	7	4.4.6 Total radiation pyrometers	22
2.11 Escaping fumes, gases and process fluids giving rise to fire, asphyxiation, toxic or explosive hazard	7	4.4.7 Optical pyrometers	23
2.12 Noise	7	4.4.8 Photoelectric pyrometers	23
2.13 Work in an enclosed place	8	4.4.9 Ratio pyrometers	23
2.14 Work on process and impulse lines	8	4.5 Level	23
2.15 Work on electrical systems	8	4.5.1 General	23
2.16 Hazardous areas	9	4.5.2 Gauge glasses	23
2.17 Ionizing and non-ionizing radiations	9	4.5.3 Float switches	23
2.18 Toxic materials	9	4.5.4 Buoyancy devices	23
2.19 Pressure testing	9	4.5.5 Dip tubes	23
Section three. Instrumentation in hazardous areas		4.5.6 Differential pressure devices	23
3.1 General	10	4.5.7 Capacitive measuring method	24
3.2 Apparatus	10	4.5.8 Ultrasonic method	24
3.3 Classification according to plant area, apparatus and temperature	10	4.5.9 Nucleonic level measurement	24
3.4 Suitability of electrical equipment	10	4.5.10 Load cell measuring method	24
3.5 Types of equipment	10	4.5.11 Electrical conductivity measuring method	24
3.6 Installation	10	4.5.12 Automatic level gauging	25
3.7 Documentation	11	4.6 Mechanical measurements	25
3.8 Pre-commissioning and commissioning of instrumentation for hazardous areas	11	4.6.1 Position	25
Section four. Detectors and measuring devices		4.6.2 Speed	25
4.1 General	12	4.6.3 Vibration and acceleration	26
4.2 Flow	12	4.7 Weighing machines	26
4.2.1 General	12	4.7.1 General	26
4.2.2 Differential pressure flow measurement	12	4.7.2 Portable machines	26
4.2.3 Variable area flowmeters	13	4.7.3 Dormant machines (mechanical)	26
4.2.4 Positive displacement flowmeters	14	4.7.4 Dormant machines (load cell type)	27
4.2.5 Turbine flowmeters	14	4.7.5 Dormant machines (pneumatic)	27
4.2.6 Vortex shedding flowmeters	15	4.7.6 Single-ended machines	27
4.2.7 Open channel flow measurement	15	4.7.7 Belt weighers	27
4.2.8 Electromagnetic flowmeters	16	4.8 Density measurement	28
4.2.9 Ultrasonic flowmeters	17	4.8.1 General	28
4.2.10 Coriolis mass flowmeters	18	4.8.2 Weighing method	28
4.2.11 Flow switches	18	4.8.3 Buoyancy method	28
		4.8.4 Pressure differential methods	28
		4.8.5 Gamma radiation absorption method	28
		4.8.6 Ultrasonic method	29
		4.8.7 Vibrating element (natural resonance) method	29
		Section five. Quality measuring instruments	
		5.1 General	31
		5.2 Chemical probes	31
		5.3 Process analysers	32
		5.4 Mountings and housings	32
		5.5 Sample conditioning systems	33
		5.6 Sampling lines	33

	Page		Page
5.7 Sampling connections	34	Section eleven. Testing, including pre-commissioning	
5.8 Vent and effluent lines	34	11.1 General	64
5.9 Manual sampling and calibration connections	34	11.2 Responsibility for testing and approval	64
5.10 Storage and handling of equipment	34	11.3 Inspection upon receipt	64
5.11 Testing	34	11.4 Pre-installation testing	65
5.12 Calibration and commissioning	34	11.5 Pressure testing of instrument piping and tubing	71
5.13 Safety	34	11.6 Testing of instrument cables	72
Section six. Regulating devices		11.7 Pre-commissioning (including loop testing)	73
6.1 General	35	11.8 Check sheets	74
6.2 Mechanical protection	35	Section twelve. Commissioning and acceptance	
6.3 Pre-installation checks	35	12.1 General	75
6.4 Control valve installations	35	12.2 Ready for commissioning	75
6.5 Access for testing and maintenance	36	12.3 Commissioning	75
6.6 Environmental protection	36	12.4 Acceptance	76
6.7 Piping	36	Appendices	
6.8 Control valve bodies	37	A Explanation of marking and labelling of equipment in hazardous areas	77
6.9 Control valve actuators	37	B Instrument pre-installation calibration sheet	79
6.10 Auxiliary equipment	37	C Pressure indicator calibration check sheet	80
6.11 Variable speed systems	38	D Alarm system check sheet	81
Section seven. Pneumatic, electrical and hydraulic supply systems		E Instrument loop check sheet	82
7.1 General	40	F Safety valve test report	83
7.2 Pneumatic supply systems	40	G List of test and calibration equipment	84
7.3 Electrical power supply systems	42	H Further reading	84
7.4 Hydraulic supply systems	42	Tables	
Section eight. Instrument panels		1 British and European Standards designating symbol type for degrees of protection	10
8.1 General	45	2 List of Parts of BS 5345	10
8.2 Handling and reception	45	3 Air header sizing guide	54
8.3 Locally mounted panels and cubicles	45	4 Piping and tubing supports	56
8.4 Instrument panels, cubicles and consoles mounted in control rooms, computer rooms or switch houses	46	5 Example of cable separation	58
Section nine. Electronic systems		6 Test status colour code	64
9.1 General	47	7 Temperature calibration bath guide	66
9.2 Lifting and handling	47	8 Principal UK certification authorities	77
9.3 Location and environment	47	Figures	
9.4 Earthing	48	1 Tapping point location on a Venturi tube	86
9.5 Power supply	49	2 Tapping point location on an orifice plate carrier ring	86
9.6 Protection	49	3 Tapping point locations for flange-mounted orifice plate	87
9.7 Data transmission systems	50	4 Radial location of tappings on a horizontal or sloping pipe	87
9.8 Field equipment	50	5 Impulse pipework connections for measurement of flow of liquid	88
9.9 Commissioning	50	6 Impulse pipework connections for measurement of flow of steam or condensing vapour	89
Section ten. Piping and wiring		7 Impulse pipework connections for measurement of flow of gas	90
10.1 General	52	8 Impulse pipework connections for measurement of flow of liquid with suspended material	91
10.2 Installation and documentation	52	9 Impulse pipework connections for measurement of flow where seal points are used	93
10.3 Installation drawings	52		
10.4 Instrument protection and storage	52		
10.5 Instrument mounting and accessibility	52		
10.6 Instrument piping and tubing	53		
10.7 Instrument cabling	56		
10.8 Protection from process materials and environmental conditions	61		

	Page		Page
10 General arrangement of pitot tube installation for measurement of liquid flow	94	29 Differential pressure level measurement on a vessel containing a liquid near saturation conditions	109
11 Detailed arrangement of pitot tube	95	30 Capacitive level measurement	110
12 Electromagnetic flowmeter installations	96	31 Ultrasonic level measurement	111
13 Cathodic protection for electromagnetic flowmeters	97	32 Nucleonic level measurement	111
14 Correct way for lifting an electromagnetic flow transducer	98	33 Electrical conductivity level switching	112
15 Ultrasonic doppler flow measurement	99	34 Accelerometer mounting	112
16 Ultrasonic transit time flow measurement	99	35 Weighing type density measurement	113
17 Ultrasonic flowmeter sensor mountings	100	36 Buoyancy density measurement	113
18 Coriolis mass flowmeter	101	37 Gamma radiation density measurement	114
19 Flap type flow switch	102	38 Ultrasonic density measurement	114
20 Pressure indicator or transducer hook-ups	103	39 Preferred arrangement for a control valve with downstream side connected to atmosphere	115
21 Pressure indicator or transducer with condensate seals for hot vapour or steam service	104	40 Preferred arrangement for a control valve when both sides could become pressurized	115
22 Arrangement of pressure gauge with chemical seal	105	41 Preferred arrangement for a control valve for highly toxic or extremely high pressure applications	115
23 Pressure gauge with seal pots	105	42 Earth resistance measurements	116
24 Independent support for pressure gauges up to 150 mm (6 in) in diameter	106	43 Fault diagnosis on modem link	117
25 Level measurement on a vessel using a standpipe	106	44 Field termination of pneumatic multitubes	118
26 Level measurement using purged dip tube	107	45 Details of copper tubing trays (examples of construction)	119
27 Level measurement using differential pressure transmitter on vented tank	107	46 Layout of thermocouple extension cable in conduit	120
28 Differential pressure level measurement on a pressurized vessel	108	47 Control centre earthing system	121
		48 Field termination of multicore thermocouple extension cable	122

Section one. General

1.1 Scope

This British Standard gives guidance on the design for the installation of instrumentation of measurement and control systems in the process industry and the implementation of this installation. It is intended to be used as a manual of good practice on the site and also to assist those who design the installation.

NOTE 1. The recommendations of this code are based on the assumption that all instruments will have been specified and all instrument panels will have been designed.

NOTE 2. The titles of the publications referred to in this standard are listed on the inside back cover.

1.2 Definitions

For the purposes of this British Standard the definitions given in BS 4727 apply, together with the following.

1.2.1 authorized person. A person authorized by management in writing to carry out certain duties and tasks on their behalf, on the understanding that the correct and appropriate procedures will be followed and standing instructions will be adhered to.

1.2.2 competent person. A person who by reason of his training, experience, theoretical and practical knowledge, and maturity of judgement is able to carry out the specified duties.

NOTE. The person should have the necessary ability in the particular operation of the type of plant and equipment with which he is concerned, an understanding of the relevant statutory regulations, an appreciation of the hazards involved, and sufficient authority to ensure that any action which he recommends is carried out. He should be duly authorized to undertake the work.

1.2.3 instrument personnel. Craftsmen and others who form the labour force required to install and commission instrumentation and associated pipework, equipment and services.

NOTE. The trades involved are likely to include pipefitters, welders, instrument mechanics and technicians, and electricians.

1.2.4 instrument supervisors. All supervisors and managers up to and including the site agent, who direct and control the installation personnel and whose responsibility to the owner/employer includes safety matters, work progress and standards, labour discipline and industrial relations.

1.2.5 responsible engineer. The engineer with particular responsibility for the specific project or parts of a project.

1.2.6 air conditioning. The control of humidity and temperature in and the preclusion of contaminants from a given environment.

1.2.7 antistatic mat. A piece of conductive material designed to lie on the ground for the purpose of safely discharging static charges from moving bodies.

1.2.8 atmospheric contamination. The presence in the environment of undesirable gases, vapours or dusts (that may be harmful to equipment or personnel working in that environment).

1.2.9 back-up power supply (standby power supply).

A power supply that supplies the load of another power supply in the event of the other supply failing.

1.2.10 computer based data logger. A system designed to collect and log data under the control of an integral central processor.

1.2.11 crash. The failure of an operating system to cycle in the prescribed manner.

1.2.12 crash dump. Information taken from a computer at or immediately after a crash (that may subsequently permit the diagnosis of the cause of the crash).

1.2.13 cathode ray tube (CRT) display. A device for presenting data in a visual form by means of a cathode ray tube.

1.2.14 disk. A flat, circular plane with a magnetic surface on which data can be stored by selective magnetization of portions of the flat surface.

1.2.15 disk drive. A device into which disks are inserted in order that data may be recorded onto or read from the disc surface.

1.2.16 diskette. A flexible circular piece of material coated in a magnetic recording medium on which data may be recorded magnetically.

1.2.17 distributed control system. A system where control responsibility is divided into a variety of modules that are arranged either geographically (per unit process) or logically (control functions) around a plant so that the failure of one does not affect the operation of others.

1.2.18 drum storage device. A right circular cylinder with a magnetic surface on which data can be stored by selective magnetization of portions of the curved surface.

1.2.19 dual alternating current. A power supply system where two a.c. supplies are provided (normally from separate sources for security reasons).

1.2.20 gas flooding system. A system which in the event of smoke or fire being detected in a given area has the ability to fill that area with a fire retardant gas.

1.2.21 inverter. A device that converts a direct current to an alternating current (normally employed to provide 110 V a.c. or 240 V a.c. from a battery supplied d.c. source).

1.2.22 line printer. A printing device that prints an entire line of data at a time and then advances to the next line.

1.2.23 listing. A document containing all of the codes and comments associated with a particular computer program.

1.2.24 loop back. A facility whereby the output channel of a modem may be connected to an input channel (for diagnostic purposes).

1.2.25 modem. A device that converts data from a form which is compatible with data-processing equipment to a form that is compatible with transmission facilities, and vice versa.

1.2.26 paper feed bin. A container from which blank paper is drawn into a printer.

1.2.27 paper catcher. An apparatus designed to catch and stack paper as it leaves a printing device.

1.2.28 power line disturbance monitor. An instrument designed to analyse and monitor various power line parameters such as frequency, r.m.s. values, transient-amplitudes, -duration and -frequency.

1.2.29 print head. That part of a printing device that translates the electronic/electromechanical signals generated in such a device into a character on paper.

1.2.30 printing terminal. An output device that converts data into a printed form.

1.2.31 process control computer. A computer that, by means of inputs from and/or outputs to a process, directly controls and/or monitors the operation of elements in the process.

1.2.32 programmable multi-loop controller. A controller capable of controlling two or more variables and whose control strategy is changeable by programming or software configuration.

1.2.33 semi-rigid coaxial cable. A transmission line with two concentric conductors separated by an insulator, the outer conductor being of a solid rather than the normal braided construction resulting in a stiff though not inflexible cable.

1.2.34 shared display control system. A control system where the operator interface is by means of a multiplexed CRT display.

1.2.35 software update. A modification to a computer program.

NOTE. This is normally issued by manufacturers as improvements and error corrections are introduced into existing programs.

1.2.36 star configuration. A set of three or more branches with one terminal of each connected to a common node.

1.2.37 tape cassette. A portable container housing a spooled tape with a magnetic surface on which data can be stored by selective polarization of portions of the surface.

1.2.38 time domain reflectometer. A device designed to detect and locate cable faults in coaxial and twisted pair cables.

NOTE. The principle involves applying a pulse to the cable under test and measuring the delay in reception of any reflections and analysing the shape of any reflected pulses.

1.2.39 transmission line. A cable connecting two remote points along which electrical/electromagnetic signals are transmitted.

1.2.40 video terminal. A device for sending and/or receiving data from an electronic system that is provided with a visual display normally in the form of a cathode ray tube.

1.2.41 control valve. A power operated device forming a final element in an industrial process control system.

NOTE. It consists of a body subassembly containing internal means for changing the flow rate of the process fluid. The body sub-assembly is linked to one or more actuators which respond to a signal transmitted from a controlling element.

1.2.42 actuator. A mechanism for changing a signal into a corresponding movement.

1.2.43 positioner. A device to position an actuator in accordance with a standardized signal.

NOTE. The positioner compares the input signal with a mechanical feedback link from the actuator, then produces an output signal necessary to move the actuator until the position feedback corresponds with the signal value.

1.2.44 converter. A specialized device that converts one standardized transmission signal into another.

1.2.45 booster. A power amplifier of which the signal gain is unity.

1.2.46 hysteresis. The property of a device or instrument whereby it gives different output values in relation to its input values depending on the direction sequence in which the input values have been applied.

Section two. Personnel safety

2.1 General

The advice given in this section is primarily concerned with those personnel who are engaged in the installation of instrumentation.

It is recommended that in all premises the occupier should formulate a set of safety rules and site recommendations or procedures appropriate to his type of installation. These should cover the operation of equipment/plant and the work to be carried out.

2.2 Statutory regulations

NOTE 1. Attention is drawn to relevant statutory regulations and codes of practice. It is essential that the provisions of these documents are incorporated in the site safety rules and procedures.

The major statutory acts and regulations relevant to instrument installation are as follows.

(a) Health and Safety at Work, etc. Act 1974.

The following sections are particularly relevant:

Section 2. General duties of employers to their employees

Section 3. General duties of employers and self-employed to persons other than their employees

Section 4. General duties of persons to persons other than their employees

Section 6. General duties of manufacturers, etc., as regards articles and substances for use at work

Section 7. General duties of employees at work

Section 8. Duty not to interfere with or misuse things provided pursuant to certain provisions

(b) The Factories Act 1961.

(c) Electricity (Factories Act) Special Regulations 1908 and 1944.

(d) The Construction (General Provisions) Regulations 1961.

(e) The Mines and Quarries Act 1954.

(f) Mineral Workings (Offshore Installations) Act 1971.

(g) Offshore Installations (Operational Safety, Health and Welfare) Regulations 1976 (SI 1976 No. 1019).

NOTE 2. This list is not necessarily complete. Some of the other relevant statutory regulations relating to specific problems are referred to elsewhere in the text.

2.3 Responsibility

2.3.1 The responsibility for ensuring safe methods of working and operating equipment rests primarily on the occupier or employer but is not restricted to him. He should ensure that precise instructions are issued setting out the procedures for handling and testing equipment safely. He should monitor the arrangements to ensure that these procedures are effectively carried out. The employer or

occupier has general overall responsibility for the premises and work activities.

NOTE 1. There is an obligation on all agents, workmen and employed persons to carry out their work in accordance with the statutory requirements and relevant site regulations.

NOTE 2. The attention of all personnel is drawn to HSC3 'Advice to Employers' and HSC5 'Advice to Employees', published by the Health and Safety Executive.

2.3.2 Management should ensure that all personnel are fully aware of their responsibility for the safety of installations under their control and for ensuring that their own work is carried out safely.

2.3.3 Instrument supervisors should be fully conversant with the safety requirements and recommendations, and should ensure that instrument personnel under their control have been made familiar with the site safety practices.

2.3.4 It is important that all instrument personnel are aware of the site arrangements for emergency services, including the type and location of available first aid equipment, the method of summoning medical assistance, the fire service and other emergency services and should also know the location of all the personnel assembly points in the event of a site emergency.

2.3.5 Before commencement of work, the person in charge of the premises (or site) should inform all instrument personnel of the potential hazards on site and the action to be taken in an emergency.

2.3.6 Where procedures or processes that are the responsibility of the person in charge of the premises (or site) or of any contractor could endanger persons not in their employment, there is, under section three of the Health and Safety at Work, etc. Act 1974, a legal obligation on the site management to provide information and instruction to all personnel about the safety procedures to be adopted.

NOTE. The term 'responsible person' is defined in HS(R)5 'The Notification of Accidents and Dangerous Occurrence Regulations 1980', published by the Health and Safety Executive. Attention is drawn to these regulations.

2.4 Permit to work

A permit to work may form part of the site procedures that enable an operating department to authorize certain specified engineering work to proceed on the installation. It will normally contain written instructions on the nature of the work, the whereabouts and the part of the installation to which it applies, the protective equipment to be provided, and to be used or worn, the precautions to be taken, the precautions already taken, the period for which it is valid, the name of the person and organization to whom it is issued and the name of the person authorized to issue it. It may also include details of any additional permits deemed to be necessary for the safe execution of the work. Installation in this context includes work on all plant and equipment within the area covered by the permit to work system, i.e. instrumentation, electrical switchgear, pressure testing, radiography, etc.

2.5 Protective equipment

It is essential that protective equipment and clothing, e.g. safety belts and harnesses, storm clothing, means for head, eye and foot protection, protection against heat, and hearing protectors, are in accordance with site requirements.

NOTE. Attention is drawn to the Health and Safety at Work, etc. Act 1974 and to the specific regulations that apply to the work.

2.6 Use of tools

Acceptable standards for welding, brazing, the use of handtools and portable machinery should be specified by the responsible engineer. It is essential that the practices adopted comply with the site requirements. Installation personnel are responsible for the care, regular examination and arranging replacement (when necessary) of tools and equipment. In areas where there may be a risk of fire or the presence of flammable material, installations should be carried out using only approved non-sparking tools used in accordance with permit to work procedures. Unattended tools should be left in a safe condition.

2.7 Lifting gear and lifting appliances

All lifting gear and appliances will need certification before use, together with statutory tests, examinations or inspections by a competent person. The user of the equipment should ensure that such certification, testing, examination or inspections have been so carried out and that the statutory forms have been completed.

2.8 Ladders and scaffolding

All ladders and scaffolding should be properly maintained and every part should be kept so fixed, secured or placed in position as to prevent, so far as is reasonably practicable, accidental displacement. The user is responsible for ensuring that such equipment has been inspected by a competent person within the previous 7 days, or more frequently in bad weather.

2.9 Safe access and egress

Suitable and sufficient safe access and egress to and from the working area and any health/welfare facilities should be provided and be free of obstruction.

NOTE. Attention is drawn to the relevant statutory regulations and site requirements.

2.10 Safety signs

Management should ensure that all personnel are familiar with the meanings of the signs covered in The Safety Signs Regulations 1980 (see Health and Safety publication HS(R)7), as detailed in BS 5378 : Part 1, and such other safety signs as may be designated in the site requirements.

2.11 Escaping fumes, gases and process fluids giving rise to fire, asphyxiation, toxic or explosive hazard

2.11.1 Adequate precautions should be taken to avoid the escape of flammable, toxic, asphyxiating and noxious fumes, gases and liquids from the plant. These are particularly important where such emissions are not detectable by smell or where sensory nerves in the nose become desensitized in a gradually increasing concentration.

Where the possibility of dangerous emissions exists, particularly in enclosed spaces, the employer should arrange for the relevant precautions, including atmosphere monitoring, to be applied before installation personnel enter the area. This will include a permit to work system (see 2.4 and 2.13).

2.11.2 Arrangements should be made to warn personnel of the specific dangers, before the commencement of work, including fire and explosion hazards, that would arise from an accidental escape of process fluids.

Instruction should be given on the action to be taken if such an escape occurs, e.g. the need for eye washes and, when appropriate, for the person to take a shower and wash protective clothing.

2.11.3 All personnel should be informed of the location of fire alarms and the method of initiating such alarms, the operation of fire fighting equipment, the position of escape routes and also the fire reporting arrangements. These instructions should be incorporated into the requirements for site safety.

2.11.4 It is imperative that personnel working in an installation where oxygen may have escaped or been released should be made fully aware of the fire risks created by the oxygen enriched atmosphere, including the likelihood of an increase in the flammability of clothing and the possibility that the hazard will persist for a time.

2.12 Noise

Excessive noise is recognized as a potential health hazard and in some cases can cause hearing damage; the HSE 246 'Code of practice for reducing the exposure of employed persons to noise', published by the Health and Safety Executive, gives advice on levels that should be regarded as a serious risk to hearing and the action that should be taken to deal with the problem.

As far as reasonably practicable, noise exposure should be kept below the values set out in the HSE code by engineering control of the working environments, for example, by enclosure or separation of noisy items of plant from areas to which workers need access while installing equipment, or by arranging for installation to be done while noisy plant is shut down. Machine suppliers should be required to supply information on the noise output of items likely to cause hazardous noise levels, so that places and tasks that might cause exposure above the levels in the HSE code can be identified at the design stage, and any necessary remedial action taken.

Where it is necessary for workers to be exposed to noise above the levels recommended in the HSE code, they should be provided with suitable ear protectors and given clear information on why, when and where it should be used. Workers should cooperate in the use of ear protection, noise surveys and noise control. The HSE code gives advice on actions by employers and employees to ensure that ear protection programmes are effective.

2.13 Work in an enclosed place

2.13.1 Where work is to be carried out inside confined places, such as plant, instrument cubicles, ducts, or behind wall panels, the maximum natural ventilation should be provided; sometimes this can be achieved by securing the cubicle door in the open position or by removing it altogether, or by opening up the duct or demounting part of the panel. If there is a possibility of a hazard from oxygen deficiency, or where toxic or flammable gases exist within the space or are produced in the course of the work, effective steps should be taken to remove that hazard. The source(s) of any dangerous substances needs to be isolated and an atmosphere adequate for normal respiration maintained, if necessary by the use of forced ventilation. Alarms triggered by oxygen-deficiency detectors should be installed when considered appropriate. Where the risk cannot be removed then personnel protection such as breathing apparatus should be provided (see 2.13.2).

2.13.2 In areas provided with a gas-flooding fire extinguishing system, e.g. containing carbon dioxide or bromochlorodifluoromethane (BCF), there may be a suffocation or toxic hazard. In all cases it is preferable to lock off the system before work is done in the area, and with some systems lock off is required (see HSE Guidance Note GS 16 and BS 5306). Adequate ventilation should be provided and maintained, the atmosphere monitored and a permit to work system applied before installation personnel are allowed to enter the area. The permit to work certificate will state the condition under which entry is permitted, the safety equipment to be used and the validity period.

2.13.3 It is essential that no person at any time enters a confined space unless a second person equipped to render immediate assistance is within sight and hearing.

NOTE. For further information on this subject, see HSE Guidance Note GS 5.

2.14 Work on process and impulse lines

Where installation work necessitates breaking into process or impulse lines which are, or have been, in operation care should be taken to reduce any risks that may arise from the escape of dangerous substances or fluids under pressure e.g. compressed air, steam, oxygen, water and chemicals. Such lines should be fully isolated from the remainder of the system and made safe for work by removing the contents by draining, venting and purging, where necessary. Isolation should be achieved by the use of isolating valves, manually secured in the closed position, while valves used

for draining and venting should be secured in the open position. Control valves should not be used for these purposes and it should be noted that, in certain cases, single valve isolation may not be relied upon. In such situations, two isolating valves are normally provided for this purpose but where this is not the case it may be necessary to fit a spade in the line. The latter is particularly recommended if the isolation is applied over an extended period of time. Installation personnel should be made aware of any hazards and the work should be controlled by a suitable permit to work system.

2.15 Work on electrical systems

NOTE. It is essential that all persons employed on the installation of apparatus are fully acquainted with the appropriate statutory regulations and the owner's electrical safety requirements.

2.15.1 In addition to the requirements of the Health and Safety at Work, etc. Act 1974, certain premises have specific requirements for electrical systems. Some of these are as follows.

On all premises subject to the Factories Act 1961, the Electricity (Factories Act) Special Regulations 1908 and 1944 apply.

Particular attention is drawn to the 'Memorandum on the Electricity Regulations' SHW 928, issued by the Health and Safety Executive.

Installations in mines and quarries are subject to the provisions of Mines and Quarries Act 1954 and the relevant regulations made under the Act.

Offshore installations are subject to the provisions of the Mineral Workings (Offshore Installations) Act 1971 and the relevant regulations made under this Act.

2.15.2 Work on electrical equipment or circuits that have been energized or are connected to a live distribution board will be subject to special safety requirements in accordance with relevant site rules and it may be necessary for personnel to be issued with permits to work.

2.15.3 Any installed or partly installed electrical conductor should be regarded as live unless otherwise proven to be dead and isolated.

Particular attention should be paid to conductors associated with interlocking circuits that may become live from the functioning of other apparatus.

Attention is drawn to the need to follow warning signs or instructions on any cover or access plate.

2.15.4 Whenever practicable conductors and equipment should be made dead and isolated before work on the equipment commences. Advice on safe isolation procedures is given in appendix A of BS 6423 : 1983. In cases where work is to be carried out on equipment in areas where there may be a potentially explosive atmosphere, it is essential that the electrical supplies to the equipment be isolated. (An exception is intrinsically safe equipment.)

NOTE. In mines and quarries, isolation and making equipment electrically dead prior to work on electrical or electrically operated apparatus is a mandatory requirement except where stated otherwise in the relevant regulations.

Isolation procedures should ensure that:

- (a) accidental or inadvertent re-energization is prevented;
- (b) the equipment is proved to be de-energized using a suitable voltage indicator.

Where one person isolates and another does the work, the person responsible for isolation, wherever practicable, should demonstrate effectively to the other person that the equipment is de-energized and is safe and that there are safeguards in use to prevent re-energization.

2.15.5 In view of the risk of accident and the severity of injuries that can occur from electric shock and burns associated with accidents during functional testing and work on or near exposed live apparatus, such activities should not be undertaken unless there is good reason. Where it is decided that there is justification for work to proceed while the conductors are live, special safety precautions should be observed. These precautions should include the provision of, and adherence to, written guidance or the operation of a permit to work system (see 2.4).

The special safety precautions to be observed and the procedures to be adopted will depend on the design of the apparatus and the nature of the task and normally will be carried out in accordance with the site electrical regulations work permit. Such work should be performed only by a competent person. Where an accompanying person is required, that person should be familiar with the appropriate safety precautions and should know how to protect himself and the action to be taken in case of an accident.

Inspection and work on live apparatus with covers removed is not generally permitted in mines and quarries.

2.16 Hazardous areas

For work in potentially explosive atmospheres special safety precautions should be applied, including the operation of a permit to work system (see also 2.6, 2.12 and section three).

2.17 Ionizing and non-ionizing radiations

2.17.1 General

Installation staff should be instructed in the hazards, and in the safe handling of apparatus capable of generating hazardous levels of radiation or containing radioactive materials. Sources of radiation include X-ray equipment, radioactive isotopes, lasers, ultraviolet equipment and radio-frequency apparatus.

2.17.2 Ionizing radiations

Both the Ionizing Radiations (Unsealed Radioactive Substances) Regulations 1968 and the Ionizing Radiations (Sealed Sources) Regulations 1969 require the appointment of a competent person to exercise special supervision with regard to the requirements of these regulations. Movements of radioactive sources or substances within a factory should be made under the supervision of an authorized person.

In the field of industrial instrumentation, radioactive isotopes are likely to be in the form of a sealed source, i.e. suitably encapsulated, and, whenever possible, should be in this form, thus reducing the risks associated with the dispersal of radioactive material.

The shutter mechanism in a radioactive source holder may only be operated after unlocking a part of the mechanism. To prevent a radiation hazard being caused by unauthorized interference, the key is required to be held by the 'authorized person' referred to previously.

Detailed instructions should be obtained from the instrument manufacturers for the installation of their equipment, including full information on the safe handling of any radioactive source; these instructions should be strictly obeyed.

The basic symbol to denote actual or potential presence of ionizing radiation is given in BS 3510 and BS 5378 : Part 1.

2.17.3 Non-ionizing radiations

Lasers and laser installations should comply with BS 4803. When lasers of a higher class than class 2 lasers (as defined in BS 4803) are installed or used, a laser safety officer should be appointed whose task should be to review the precautions given in BS 4803 : Part 3, and advise on the appropriate controls to be implemented. This requirement is mandatory where lasers of class 3A, class 3B and class 4 are in use. Appropriate control procedures which may include permits to work should be formulated at an early stage and put into effect as appropriate during installation, testing and commissioning. Such procedures for hazard control are dealt with in section eight of BS 4803 : Part 3 : 1983.

2.18 Toxic materials

The installation supervisor should ascertain which toxic hazards, if any, are likely to be encountered in the work and should inform the personnel concerned about the hazards, the equipment to be used, and the method of work to be adopted in order to comply with the relevant regulations.

NOTE. Such regulations include the Asbestos Regulations 1969.

2.19 Pressure testing

Where relevant, pressure testing of impulse lines should be carried out in accordance with the guidelines given in HSE Guidance Note GS4 'Safety in pressure testing'. Any liquid used for hydraulic testing should be compatible with the process fluid and should not contaminate the interior of the impulse lines. In addition, such tests should be carried out only:

- (a) after disconnection of all instruments that may be damaged by the test pressure; and
- (b) under strict supervision.

Section three. Instrumentation in hazardous areas

3.1 General

This section covers the installation of electrical instrumentation in areas that are defined as being hazardous because of the presence of flammable gases and vapours or of the likelihood of them occurring.

NOTE. The precautions necessary for personnel safety are given in section two.

Pneumatic instrumentation is inherently free from electrical risk but the material from which it is constructed may itself present a hazard when used in such areas.

3.2 Apparatus

3.2.1 Recommendations for the selection and installation of electrical apparatus for use in hazardous areas excepting mining applications are given in BS 5345.

3.2.2 Electrical apparatus intended for use in hazardous areas should comply with BS 229, BS 1259, BS 4137, BS 4683 or BS 5501.

3.2.3 BASEEFA is the principal certifying authority for non-mining apparatus but since the advent of harmonization of European design standards BASEEFA usually does not re-certify equipment that has already been certified by the certifying authority of one of the other CENELEC countries as complying with a harmonized standard. Therefore equipment that has been certified by any of the CENELEC certifying authorities is acceptable for use as certified. Equipment from non CENELEC countries may be suitable for use but each application should be carefully assessed to ensure that it meets the requirements of the national standards of the country concerned as these may differ from the corresponding British Standards.

NOTE. See also appendix A.

3.3 Classification according to plant area, apparatus and temperature

When considering instrumentation in hazardous areas, it is essential that the following are taken into consideration:

- (a) the zone classification of plant area;
- (b) the apparatus enclosure group;
- (c) the apparatus temperature classification.

NOTE. For further information see BS 4683, BS 5501 and BS 5345.

3.4 Suitability of electrical equipment

Before installation, all equipment should be examined to ensure that it is suitable for the zone for which it is designated. For this purpose, plant layout drawings should be available showing the limits of each hazardous area, with the group and temperature class for each area.

3.5 Types of equipment

The types of protection available are shown in table 1.

Table 1. British and European Standards designating symbol type for degrees of protection		
British Standard	European Standard	Title
BS 5501 : Pt. 1	EN 50 014	General requirements
BS 5501 : Pt. 2	EN 50 015	Oil immersion 'o'
BS 5501 : Pt. 3	EN 50 016	Pressurized apparatus 'p'
BS 5501 : Pt. 4	EN 50 017	Powder filling 'q'
BS 5501 : Pt. 5	EN 50 018	Flameproof enclosure 'd'
BS 5501 : Pt. 6	EN 50 019	Increased safety 'e'
BS 5501 : Pt. 7	EN 50 020	Intrinsic safety 'i'
BS 5501 : Pt. 9	EN 50 039	Intrinsically safe electrical systems 'i'
BS 4683 : Pt. 3	—	Type of protection N

3.6 Installation

Details for the installation of the various types of protection are given in BS 5345, the Parts of which are given in table 2.

Table 2. List of Parts of BS 5345	
Part	Title
Part 1	General requirements
Part 2	Classification of hazardous areas
Part 3	Flameproof enclosures type 'd'
Part 4	Intrinsically safe equipment type 'i'
Part 5	Pressurization and continuous dilution type 'p'
Part 6	Increased safety equipment type 'e'
Part 7	Type 'n' protection
Part 8	Type 's' special protection
Part 9*	Oil immersed type 'o' and sand filled type 'q' protection
Part 11*	Specific industry applications
Part 12*	The use of gas detectors
* In preparation.	

3.7 Documentation

Correct drawings and documentation are desirable with any instrument installation, but are a requirement for instrumentation for use in hazardous situations, and of particular importance for intrinsically safe installations.

The following should be documented:

- (a) the zonal classification of the areas in which the apparatus is to be used and in which any interconnecting cables are to be installed;
- (b) the certificate detail and numbers of all equipment;
- (c) detailed reference to any item of uncertified equipment;
- (d) details of the types of cable used with cross-reference to any cable requirement contained in the certification documentation;
- (e) reference to any special requirements in the certification documentation;
- (f) the physical location on the plant of each item of electrical apparatus and routing of any interconnecting cables;
- (g) categorization and grouping of each intrinsically safe system or part thereof or each item of self-contained intrinsically safe electrical apparatus;

(h) inspection check lists against which commissioning and routine inspections should be carried out (see section eight);

(i) details of any electrical testing permitted or required as part of commissioning or routine inspections;

(j) replacement of any and all modifications made to the equipment or installation.

3.8 Pre-commissioning and commissioning of instrumentation for hazardous areas

3.8.1 Recommendations for the pre-commissioning of instrumentation are given in section eleven. However, additional checks are necessary when using instrumentation in hazardous areas; for this purpose a check list is advisable.

3.8.2 It is important that instrumentation installed in hazardous areas is in all respects suitable for the area concerned and has been correctly installed, tested, pre-commissioned and commissioned in accordance with the appropriate British Standards and that due attention has been given to earthing, cabling and cable entries.

Section four. Detectors and measuring devices

4.1 General

This section deals with devices commonly used in industry for the measurement of flow, pressure, temperature, level and some mechanical functions such as speed and vibration.

NOTE. Quality measuring instruments are covered separately in section five.

The detecting element or measuring device responds directly to the physical condition and its location needs to be carefully selected so that the reading or output obtained is truly representative of the variable to be measured.

4.2 Flow

4.2.1 General

There are many types of flow measuring device which are each appropriate for a different range of applications. Many of these devices form part of the process pipework and therefore may be installed by mechanical rather than instrument personnel. It is therefore recommended that an instrument supervisor be available to ensure that all necessary precautions are taken to provide a satisfactory installation (see section ten).

Flowmeters often have considerable commercial importance when the price paid for a quantity of product is calculated from flowmeter readings. These tariff metering applications have requirements for high accuracy and repeatability.

Tariff meter systems employ calibrated flowmeters and often use density, temperature or pressure measurements close to the flowmeter to allow corrections to a standardized set of conditions to be made. These measurements should be made so that they are representative of the whole flow. Installation of devices for these correction measurements should be in accordance with this code.

Where the tariff flowmeter has been calibrated complete with adjacent pipe sections, the whole calibrated assembly should be delivered in one piece for installation. The flowmeter and the adjacent pipe sections should not be dismantled before or during installation in the process line or the calibration certificate will be invalidated.

It is essential that all flow-measuring devices be installed precisely according to the design requirements and that no alteration be made without prior reference to the responsible engineer. This applies particularly to straight-pipe length requirements upstream and downstream of the device.

Instrument manufacturers' instruction manuals should be carefully retained and the specified installation procedure strictly followed in order to minimize the risk of measurement inaccuracies and instrument damage.

4.2.2 Differential pressure flow measurement

4.2.2.1 Principle. Flow through a primary element causes a fall in static pressure and the differential pressure so created is a function of the flow rate. This differential is measured by a differential pressure instrument which may be calibrated in flow units, or the conversion to flow units may be performed on the instrument output signal elsewhere.

4.2.2.2 Installation arrangement

4.2.2.2.1 Primary element location. To obtain the best accuracy from a differential pressure flow measurement it is important that flow disturbances are eliminated before they reach the measuring point. Selection of a measurement location preceded by a sufficient length of straight piping will minimize such disturbances. The length of straight piping depends upon the source of disturbance, such as valves, bends, tees, concentric/eccentric reducers, or changes in section upstream of the device and on the type of primary element employed. Minimum straight lengths upstream and downstream to obtain the desired accuracy and repeatability of measurement are specified in BS 1042, and should be incorporated in the pipework design. Where straight lengths are impossible to accommodate, flow conditioners or straighteners should be used (see 6.3 of BS 1042 : Section 1.1 : 1981).

4.2.2.2.2 Primary element mounting. Certain primary elements, particularly nozzles or Dall inserts, are mounted within the process pipework. To facilitate installation and removal of these inserts they should normally be located at the inlet to a short flanged pipe spool.

4.2.2.2.3 Tapping point location. Tapping points may be integral with the primary element, be part of a carrier ring or be made on the pipe itself in accordance with the design specification and BS 1042 (see figures 1 to 3).

4.2.2.2.4 Tapping points on horizontal or sloping pipes. The radial location of the tapping points on horizontal or sloping pipe sections should take into account the nature of the process fluid as shown in figure 4. Other orientations are permissible but may require special arrangements for venting and draining.

4.2.2.2.5 Vertical lines. Where metering orifices are installed in vertical lines the direction of flow should preferably be upwards for liquids and downwards for gases. This practice obviates the need for drain or vent holes in the primary element.

4.2.2.2.6 Impulse pipework connections. Connections between the tapping points and the differential pressure measuring devices should be as short as possible and should comply with section ten. Examples of arrangements are shown in figures 5 to 9. Wherever possible the transmitter should be mounted below the line. Where impulse lines are situated in areas where the ambient temperature may approach the freezing or pour-point of the measured fluid, the lines should be suitably thermally insulated or heat traced. All impulse/transmitter valves should be of suitable material and rating for the pipeline service.

4.2.2.2.7 Condensate pots. For the measurement of steam or condensing vapours, appropriate condensing devices should be provided at the tapping point. For large displacement instruments condensate pots should be fitted. For instruments with negligible displacement, such as differential pressure cells, filling tees of about 35 mm bore have adequate capacity. Examples of pipework arrangements are shown in figure 6.

NOTE. If the process temperature exceeds 400 °C, vaporizing vessels should be incorporated into the pipework arrangements.

4.2.2.2.8 Wet gas drains. Impulse lines for flow measurement of wet gases should incorporate drain vessels and valves and should slope to ensure drainage. Drain disposal lines, if required, should be of adequate size to avoid excess back pressure (see figure 7).

4.2.2.2.9 Vents and rodding points. Liquid flow measurement installations should be arranged to prevent gases or suspended material collecting in the impulse pipework. The exact configuration for any particular application will depend on the nature and concentration of the suspended material, the quantity of entrained gas present and the active volume of the measurement transducer. Where solid matter is suspended in the liquid, rodding facilities may be required to clear tapping points. Where the vented gases may be combustible or otherwise hazardous, the vent line should be led to the specified location or to an adjacent well ventilated point.

4.2.2.2.10 Seal pots and diaphragm seals. Where it is necessary to protect the differential pressure transducer from process conditions, it is essential that seal pots or remote diaphragm seals are fitted. Some examples of such conditions would be viscous or corrosive fluids and suspended solids or powders.

Arrangements for impulse pipework with seal pots are shown in figure 9.

Diaphragm seals are supplied connected to the differential pressure transducer by a fixed length of capillary tubing filled with a special oil, usually silicone based.

The transducer's calibration would have been selected for a given mounting position relative to connection points. If this is required to be modified, for instance due to site changes, the transducer will require change to the elevation or suppression of the range. The span of the instrument will not require to be changed.

If the capillary is found to be shorter than required, site modification is not possible and the transducer should be returned to the manufacturer for modification.

4.2.2.2.11 Pitot tube connections. Connections to a pitot tube installation usually include flexible connections to allow a traverse across the pipe to obtain an average velocity measurement. Such connections are shown in figures 10 and 11. Averaging and amplifying pitot tubes have several impact tubes and therefore do not require traversing facilities. In this case the flexible connections may be omitted unless otherwise specified in the original design drawing.

NOTE. Caution should be exercised if quick-release connections are used.

4.2.2.3 Installation

4.2.2.3.1 General. Many problems with flow measuring devices are caused by dirt and foreign matter left in the lines after installation. Consequently the proper sequence of cleaning and assembly should be followed to minimize difficulties.

4.2.2.3.2 Tapping connections. Where tapping connections are to be made into the pipe, the bosses should be fitted and drilled before the lines are cleaned. Bosses should be drilled after welding. Taps in flanges should be drilled and deburred as necessary.

4.2.2.3.3 Cleaning and purging. The pipework upstream of the flow measuring primary elements should be descaled and flushed with the primary devices omitted and spool pieces used where necessary for pipework continuity. Where descaling is not possible other approved cleaning techniques should be used to clear the line of dirt and foreign matter.

4.2.2.3.4 Mounting

4.2.2.3.4.1 General. Only when cleaning is complete should the flow measuring primary elements be installed.

In all cases the concentricity of the primary element with the pipe is important and where this is not ensured by the element construction, careful assembly is necessary to ensure concentricity.

It is important that the jointing materials used are of the specified type and thickness and do not project into the bore of the pipe.

4.2.2.3.4.2 Angle of mounting. Primary elements with integral tappings should be mounted in horizontal or sloping pipes so that the tappings are at the correct angle as shown in figure 4.

Orifice plates in horizontal or sloping pipes should be located so that the vent and drain holes, if provided, may be positioned as follows.

(a) *Gases and steam.* The drain hole should be at the bottom of the pipeline.

(b) *Liquids.* The vent hole should be at the top of the pipeline.

Care should be taken to ensure that vent and drain holes are not obscured by the jointing material or the flange.

4.2.2.3.5 Direction of flow. In all cases the direction of flow should be checked and the primary device installed accordingly, e.g. square edged orifices with the square edge facing upstream and arrow markings on the Venturis pointing downstream.

4.2.2.3.6 Pitot tube alignment. Pitot tubes should be correctly aligned with the pressure port axis within 5° of the pipe axis or in the case of large gas ducts within 5° of the specified direction.

4.2.3 Variable area flowmeters

4.2.3.1 Principle. The most common type of variable area flowmeter operates on the principle that a loose float within a vertical tapered tube will assume a position where the differential pressure across the float is equal to its mass and this position is a function of the upward flowrate. Variable area orifice flowmeters incorporate a profiled plug which is sprung against the force of flow through an orifice. The movement of the plug is a measure of flow and is sensed electronically or pneumatically.

In high flow applications float-type variable area flowmeters may be connected across a flow-sharing orifice plate or other differential pressure generator to form a bypass flowmeter. The primary element is calibrated so that the flow through the variable area meter is a known proportion of the total flow rate.

4.2.3.2 Installation arrangement

4.2.3.2.1 Pipework layout. Float-type variable area flowmeters should be mounted vertically. They are not sensitive to flow disturbances caused by upstream pipework layout and installations frequently include elbows adjacent to the meter.

Other types of variable area flowmeter are generally insensitive to flow disturbances resulting from pipework layout but may have special requirements for layout defined by the manufacturer.

4.2.3.2.2 Bypass piping. Variable area meters should be installed in a manner that permits easy meter and float removal for repair purposes and, where specified in the original design, should be provided with a line size block and a bypass gate valve. Drain valves should be provided at the meter inlet in such installations.

4.2.3.2.3 Strainers. Small variable area flowmeters should be protected by a strainer to prevent jamming by pipe scale or foreign matter.

4.2.3.2.4 Location. The meter should be located where it is accessible for observation and maintenance, and in an area free from vibration.

4.2.3.3 Installation

4.2.3.3.1 Cleaning and purging. As for other flowmeters the pipework should be purged and cleaned before the meter is installed. However, if this is not possible, it is essential that the meter be removed temporarily while the pipework is cleaned.

4.2.3.3.2 Mounting and alignment. Alignment and support of adjacent pipework is important in the installation of variable area flowmeters to avoid distortion or damage. It is essential to avoid stressing the meter during installation. Care should be taken to ensure that the meter is installed vertically and retained in this position under operating conditions.

4.2.4 Positive displacement flowmeters

4.2.4.1 Principle. Positive displacement flowmeters measure flow by isolating, counting and totalizing segments of fluid of known volume as they pass through the meter. Positive displacement flowmeters are used for gas and liquid measurement but certain types are unsuitable for measuring the flow of liquids laden with suspended particles.

4.2.4.2 Installation arrangement. Positive displacement flowmeters are not sensitive to pipework arrangement provided that throttling valves are not located immediately upstream of the meters. The pipework arrangement should not impose stresses on the flowmeter and larger meters should either stand on the floor or be provided with a support structure. Strainers and vapour eliminators should normally be incorporated in the upstream pipework to obtain maximum accuracy and reliability of the measurement.

4.2.4.3 Installation

4.2.4.3.1 Pre-installation inspection. When the meter is received on site it should be inspected. If the manufacturer's flange seal has been disturbed, care should be taken to ensure that the inlet and outlet ports are free from packing or foreign matter as such material entering the measuring chamber may cause serious damage. The process connections should then be completely sealed until the meter is required for installation in the line.

4.2.4.3.2 Cleaning and purging of pipework. Prior to installing the meter, strainers, filters or gas eliminators, the pipework should be thoroughly descaled and flushed, where necessary, with a suitable liquid.

4.2.4.3.3 Mounting and alignment. The strainers, filters, vapour eliminators, etc. should be installed in the pipe and the dimensions between the final meter connections should be carefully checked, allowing for joint rings where applicable. The flange seals should be removed and cleanliness of the ports checked. The meter should then be installed ensuring that the direction of flow is correct and that the dials of the local integrating mechanism, if fitted, are correctly located. Normally these dials are on the top of the meter.

4.2.5 Turbine flowmeters

4.2.5.1 Principle. A turbine flowmeter comprises a turbine rotor mounted on bearings along the axis of the pipe which is forced to rotate by the movement of the process fluid.

The rotation of the turbine rotor is indicated by a mechanical or an electronic output.

4.2.5.2 Installation arrangement

4.2.5.2.1 Pipework layout. The accuracy and repeatability of a turbine flowmeter is especially dependent upon upstream and downstream piping arrangements. In addition to sufficient upstream and downstream straight runs, a flow straightener is often required if the potential accuracy of a turbine meter is to be achieved.

4.2.5.2.2 Location. The turbine flowmeter should be installed in process pipework that is free of vibration.

Turbine flowmeters are generally installed in horizontal lines. Certain types may be mounted in vertical lines but special calibration would be required.

4.2.5.2.3 Strainers. Generally, all turbine flowmeter installations require strainers upstream to prevent foreign matter from damaging the device or blocking the flow passages.

4.2.5.2.4 Gas eliminators. For maximum accuracy and reliability of measurement of liquid flow, means should be provided for automatic removal of gas in the upstream pipework.

4.2.5.2.5 Operating pressure. Turbine flowmeters in liquid service should operate with sufficient pressure to prevent cavitation and avoid the resulting errors or damage.

4.2.5.2.6 Electrical connections. The low level signals generated by some transducers are prone to interference. Manufacturer's instructions for electrical installation should be followed.

4.2.5.3 Installation

4.2.5.3.1 Cleaning and purging. The flowmeter should be installed only after the process pipework has been cleaned and flushed. If strainers are used they should be cleaned after flushing and periodically during operation. Pressure testing should be carried out with the flowmeter installed.

4.2.5.3.2 Mounting and alignment. Prior to assembly a check should be made that the flowmeter is correctly calibrated for the mounting attitude.

The pipework should be carefully aligned before fitting the flowmeter. When a flanged flowmeter is installed the inside bore of any pipeline gasket should not project into the bore of the line. The flowmeter should be fitted with the direction of flow arrow on the casing pointing the correct way for the application.

4.2.5.3.3 Line filling. Flow should be introduced slowly to the flowmeter to prevent damage to the turbine blades by hydraulic impact or overspeed.

4.2.6 Vortex shedding flowmeters

4.2.6.1 Principle. Vortex shedding flowmeters measure the rate at which vortices are shed by a bluff body in the flow stream. The frequency of vortex shedding is proportional to flow velocity over a range of flow.

Signal output from the vortex sensor is converted by an integral or local signal conditioning unit to a pulse rate or current signal proportional to flow rate.

4.2.6.2 Installation arrangement

4.2.6.2.1 Pipework arrangement. Vortex flowmeters are sensitive to pipework arrangement particularly upstream and immediately downstream of the meter. The manufacturer's recommendations for the pipework arrangement should be followed, particularly as the requirement varies significantly with the type of vortex transducer and its application.

4.2.6.2.2 Location. Vortex flowmeters may be installed in vertical or horizontal pipe runs. The pipe needs to be adequately supported and should not be subject to vibration.

4.2.6.2.3 Electrical connections. The low level signals generated by some vortex shedding sensors are prone to interference. The manufacturer's recommendations for maximum cable length and type should be followed.

4.2.6.3 Installation

4.2.6.3.1 Cleaning and purging. The vortex flowmeter should be installed only after the process pipework has been cleaned and flushed. The pipework should be pressure tested after meter installation.

4.2.6.3.2 Mounting and alignment. When the flowmeter is installed, the inside bore of any gasket should not project into the bore of the line. It should be ensured that the flowmeter is mounted so that the direction of flow arrow on its casing points the correct way for the application.

4.2.7 Open channel flow measurement

4.2.7.1 Principle. Measurement of flow in open channels is similar to differential pressure flow measurement except that the head of fluid flowing over the crest of a weir or through a flume is related to the rate of flow.

Various designs of weir or flume are used, which fall into four general types:

- (a) thin-plate notch weirs;
- (b) broad-crested weirs;
- (c) Venturi and standing wave flumes;
- (d) compound weirs or flumes.

Each of these types may incorporate different geometries of the weir or flume section.

Often, open channel flow measurements are on large flows where the major parts of the works associated with the weir or flume are constructed in concrete as a civil engineering operation. For smaller flows prefabricated flumes or thin plate weirs are used and the erection of these should be supervised since accuracy of measurement is significantly affected by errors in installation. The location and installation of head measuring devices are particularly important.

4.2.7.2 Installation arrangement.

4.2.7.2.1 Location. All weirs and flumes require steady upstream flow conditions to give predictable performance. Where the approach channel is very much larger in section than the weir or flume its shape is generally not significant. In other situations the approach channel should have a smooth straight section of at least 10 times the maximum width of the weir or flume.

The slope of the approach channel should be sufficiently slight to avoid a standing wave developing in the approach channel. If this is not possible the detailed recommendations of BS 3680 should be followed.

Downstream conditions should be such that the tail water level does not build up to drown the weir or flume under operating conditions. To achieve this the downstream channel bottom should be no higher than that specified in BS 3680 for the weir or flume type employed. Where a weir or flume is designed to operate drowned, special conditions apply (see BS 3680).

4.2.7.2.2 Head measurement facilities. The head generated by a weir or flume may be measured by most of the methods described in 4.5. Most commonly, open channel water levels are measured by means of displacement devices in gauge wells or by differential pressure or ultrasonic level sensors.

Generally, only one measurement of head is required, but where weirs are designed to operate drowned, a second level measurement at the weir crest is used. In triangular profile weirs or flat-V weirs this second head measurement is located at the weir crest.

The head measurement location depends on the weir or flume type employed.

The head measurement locations for different types of weir or flume are given in the following Parts of BS 3680:

- (a) thin-plate notch weirs: BS 3680 : Part 4A;
- (b) triangular profile weirs: BS 3680 : Part 4B;

(c) rectangular, trapezoidal or U-throated flumes: BS 3680 : Part 4C;

(d) compound weirs: BS 3680 : Part 4D;

(e) rectangular-profile weirs: BS 3680 : Part 4E;

(f) round-nose horizontal crest weirs: BS 3680 : Part 4F;

(g) flat-V weirs: BS 3680 : Part 4G.

4.2.7.3 Installation

4.2.7.3.1 Pre-installation inspection. Prefabricated flumes and notch weir plates should be examined to ensure that the flume or notch is free from dents, burrs or other damage as these will affect accuracy.

4.2.7.3.2 Alignment. Prefabricated flumes and notch plates should be aligned carefully before they are fixed in the channel. The devices should be centrally located in the channel, level both across and along the channel. In all cases the manufacturer's instructions should be followed.

Where the weir or flume is not prefabricated the dimensions and geometry of the structure should be checked. For tolerances on dimensions to obtain a given accuracy see BS 3680. Where dimensional errors are excessive, remedial work should be carried out to obtain the desired accuracy.

4.2.7.3.3 Setting zero flow. The zero flow datum should be accurately set on site so that there is no systematic error in the measurement of head. The method of setting the zero level depends on the type of weir and the appropriate method described in BS 3680 : Part 4 should be followed.

4.2.7.3.4 Head sensing device. The head sensing device should be installed in accordance with the appropriate subclauses of 4.5.

Particular care should be taken to maintain proper clearances between displacer elements and the sides of the gauge well.

4.2.8 Electromagnetic flowmeters

4.2.8.1 Principle. Electromagnetic flowmeters function by measuring the voltage induced in a liquid flowing through a magnetic field. A flowmeter is installed in the process pipe and the signals generated are processed by an integral or remote transducer.

4.2.8.2 Installation arrangement

4.2.8.2.1 Location. The electromagnetic flowmeter averages the velocity profile across the pipe so that it is not particularly sensitive to upstream or downstream piping arrangements. However, for accuracy, the manufacturer's instructions should be followed.

The flowmeter unit may be installed in pipework in any position (vertical, horizontal or at any angle) but it should remain full of liquid at all times to ensure accurate measurement. When mounted horizontally the electrode axis should not be in a vertical plane. The electromagnetic flowmeter should normally be mounted where the instrument is not subjected to vibration nor exposed to ambient conditions outside its specified limits.

4.2.8.2.2 Pipework support. Normally, magnetic flowmeters up to 300 mm bore require no extra support than that provided for a similar length of pipe. For larger sizes the manufacturer's recommendation for support structures should be followed.

4.2.8.2.3 Bypass piping. Where flow interruption for maintenance or for zero checking is not acceptable, bypass pipework may be incorporated. Examples of arrangements are shown in figure 12. If a cleanout tee is required, the recommended arrangement is shown in figure 12(b).

4.2.8.2.4 Electrical requirements. For predictable measurement it is essential that the process liquid be at earth potential. This may be achieved by earthing metallic pipework, or by the use of metallic earthing rings, probes or gaskets where the process pipework or its lining is non-conductive. Earthing arrangements should follow site practice as far as possible. Nevertheless, it is essential that the manufacturer's instructions for earthing are followed.

Electrical connections between the flowmeter and the transducer should not exceed the maximum distance permitted by the manufacturer.

4.2.8.2.5 Cathodic protection. If the detector head is installed in a system that is cathodically protected or where electrolysis is used in the process, special precautions should be taken to ensure that:

(a) current at supply frequency does not flow through the liquid in the detector head;

(b) any current, at supply frequency, flowing through the body of the detector head does not exceed 10 A r.m.s.

These precautions will limit the magnitude of any spurious magnetic fields.

In systems where a metal pipeline without an insulating liner is used, the liquid in the system can be placed at earth potential by bonding the detector head to the adjacent pipeline as shown in figure 13(a). This arrangement should only be used for systems where it is known that any current flowing through the body of the detector head does not exceed 10 A r.m.s. If the current flowing through the body of the detector head exceeds 10 A r.m.s., the detector head should be bonded to the adjacent pipeline as shown in figure 13(b). When bonding the detector head flanges, flange bolts should not be relied upon as electrical connectors. Troublesome potential differences may occur in systems where, for example, a cathodically protected pipeline joins a grid system, not quite at earth potential, or joins an earthed pumping station. In these cases it may be necessary to insert short lengths of unlined pipework bonded to the detector head as shown in figure 13(c). The length of these sections will depend upon the magnitude and ripple content of the cathodic voltage and upon the nominal bore of the pipeline.

4.2.8.3 Installation

4.2.8.3.1 Storage. The flowmeter and transducer should be stored in a clean dry area until required for installation, and protective covers should not be removed until necessary to permit erection of the equipment. The flowmeter should be stored in its packing or in a cradle; it should never be stood on its end flanges. The flowmeter, which may appear to be a conventional piece of flanged pipe, is a precision-built instrument and should be treated as such.

4.2.8.3.2 Handling. Although the flowmeter appears to be a robust pipe spool, care should be taken in handling it to

avoid damage, particularly to the liner. Lifting should always be accomplished with slings as shown in figure 14. A bar threaded through the flowmeter should never be used for lifting. If the liner is damaged during handling it should be repaired or replaced using an approved procedure before the flowmeter is installed.

4.2.8.3.3 Cleaning and purging. The flowmeter should be installed only after the process pipework has been cleaned and flushed. The pipework should be pressure tested after the flowmeter has been installed.

4.2.8.3.4 Mounting. Care should be exercised during installation to avoid damage to the flowmeter and its lining. Where the liner is brought out over the flange face, the liner should not be forced between flange faces but a suitable gasket should be installed between the pipe and the flowmeter flanges. Such a gasket should not protrude into the bore of the pipe.

During installation it is essential to avoid undue stress on the flowmeter. It is desirable to bolt the flowmeter to its upstream and downstream pipework before completing pipework assembly at a flange remote from the flowmeter. Care should be taken to align the flowmeter with its adjacent flanges and the fixing bolts should be tightened evenly.

4.2.8.3.5 Electrical connections. Special low capacitance cable, in accordance with manufacturer's instructions, should be used when the flowmeter does not incorporate an integral transducer. Such connecting cable should not be installed close to power cables nor share a common conduit with power supply wiring.

4.2.8.3.6 Earthing. The instrument manufacturer's recommendations for earthing should be followed during installation.

4.2.9 Ultrasonic flowmeters

4.2.9.1 Principle. There are two main types of ultrasonic flowmeter employing different principles to measure flow, e.g. doppler and transit time.

For each of these methods of measurement there are variations for different applications. These include the use of different paths and layouts, e.g. direct or zigzag across the pipe and more sophisticated measurement techniques to give better accuracy.

Examples of arrangements for both types of ultrasonic flowmeter are shown in figures 15 and 16.

4.2.9.2 Installation arrangement

4.2.9.2.1 Location. Ultrasonic flowmeters are calibrated for a fully developed flow profile and errors will occur when the flow profile at the point of measurement is disturbed. The manufacturer's recommendations should be followed but for most types of ultrasonic flowmeters an upstream straight length of at least 10 pipe diameters should be allowed after bends or tees and 20 diameters after throttling valves or an increase in pipe diameter. Installations using multi-path transit time methods require much shorter upstream straight lengths. Minimum lengths should be indicated at the design stage.

Ultrasonic flowmeters sense vibration or noise generated in cavitating valves and they should be located on a vibration free section of piping as remote as possible from any upstream or downstream valve where cavitation noise may be generated.

4.2.9.2.2 Pipework. Ultrasonic flowmeters may be pre-assembled on a short length of pipe or the flowmeters may be fixed to a suitable section of pipework by clamps, adhesives or as inserts in pockets. For some applications and types of flowmeter the sensor is mounted on a block or bar fixed to the pipe (see figure 17).

Ultrasonic sensors may be mounted on the outside of suitable rigid unlined metal or plastics pipe. For these applications it is essential that the bore of the pipe is accurately known and that it is reasonably smooth and free from deposits. In all cases the manufacturer's instructions should be followed.

To minimize errors from entrained gases or from solid deposits the ultrasonic sensors should generally be arranged in a horizontal plane across the pipe.

4.2.9.2.3 Electrical connections. The connecting cable between the ultrasonic sensors and electronic units is usually prefabricated as part of the sensor and is often of special construction. The length of cable permitted between sensor and electronic unit is generally limited and the manufacturer's instructions should be followed.

The electrical signals employed are at a low level and may be prone to interference. Consequently, connections should be kept short and should be routed away from other cables which may be sources of interference.

The electronic unit should be mounted in an accessible location suitable for the temperature rating of the equipment.

4.2.9.3 Installation

4.2.9.3.1 Pipework preparation. Good coupling of ultrasonic waves between the sensor and the fluid being metered is necessary to ensure reliable measurement. Externally mounted sensors should be fixed to a carefully prepared area on the outside of the pipe. Instructions should be followed for the use of adhesives or coupling jelly to obtain good performance. Where the sensor is mounted on a rod or block the fixing of both the block to the pipe and the sensor to the block should be in accordance with the manufacturer's instructions.

4.2.9.3.2 Mounting and alignment. Where two separate sensors are employed, the relative positions of the two devices on the pipework should be carefully checked before permanently fixing in accordance with the manufacturer's instructions.

4.2.9.3.3 Prefabricated flowmeters. Where ultrasonic sensors are mounted on a prefabricated section of pipe, this section should be assembled with the pipework. Suitable jointing materials should be used and care should be taken to avoid jointing material projecting into the bore of the pipe.

4.2.9.3.4 Cleaning and purging. Externally mounted ultrasonic sensors are not affected by cleaning or purging processes provided that fluid temperatures do not exceed the rating of the sensors.

Means should be provided for the removal of sensor elements in contact with the process fluid when these are likely to be damaged by cleaning operations. The manufacturer's instructions should be followed.

4.2.9.3.5 Electrical connections. Electrical connections should be made in accordance with the manufacturer's instructions.

4.2.10 Coriolis mass flowmeters

4.2.10.1 Principle. The meter operates by diverting the fluid through two parallel flow tubes which are vibrated at their natural frequency. The forces induced by the fluid on the sensor tubes cause them to twist. This twist is directly proportional to mass flow and is sensed by magnet position detectors which feed the lag and lead data to electronics for processing into suitable output signals. An example of an arrangement is shown in figure 18.

4.2.10.2 Installation arrangement

4.2.10.2.1 Location. It is essential that the sensor is at least 0.6 m from any large transformer, motor or other large interfering electromagnetic field.

Although normal vibrations are not a problem, areas susceptible to high vibration, e.g. motors or pumps, should be avoided.

When measuring gas flow the equipment should be installed as shown in figure 18 to prevent accumulation of condensate within the flow tubes.

When measuring liquid flow the equipment should be installed inverted so that the case is below the pipeline, thereby avoiding the trapping of air in the tubes.

When measuring liquid slurries the sensor should be installed in a vertical line to avoid particle accumulation in the flow tubes. This facilitates cleaning if process lines are purged with gas or steam.

It is important to ensure that vapour/air cannot collect in the meter (for liquid applications) during zero flow, nor be present in large quantities during normal operation.

4.2.10.2.2 Pipework. Good piping practices should be observed during meter installation. For best results, pipe supports should be provided near the flange connections. The fluid fittings should not be used as pipe supports. Inlet and outlet piping should be installed using appropriate anchors, guides, expansion joints, hangers or other mechanical support systems. For smaller units, the process piping should be secured to the same mounting surface as the sensor units. On larger meters, which are installed directly in-line, additional pipe supports should be placed near the first elbow in the process line or 10 to 20 pipe diameters from the fluid fittings.

A downstream shut off valve is recommended to ensure actual flow when setting the primary zero adjustment.

In batching operations the flowmeter and shut-off valve should be located as close as possible to the receiving tank to minimize errors.

No special pipe configurations (straight pipe, elbow, etc.) are required.

4.2.10.2.3 Electrical connections. The manufacturer's instructions should be consulted to determine the maximum distance permitted between sensor and flow tube assembly.

The electronic unit should be mounted in an accessible location suitable for the temperature rating of the equipment.

Electrical connections should be made in accordance with the manufacturer's instructions.

4.2.11 Flow switches

Most of the types of flowmeter described above may be used as a flow switch, e.g. a differential pressure switch may be connected across an orifice or a variable area meter may incorporate limit switches to operate at a certain flow. For these types of device the appropriate section concerning installation should be followed. Other types of flow switches include those which operate on the principles of heat loss to a flowing fluid or changes in temperature gradient induced by a heater placed in the fluid.

There are some devices used as flow switches that are not normally used as flowmeters. These are often variable area devices providing both a visual indication and a switch output, e.g. the flap flow switch (see figure 19).

Other devices use an orifice or nozzle to generate head to operate an integral differential pressure switch; flow switches of this type are installed in the same way as primary elements for differential pressure flowmeters. The manufacturer's instructions should be followed to ensure that the flow switch is mounted in the correct attitude for operation.

4.3 Pressure

4.3.1 General

The requirements for the installation are largely independent of the type of pressure measuring device employed.

Materials of sensing elements are selected to resist corrosion by the process fluid and the mounting environment and may typically be stainless steel, bronze or monel. Sensing elements should not be exchanged, even if they have the same range, without ensuring that the element material is as specified for the application.

4.3.2 Pressure connections

4.3.2.1 Tapping points

4.3.2.1.1 Independence. In general, a separate process connection should be provided for each instrument, especially where a pressure instrument performs a critical duty, such as forming part of an emergency trip system.

4.3.2.1.2 Radial location on horizontal or sloping pipes.

The radial location of tapping points on horizontal or sloping pipe sections should take into account the nature of the process fluid as shown in figures 20 and 21. Other

arrangements may be adopted but these may require additional facilities for draining or venting the impulse lines. Where solid matter is suspended in the fluid, rodding facilities may be required to clear tapping points.

4.3.2.1.3 Installation. Tapping bosses should be fitted and drilled before the lines are cleaned. Bosses should be drilled after welding.

4.3.2.2 Impulse pipework

4.3.2.2.1 Arrangement. Examples of piping arrangements are shown in figures 20 to 23. The impulse pipework should allow for any relative movement between tapping point and instrument due to expansion.

4.3.2.2.2 Protective seals. Condensate seals should be provided in piping to devices connected to steam or hot condensable vapour service (see figure 21). Where the process fluid is particularly corrosive or has a high solids content, the instrument may be protected by seal chambers or diaphragm seals (see figure 22). Where the process fluid may congeal or become highly viscous at ambient temperatures, the impulse line may be heat traced and seal pots may be fitted to the instrument (see figure 23). Where seals are used the instrument should be calibrated taking into account the standing head or density of the seal fluid.

4.3.2.2.3 Pulsation dampeners. Pressure measuring instruments subject to pulsation, e.g. from reciprocating compressors, should be liquid filled or fitted with pulsation dampeners. Snubbers, porous metal discs or needle valves may be used for this purpose.

4.3.2.3 Isolating valves. Pressure measuring instruments should be provided with a process isolating valve and, unless otherwise specified in the original design, a vent valve should be provided between the isolating valve and the pressure instrument to facilitate zero checking and depressurization prior to instrument removal. For some applications, combined isolating and vent manifolds may be considered suitable.

4.3.3 Differential pressure measurement

4.3.3.1 Tapping points. The tapping points should be made in accordance with 4.3.2.1.

4.3.3.2 Impulse pipework. The impulse pipework arrangement for differential pressure measurement should be the same as for two separate pressure measurements. On no account should a differential pressure gauge be supported by its impulse pipework. It is important that seal chambers, diaphragm seals, condensate pots or filling tees should be at the same level and the impulse pipework should be run together to avoid static pressure errors.

4.3.3.3 Isolating valves. Differential pressure instruments should be provided with a process isolating valve for each connection. Unless otherwise specified in the original design, an equalizing valve should be provided, downstream of the isolating valves, between the two instrument ports to permit zero checking. Vent valves, unless otherwise specified in the original design, for each connection between instrument port and isolating valve should also be provided for depressurization for maintenance. The isolating, equalizing and vent valves may be incorporated in a single manifold where this complies with the relevant specification.

4.3.4 Direct reading instruments

4.3.4.1 Principle. Pressure gauges use the deflection of a bourdon tube, diaphragm, capsule or bellows under pressure to drive a mechanism linked to an indicating pointer on a scale. Low pressure gauges employ U-tube manometers, inclined tube manometers or barometer devices to indicate small gauge pressures or vacuums.

4.3.4.2 Installation

4.3.4.2.1 Location. Indicators should be mounted in a position conveniently accessible and safe for reading. The gauge may be supported by its piping if it is close coupled to the process connection. Where vibration is expected or where the connection is long, the gauge should be supported independently (see figure 24).

Pressure gauges often incorporate safety blowout devices to relieve excess case pressure in the event of element failure. The blowout back or disc insert should not be obstructed by the gauge support or other structure. The minimum clearance between a blowout disc and a nearby obstruction should be 25 mm.

Some applications require additional protection, such as the use of plastics or safety glass windows and a safety baffle plate between the bourdon tube and the dial (see BS 1780).

4.3.4.2.2 Cleaning and pressure testing. During cleaning and hydraulic pressure testing of the process pipe the gauges should be isolated and protected from damage by over pressurization.

4.3.4.2.3 Static head compensation. Gauges on low pressure liquid or condensing vapour service should be compensated for static head by resetting the pointer of the gauge. The value of the compensation applied should be marked on the gauge dial.

4.3.5 Pressure transmitters and switches

4.3.5.1 Principle. The deflection of bourdon tubes or diaphragms under pressure may be used to operate electronic or pneumatic sensing devices and switches.

Transmitters generally incorporate in the same housing the necessary components to convert the sensor signals to a standardized signal output.

4.3.5.2 Installation

4.3.5.2.1 Location. Pressure transmitters and switches should be located as close as possible to the process connection consistent with accessibility for adjustment and servicing. The devices should be mounted in a vibration-free position and should generally be supported independently of the process pipework.

4.3.5.2.2 Electrical connections. Electrical connections to the devices should be in accordance with manufacturer's instructions. Particular care is required where strain gauge transducers are employed without integral signal conversion. In this case multicore cable is required to the remote power supply and gauge amplifier and this should not exceed the length recommended by the manufacturer. This connecting cable may be required to be routed away from electrical power cabling.

NOTE. For installations in hazardous areas see Section 4.4.

4.3.5.2.3 Cleaning and pressure testing. During cleaning of the process pipework and any subsequent hydraulic test the pressure transmitters and switches should be isolated from the process line and protected from damage by over-pressurization.

4.3.5.2.4 Static head transmission. Transmitters or switches on low pressure liquid or condensing vapour service should be compensated for static head when setting up. The value of the compensation should be marked on the equipment.

4.4 Temperature

4.4.1 General

The majority of temperature measuring instruments depend for their correct operation on the positioning and location of the temperature sensitive portion of the device where the temperature is to be measured. Because of the mechanical difficulties that this requirement can present, a compromise is often necessary in the location of the sensing element.

If head mounted transmitters for the thermocouple or resistance elements are used, care should be taken to ensure that the device is suitable for the ambient temperature at the point of measurement.

In all cases, the instructions in the manufacturer's literature should be made available to the installation personnel, and any specific warnings noted.

4.4.2 Thermometer sheaths or pockets

Generally, where the temperature measurement of high pressure and/or corrosive fluids is undertaken, the sensing element is protected by a mechanical sheath or pocket that is inserted into the fluid at the point at which the measurement is required. This pocket allows the removal of the sensing device without draining or relieving the pressure of the process fluid, or any other disturbance to the process. The pocket can be constructed in a special material compatible with the process fluid, thus avoiding the need for the temperature sensitive portion of the measuring device to be constructed of non-standard materials.

The thermometer pocket is often installed by the mechanical contractor as part of the pipework or vessel system being constructed. It is essential that a careful check be carried out to ensure that the dimensions of the pocket are correct for the temperature-sensitive device to be installed.

Factors governing selection will include the following:

- (a) heat exchange area in relation to mass;
- (b) material of construction with special emphasis placed on thermal conductivity and corrosion resistance.

The introduction of a pocket adds to the time lag in the response of the instrument to changes in temperature. Where temperature changes are very slow, this may not be of importance, but where response changes are important, it may be desirable to increase the heat exchange area. This may add to the cost of manufacture, weaken the pocket or make it more susceptible to turbulent fluids.

Where it is considered essential to have a long and comparatively small diameter pocket, its resistance to fracture through turbulence vortex shedding and/or vibration should be carefully considered.

The air space between the thermometer element and its pocket should be kept to a minimum or filled with a heat conducting material. The wall thickness of the pocket should be kept to a minimum compatible with the pressure rating of the system.

NOTE. For recommended dimensions of temperature detectors and corresponding pockets see BS 2765.

If for any reason a device is installed without a pocket, a label should be attached warning of any danger resulting from removal of the instrument.

4.4.3 Expansion thermometers

Expansion thermometers utilize the thermal expansion of a metal, liquid or gas to produce a movement, proportional to temperature change, which can be measured.

NOTE. Fluid-filled devices are not fail-safe when used for high temperature protection.

Local dial thermometers usually have a bi-metallic or mercury-in-steel sensing element in a stem rigidly attached to the indicating dial.

Other instruments, including indicators, controllers and transmitters, employ gas expansion, vapour pressure and mercury-in-steel systems in which the temperature sensing bulb is connected to the measuring element by a length of capillary tubing. Such systems are factory sealed and capillaries should not be cut. Temperature sensors are often delicate devices containing liquids, gases or vapours under pressure. Sensors and any attached capillary tubing should be handled with the utmost care, as often irreparable damage may be inadvertently caused. Where capillary systems are used, they should continuously be supported and protected, and any excess length coiled on a former. Capillaries generally should not be bent to a radius less than 75 mm. Slack should be allowed in the capillary at the insertion point to allow removal of the sensor from the pocket.

In the case of vapour pressure devices, if the bulb is situated at a different level from the bourdon tube, the reading of the thermometer should be suitably compensated for head errors.

4.4.4 Thermocouples

4.4.4.1 General. If a closed circuit is formed from two metals, and the two junctions of the metals are at different temperatures, an electric current will flow round the circuit. The electromotive force (e.m.f.) generated will depend on the materials chosen for the thermocouple and the temperature difference between the two junctions. When the temperature of one junction (reference or cold) is fixed or known, a millivoltmeter connected to the thermocouple can be calibrated to indicate the temperature attained by the measuring junction.

NOTE. See BS 4937 for details of the relationship between temperature and e.m.f.

The temperature measured will be the result of the net heat supplied to the hot junction by the conventional modes of heat transfer. Factors affecting the measuring junction temperature for a particular installation are as follows.

- (a) The mass of the thermocouple, together with any insulation material or protective pockets.
- (b) The thermal conductivity of the materials chosen for the thermocouple and any protection pockets.
- (c) Ratio of heat transfer areas of the thermocouple and the body of which the temperature is to be measured.
- (d) Temperatures of the immediate surrounding areas.
- (e) Emissivity of the exposed surfaces.
- (f) Velocity, and properties of the medium whose temperature is to be measured.

4.4.4.2 Extension wire/compensating cable. In order to compensate the instrument reading for cold junction temperature changes, the cold junction is often extended to the instrument. For base metal thermocouples, extension wires generally use the same materials as the thermocouple. For high temperature applications, materials used for the manufacture of the thermocouples may be chosen from the precious (noble) metals. However, the cost of using these materials as extension leads would normally be prohibitive. The problem can be overcome by using compensating leads which, although their conductors are of different materials, have similar thermoelectric characteristics to that of the thermocouple. This can also apply when materials other than noble metals are used.

When compensating leads are used care should be taken to ensure that the temperature at the head of the thermocouple does not become too high. Compensating leads have similar characteristics to thermocouple wires for the limited range of ambient temperature specified by the manufacturer, usually between 0°C and 100 °C. The compensation will not be accurate if the actual temperature of the leads exceeds the figures specified by the manufacturer.

4.4.4.3 Installation

4.4.4.3.1 General. Wherever possible, the use of connecting heads is recommended to ensure a positive connection between the thermometer element and connecting wires. It should be ensured that:

- (a) all connections are tight;
- (b) covers are securely fixed;
- (c) all gaskets are correctly located and in good condition.

The materials and construction of the connecting heads should be chosen with regard to the environmental conditions that apply. Particular care should be taken to ensure that any weatherproofing gaskets are correctly located.

The installation should be carried out such that the thermocouple can be easily removed for renewal and its method of securing should be such that, when removing it, the possibility of securing devices, which contribute to the plant integrity, being loosened inadvertently is minimized.

Mineral insulated thermocouples should be checked to ensure that they are of the specified type and length for the application. Any spare length should be coiled and supported near to the termination. They should not be cut to length, unless specific instructions are given. Sealing ends should be handled in accordance with the manufacturer's instructions.

It is essential that compensation cables are correctly installed with regards to their polarity. Colour coded insulation is often employed and the cable manufacturer's literature should be consulted. When this is not possible, the following information can be used to determine polarity in the field.

- (1) Cables manufactured to BS 1843 have the negative conductor insulation coloured blue.

Cables manufactured to ANSI/MC 96.1 have the negative conductor insulation coloured red.

- (2) For nickel chromium (chromel)/copper nickel (constantan) thermocouples (type E), the negative conductor is silver in appearance. It has a lower resistance in Ω/km than the positive conductor of the same wire size.

- (3) For iron/copper nickel (constantan) thermocouples (type J), the positive conductor is often rusty in appearance and is magnetic. It has a lower resistance in Ω/km than the negative conductor of the same wire size.

- (4) For nickel chromium/nickel aluminium thermocouples (type K), the negative conductor is slightly magnetic. It has a lower resistance in Ω/km than the positive conductor for the same wire size.

- (5) For platinum-rhodium/platinum thermocouples (type R or S), the negative conductor is softer than the positive conductor. It has a lower resistance in Ω/km than the positive conductor for the same wire size.

- (6) For copper/copper nickel (constantan) thermocouples (type T), the positive conductor insulation is red in appearance. The negative conductor has a lower resistance in Ω/km than the positive conductor for the same wire size.

Bottoming of the thermocouple in a thermowell or pocket is often practised to improve the response to temperature change. Bottoming consists in having the thermocouple junction pressed tightly against the end or bottom of the thermopocket. In the case of sheathed thermocouples the bottoming is achieved by spring loading.

Care should be taken in the case of intrinsically safe installations to ensure that earthing requirements of the thermocouple are not invalidated.

Thermocouple extension wires and compensating cables should always be installed in a satisfactory manner to protect them from excessive heat, moisture and mechanical damage. Compensation cables, other than armoured multicores, should be protected by conduit or trunking, so that they are not subjected to excessive flexing or bending which might change the thermoelectric characteristics.

Non-integral cold junction devices should be mounted in accordance with the manufacturer's recommendations and with due regard to ambient conditions. The location of the

cold junction device should be agreed with the responsible engineer. Subject to the approval of the responsible engineer, cabling from the cold junction device to the temperature indicator or recorder should be run in twisted pair, screened copper conductors.

Where possible, the layout and arrangement of conduits or trunking system for a thermocouple system should include long radius bends instead of elbows, since cold working of extension wire materials can introduce inhomogeneity and pulling the extension wire through a number of elbows could work the wires unnecessarily.

It is generally desirable to keep the length of extension wire as short as possible, and to run the wire from the thermocouple connection head to the instrument terminal or reference junction in one continuous length. Where splices are unavoidable, they should be made by compressing the two wires to be joined to obtain intimate wire-to-wire metallic contact with a compression device, preferably of the same or compatible material. When any connections are made, polarity has to be strictly observed.

NOTE. For further information on cable installation, jointing and segregation, see section ten.

4.4.4.3.2 Installation in hazardous environments. When thermocouples are installed in hazardous areas, care should be taken to ensure that the system certification requirements of apparatus connected to the thermocouples are fully complied with. The certificate should be inspected by the installing engineer to ensure compliance with any specific installation requirements (see section three).

4.4.4.3.3 Thermocouple indication. Instruments connected to thermocouples should be housed in suitable environments, depending on their type.

When the instrument incorporates automatic cold junction temperature compensation, care should be taken to ensure that the ambient temperatures encountered are within the range of compensation specified by the manufacturer.

4.4.5 Resistance thermometers

4.4.5.1 General. Pure metallic conductors increase their electrical resistance with increase in temperature, and this property is used as a basis for the measurement of temperature over a wide range. In practical thermometry, the metals used for the construction of resistance elements are platinum, nickel and copper because they can be manufactured to a high degree of purity, and have a high degree of reproducibility of temperature/resistance characteristics.

As with other thermometers, the temperature measured will be the result of the net heat supplied to the element. The factors that are applicable are the same as those outlined in 4.4.4.1 for thermocouples.

4.4.5.2 Connecting cabling/wiring. Connecting cables between resistance elements and read out instruments employ standard copper conductors. The device that is to be connected to the resistance element dictates the method (if any) to be used to compensate for the resistance of the connecting cables between the thermometer element and the remote instrument.

In the simplest of installations, a ballast resistor should be adjusted in the circuit to bring the total resistance of the element, leads and make up resistance to some standard value.

In other systems, additional conductors are run between the thermometer head and the remote instrument to compensate for the lead resistances, and any changes within them that take place due to temperature changes along the transmission route. For the method of connection and identification leads see BS 1904. In all cases, the instrument manufacturer's instructions should be followed.

4.4.5.3 Installation

4.4.5.3.1 Resistance element. The location and use of pockets for resistance elements are similar to those outlined for thermocouples.

However, the construction of the resistance thermometer element makes it more susceptible to damage from vibration than the thermocouple, and care should be taken to ensure the element is not subjected to vibration outside the manufacturer's specification.

On thermometers incorporating rigid sheaths, particular care should be taken to ensure that these are not bent, as irreparable damage can be caused to the internal element conductors.

4.4.5.3.2 Interconnecting cables. All cores connected to a resistance thermometer have to be of the same material and size. It is recommended that they are part of a single multicore cable.

NOTE. For further information see section ten.

4.4.5.3.3 Installation in hazardous environments. As with thermocouple installations, the cabling should conform to any certification requirements for use in hazardous areas. The certificate should be inspected by the installing engineer to ensure compliance with any specific installation requirements (see section three).

4.4.6 Total radiation pyrometers

4.4.6.1 General. Temperature measurements utilizing infra-red radiation techniques are particularly useful in applications above 1400 °C. They are also useful for measuring lower temperatures of objects that are inaccessible to other forms of thermometer, as they do not require to be in contact with the object of which the temperature is to be measured.

In the total radiation pyrometer, the radiation emitted by the body whose temperature is required is focused on a suitable type of thermal element, the output of which is proportional to the temperature.

4.4.6.2 Installation. It is essential that the installation requirements of the manufacturer are fully understood by the installing engineer, as the success of the measurement will depend on their correct application. The following points in particular need to be checked.

The indication of the pyrometer should be independent over a considerable range of the distance of the source; however, the distance between source and sensor should be checked to ensure that it complies with the manufacturer's specification.

Where a refractory tube is inserted through a furnace wall, it should protrude into the furnace a distance between two and five tube diameters depending on the tube material.

4.4.6.3 Filters. Particular types of flame, or the presence of particular flue gases, may require the use of special lenses or filters. In difficult applications, the use of a sighting tube purged by dry air or nitrogen may be considered.

4.4.7 Optical pyrometers

4.4.7.1 General. Optical pyrometers are not suitable for recording or controlling temperatures, but they provide an accurate method of measuring temperatures up to 3000 °C and are particularly useful for checking and calibrating total radiation thermometers.

4.4.7.2 Installation. The majority of optical systems are portable and as such do not require any installation. However, their use may involve the selection of particular filters, and the careful setting of adjustments. It is essential that the manufacturer's instructions are followed.

4.4.8 Photoelectric pyrometers

To overcome the necessity for the use of a skilled operator with the optical pyrometer, measurements of radiation at shorter wavelengths can be achieved by the use of photoelectric cells. These devices are often used for the measurement of small objects at high temperatures, e.g. the temperature of an object 25 mm in diameter, at 2000 °C, can be accurately measured with a detector 3 m from the source.

4.4.9 Ratio pyrometers

4.4.9.1 General. This type of device has been developed principally to reduce the emissivity error in surface temperature measurement, by measuring the ratio of radiation intensities at two wavelengths.

4.4.9.2 Installation. The installation of photoelectric and ratio pyrometers is similar to that for total radiation pyrometers.

4.5 Level

4.5.1 General

There are many types of level measuring devices and these can be generally classed in three groups.

In the first group, level is measured directly by such means as dip-sticks, sight glasses or float actuated mechanisms.

The second group operates on the general principle that the pressure exerted at the bottom of the tank or vessel depends only on the depth and density of the liquid. (In the case of a closed tank or vessel account should be taken of the air or vapour pressure acting upon the liquid.) If, therefore, the density remains constant, the depth (or level) is directly related to the pressure. This would include devices such as dip tube and differential pressure instruments.

The third group covers electrical/electronic methods (such as capacitance probes), ultrasonic, nucleonic, load cell, electrical conductivity and optical methods, etc.

4.5.2 Gauge glasses

Gauge glasses are normally fitted directly to screwed bosses or flanged nozzles on the vessel but may occasionally be connected by pipes where other equipment may obscure observation and prevent access if the gauge is directly fitted. In all cases the branch connections should be finalized at the design stage but care should be taken during installation to ensure there is good visibility and also that the gauge glass is mounted vertically and is not subject to any strain.

When gauge glasses are used in conjunction with a level measuring device both may be mounted on a standpipe, thus reducing the number of connections required on the vessel (see figure 25).

NOTE. Requirements for boiler applications are given in BS 759 : Part 1.

When gauge glasses are used they should be protected against mechanical damage.

4.5.3 Float switches

Float switches operate by the physical movement of a float being transmitted directly via a gland or indirectly via a magnetic coupling to an electrical or pneumatic switch. These are usually mounted in an external float chamber but the float may be directly mounted through the vessel wall where choking of extended connections is liable to occur.

The branch or pad on to which the switch is fitted should be specified at the original design stage but the position should be checked to ensure that there is adequate clearance for fitting, that it is possible to remove it for maintenance purposes, and that there is freedom of movement to allow proper operation.

NOTE. Requirements for boiler applications are given in BS 759 : Part 1.

4.5.4 Buoyancy devices

Buoyancy devices operate by transmitting the change in buoyancy of a float as its immersion varies. In general the recommendations given in 4.5.3 apply. The buoyancy change is indicated as level directly or transmitted electronically or pneumatically; in any event the manufacturer's instructions should be followed (see figure 25).

4.5.5 Dip tubes

Dip tubes operate by passing a constant flow of air or other suitable gas through a dip tube in the vessel.

The pressure (or differential pressure in the case of sealed vessels) required to maintain the constant flow can be directly related to the level and indicated directly on a manometer or differential pressure gauge or transmitted via a differential pressure cell. Adequate clearance for fitting and removing the dip pipe is essential.

In applications where sedimentation is likely to occur in the bottom of the vessel the dip tube should be positioned such that sediment does not obstruct air flow (see figure 26).

4.5.6 Differential pressure devices

Differential pressure devices operate by measuring the hydrostatic head at a branch situated near the bottom of

the vessel and transmitting the signal either electronically or pneumatically by a differential pressure cell (see figure 27).

Where the vessel is pressurized, a more complicated system of connections to the differential pressure cell is necessary, depending upon the physical properties of the liquid. If the liquid is not volatile under any operating or ambient condition, the basic arrangement shown in figure 28 may be employed. If it is volatile at ambient temperatures, precautions should be taken to prevent condensation of the liquid in the balance line, resulting in serious errors in measurement. The balance line may be heat traced or a catch pot may be added to the arrangement shown in figure 28. For liquids close to saturation conditions, or in any other situation if specified in the original design drawing, a 'wet lag' may be used to ensure that the balance retains a constant head of fluid; however, the zero of the instrument should be suitably suppressed (see figure 29).

4.5.7 Capacitive measuring method

4.5.7.1 Principle. This method depends for its operation on the variation in capacitance between two electrodes which occur when the dielectric between the electrodes varies due to level changes.

Process media to be monitored in this way can be classified as either insulating materials or electrolytes (as in the case of water). The relative dielectric constant is the factor by which the electrical field strength in the appropriate medium is greater than the field strength in a vacuum.

There is a wide range of probe types available and care should be taken in matching the probe to the process medium involved and physical application (see figure 30 for a typical installation arrangement).

4.5.7.2 Installation arrangement. Generally, the self-contained nature of the probe makes it especially suitable for simple and practical installation, the power supply and output signal being the only connections necessary.

Care should be taken in positioning probes to ensure that they do not foul the path of incoming or outgoing process media. Output signal cables should be segregated from any power cables so that they are not subjected to induced electrical interference from the power supply cables.

4.5.8 Ultrasonic method

4.5.8.1 Principle. An ultrasonic pulse is transmitted by a transducer and this is reflected from the surface of the material in the container back to the transducer which converts the ultrasonic energy in the pulse to an electrical signal. The transducer therefore acts first as a transmitter and then as a receiver.

The applications that generally favour the ultrasonic method are those where contact with the process medium would be undesirable. If foam is present on the surface of the liquid to be measured, then better results can often be obtained at longer wavelengths, i.e. below 25 kHz. Where fluctuations in temperature occur, it may be necessary to fit a temperature compensation probe (see figure 31).

Ultrasonic devices are also available operating in the 'bottom up mode', i.e. with the transducer mounted at the bottom of the vessel. An echo from the liquid surface is received and the time of flight measured. This application is ideally suited to clear liquids.

4.5.8.2 Installation arrangement. Installation of these devices is relatively simple with the fixing generally being of the flange type, but care should be taken to ensure the face of the sensor is completely clear.

4.5.9 Nucleonic level measurement

4.5.9.1 Principle. Nucleonic level measurement systems are based on the absorption of gamma rays. The amount of absorption for a given material is a function of the density and path lengths through the material. In this method a radioactive source is positioned to direct a beam of gamma rays through the tank or vessel to a detector mounted on the opposite side. As the level of the material rises it attenuates the radiation over an increasing length of the detector, the output signal of which is proportional to the level.

Applications are generally confined to the measurement of level in tanks or vessels operating under difficult conditions, e.g. high pressure, corrosive or abrasive media and high temperature.

NOTE. See figure 32 for an example of an installation arrangement.

4.5.9.2 Installation arrangement. Each installation should be designed and installed so that the radiation dose rate at all accessible points meets the requirements of the National Regulations under which the system is to operate. In the UK these requirements are defined by the Ionizing Radiations (Sealed Sources) Regulations 1969 which require that the dose rate at all accessible points is less than 0.75 mrem/h*.

4.5.10 Load cell measuring method

4.5.10.1 Principle. An indirect method of determining level is by measuring the mass of a vessel and its contents by means of one or more load cells placed under the vessel support structure. Several types of load cells are available, e.g. volumetric type and the electronic strain gauge type. One to four elements can be used, depending on the supporting system of the vessel and the accuracy required. The relationship between mass and level will depend on the geometry of the vessel (see 4.8).

4.5.10.2 Installation arrangement. Installation of the load cells is generally carried out by the mechanical contractor but vessels should be freely supported and care taken to ensure that any connecting pipework does not impose any unexpected forces on the vessel as these can cause errors in the measurement.

4.5.11 Electrical conductivity measuring method

4.5.11.1 Principle. This type of measurement can operate only with electrolyte solutions such as water. An electrode on insulated mountings is inserted in the metallic tank. An a.c. voltage is applied between the electrode and the wall of

* Millirems per hour.

the tank. When the process medium touches the electrode, a current flows between the electrode and the tank wall and the output of the sensor switches. An a.c. voltage is used to prevent electrolysis at the electrode. High and low level switching can be achieved using two electrodes, the limits being determined by the lengths of the probes.

4.5.11.2 Installation arrangement. Generally the self-contained nature of the probe(s) makes it especially suitable for single practical installation. If the tank is not metal a further electrode is required to earth the liquid and this has to be longer than any of the other electrodes.

NOTE. See figure 33 for an example of an installation arrangement.

4.5.12 Automatic level gauging

4.5.12.1 Principle. The electrically powered servo-operated gauge has a surface sensor as the detecting element which follows variations in level by means of a servo-mechanism. Electrical power provides both gauge operation and remote transmission.

Mechanically operated types are also in use with the detecting element, which is normally a float, providing sufficient power directly to drive a transmitter.

4.5.12.2 Installation arrangement. The gauge should be mounted on either the lower part of the tank shell or by the preferred method of a support pipe, but this will be dependent on the type of gauge and whether the tank has a fixed-roof or a floating roof.

After the tank has been hydrostatically tested, a check should be carried out to ensure that the support pipe is plumb and the guide wires are in their correct position, prior to any adjustment.

NOTE. For detailed installation requirements refer to Institute of Petroleum Publication 'Petroleum Measurement Manual. Part V. Automatic Tank Gauging', available from Heyden and Son Ltd., Spectrum House, Hillview Gardens, London NW4 2JQ.

4.6 Mechanical measurements

4.6.1 Position

4.6.1.1 Principle. Linear and angular position measurements employ one of five classes of device:

- (a) magnetic devices, e.g. linear variable differential transformers;
- (b) synchro devices and proximity switches;
- (c) electrical devices, e.g. potentiometers and limit switches;
- (d) optical devices, e.g. interrupted beam sensors;
- (e) pneumatic devices.

Continuous measuring devices are generally of similar appearance for their application, i.e. linear or angular. Position switches have arrangements dependent on whether they are contact or non-contact types.

Although there is a wide range of position measurement and sensing devices, the requirements for installation are similar.

4.6.1.2 Installation

4.6.1.2.1 Location. Position sensing devices should, where possible, be mounted remote from sources of heating or leakage of process, gases or liquids.

The best performance of position sensors is obtained in a vibration-free location. Where vibration cannot be avoided it is desirable to provide flexibility in the coupling of the device to the point of measurement and in the transducer mountings.

4.6.1.2.2 Mounting. Devices should be mounted only after the mechanical assembly of other parts is complete.

4.6.1.2.3 Alignment. Alignment of contact measuring devices with the moving point should be arranged and adjusted to avoid stress due to movement in directions other than the direction of interest. Flexible joints, elastic or spring couplings or ball joints can be used to avoid such stresses.

Slack linkage joints should not be used to obtain flexibility; all joints should be tightened to avoid slackness while permitting free movement.

Non-contact devices should be arranged so that clearance between the device and the detected point is not subject to large variations as parts wear. The clearance should be set up in accordance with the manufacturer's instructions.

Interrupted beam devices should be arranged and adjusted to avoid contact between the moving part and the emitter or detector elements.

4.6.1.2.4 Travel. The sensing device should be arranged so that any overtravel due to wear or fault will not damage the device.

Adjustable linkages or cams should be set to give correct operation over the normal range of travel and to avoid damage in case of overtravel.

4.6.1.2.5 Electrical connections. The electrical arrangement should be in accordance with the manufacturer's instructions. Flexible wiring to transducers should be supported and protected so that it is neither trapped, drawn tight nor bent too tightly by moving parts.

4.6.2 Speed

4.6.2.1 Principle. The various types of speed transducers employ different principles of operation.

The drag cup indicator employs the eddy current drag of a rotating magnet on a sprung conducting cup or disc to indicate speed.

Tachogenerators generate an output voltage (d.c. or a.c.) proportional to speed.

Speed may be measured by counting electrical pulses induced in a magnetic probe close to moving teeth or slots on a shaft.

Pulses of light or infra-red radiation reflected from or interrupted by markings or teeth on a shaft may be counted to measure the speed by using optical devices.

Devices employing these different methods of measurements form two groups, contact and non-contact devices, which have different installation requirements.

4.6.2.2 Installation

4.6.2.2.1 Mounting. Devices should be installed only after mechanical assembly of related parts is complete.

4.6.2.2.2 Contact transducer alignment. The transducer should be mounted so that misalignment and vibration do not affect reliable operation.

Where vibrations or adverse environmental conditions are a problem, transducers or speed indicators can be mounted a limited distance from the point of measurement by using a flexible Bowden cable drive. Such a flexible drive should be supported and routed to avoid excessive bending of the cable.

Where the transducer is coupled directly, flexible couplings should be used to minimize problems due to misalignment. The transducer mounting should be positioned to permit close coupling to the moving parts so that the relative motion between the mounting and point of measurement is minimized. Alignment should be adjusted to minimize flexing of couplings.

In some types of transducers, the tachometer rotor is fixed rigidly to the end of a motor or drive shaft and has no separate bearings.

4.6.2.2.3 Non-contact transducer alignment. Non-contact transducers should be mounted so that they retain a fixed relationship to the moving parts. It is preferable to mount the transducer adjacent to bearings unless the device design is tolerant of misalignment.

Magnetic induction probes should be aligned to maintain the specified clearance from the tooth or shaft surface. It is advisable to check that the clearance is correct with the shaft in different angular positions.

Optical transducer alignment should be in accordance with manufacturer's instructions.

4.6.2.2.4 Electrical connections. Where the transducer has an associated power supply or signal converter unit, this should be located in a convenient position in accordance with the manufacturer's instructions.

4.6.3 Vibration and acceleration

4.6.3.1 Principle. Vibration is measured either by position velocity or acceleration transducers.

Non-contact position transducers are used for lower frequency vibration measurement and are installed as described in 4.6.1. Position transducers are an integral part of absolute vibration transducers which measure shaft vibration, the output being corrected for vibration of the transducer mounting.

Velocity transducers for vibration measurement sense the relative velocity of a suspended mass and the transducer casing. Relative movement between the mass and the transducer magnetic circuit induces voltages in the output coil proportional to vibration velocity.

Acceleration transducers measure vibration forces on a mass within the transducer using either piezo-electric or strain gauge elements.

The vibration transducer may incorporate an integral signal conditioning or charge amplifier to generate a low impedance output signal or the amplifier may be mounted separately.

4.6.3.2 Installation

4.6.3.2.1 Location. Vibration transducers for machinery monitoring are normally mounted on the bearing housings either in the vertical or horizontal plane. For special applications other mounting locations may be specified in the original design.

Vibration transducers should be protected against environmental and mechanical hazards, preferably by means of a protective enclosure.

4.6.3.2.2 Mounting. For correct operation vibration transducers need to be closely coupled to the machine component of interest. It is recommended that wherever possible integral bosses be provided for mounting vibration transducers.

Vibration transducers that are mounted by means of a stud or clamp should be fixed to a mounting plate having a very low surface roughness to ensure rigidity of coupling. Mounting plates should be fixed by a suitable adhesive to the prepared surface of the mounting boss or bearing housing as shown in figure 34.

For all aspects of mounting arrangement and practice, it is important that the manufacturer's instructions are followed.

4.6.3.2.3 Electrical connections. The output signals generated by accelerometers and position transducers without integral signal conversion amplifiers are often of high impedance and need to be shielded from interference to avoid measurement errors. Manufacturer's standard cableforms with ready-made terminations should be used as far as possible for connecting the transducers to external amplifiers.

Flexible cables from transducers should be protected from mechanical and environmental damage by the use of flexible or rigid conduit appropriate to the application. Where these conduits pass from a hazardous to a safe area the cable should pass through a gas tight seal. To avoid damage when screwing the transducer into its mounting plate, flexible cables should not be connected until the transducer has been fixed and fully tightened.

4.7 Weighing machines

4.7.1 General

Industrial weighing machines fall into three categories: portable, dormant (mechanical, load cell and gyroscopic) and special application. Where machines are used for weighing for sale or excise duty, it is a statutory requirement to have them passed by a Weights and Measures Inspector of the Department of Trade and Industry. Because of their size and apparent robustness it is not always appreciated that weighing machines are very sensitive to mechanical shock but with careful treatment accuracies of 0.02 % are achieved and can be maintained over a temperature range from - 10 °C to +40 °C.

4.7.2 Portable machines

Portable machines are normally supplied as a complete unit and require levelling only when placed in their final position.

4.7.3 Dormant machines (mechanical)

The bottom work for mechanical dormant machines is permanently fixed in concrete flooring or plant steelwork. Detailed drawings of the mounting should be provided and all necessary concrete plinths, fixing brackets for knife edge supports and transfer levers should be carefully checked.

dimensionally before the machine is installed. The installation should be carried out by the manufacturer's engineers or at least supervised by them; however, the installation contractor may be called on to supply unskilled labour, particularly with large machines. Where machines are installed in the open, e.g. road or rail weighbridges, or in plant areas likely to be sluiced down or where spillages are anticipated, special features will have been designed in the bases to ensure adequate drainage. Such features should be carefully checked before machine assembly commences.

The indicating or recording portion normally referred to as the headwork can take a variety of forms. Headworks mounted directly on the bottom work present no problems but if the indicator is remote, e.g. one floor above, the lever movement may be transmitted via a steel rod; it is essential in such cases that the headwork is fastened to supports so designed that there is no movement of the headwork relative to the bottom work. Where the movement is transmitted electrically then the relevant advice given in section ten applies.

The manufacturer's engineer is ultimately responsible for accurate operation but careful checking by the installation contractor can avoid delays. If a tank is fitted on to the machine and is connected by pipes to other process equipment such piping arrangements should be carefully considered at the design stage and the equipment should be supplied in accordance with the design specification. It is important to ensure that when the pipe joints are made there is no strain transmitted to the bottom work. All such pipework should be carefully fitted. It is essential that the manufacturer's engineer is present when all pipe connections are made.

4.7.4 Dormant machines (load cell type)

Dormant machines of the load cell type utilize strain gauges at the loading points and generally require much shallower and less complicated concrete foundations. Nevertheless all concrete or steelwork supports should be carefully checked dimensionally before machine installation. As there is virtually no movement in the bottom work portion, with the exception of large weighbridges, and as all indication is transmitted electronically most of the recommendations for mechanical machines do not apply. Full instructions for cable connections, etc. should be provided by the manufacturer but the relevant recommendations given in section ten also apply. The manufacturer's engineer is responsible for the completed installation but liaison will be necessary. Many load cell machines carrying vessels that are subject to lateral forces, e.g. stirred vessels on large hoppers in windy situations, should have an appropriate design of restraining system. These should be carefully fitted in accordance with the design requirements.

All load cells should be upright and rigidly mounted.

It is most important when welding is performed adjacent to load cells that the cells are kept well protected and on no account should the load cell unit be used as an earth as they

can be easily damaged electrically. Where load cells are mounted in hazardous areas they should be certified as being suitable for such use. Alternatively, the circuit may have been designed using barrier units but these reduce the accuracy of the system.

Most load cell weighing systems are supplied complete by specialist manufacturers. In the event of a system being designed by a non-specialist, who obtains the load cells and indicators from different manufacturers, it is essential to ensure that the load cells and indicators are compatible electrically.

4.7.5 Dormant machines (pneumatic)

Pneumatic dormant machine installations are almost always designed for specific installations and the relevant installation instructions should be supplied by the manufacturer.

4.7.6 Single-ended machines

Single-ended machines are used on horizontal tanks with a fulcrum at one end of the tank and the weighing arrangement (load cell or mechanical) at the other. It should be noted that such machines can be used only on liquid and calibration is checked only by adding known quantities of liquid and by using an accurate integrating flowmeter or a calibration tank.

Other relevant recommendations in this clause are also applicable.

4.7.7 Belt weighers

There is a variety of types of belt weighers, based on different principles, e.g. electronic, pneumatic, hydraulic, mechanical and *nucleonic.

However, all comprise four basic elements, the weigh length element, force sensing element, tachometer or odometer and the computing element which computes the weight from the force exerted by the load on the belt for a fixed weigh length at whatever speed the belt is travelling.

The accuracy of a belt weigher depends not only upon the characteristics of the individual components of the weigher but also upon the belt weigher being correctly installed.

Weighers should be fitted in belts that are correctly tensioned (this usually necessitates an automatic tension device) correctly aligned and without non-vulcanized joints. Particular attention is required for imperfect or misaligned idlers, and structural deformation of the belt supports should also be avoided.

Spillage from, or dirt adhering to, the belt can cause serious inaccuracies to occur and the installation should provide means to prevent this happening.

The effect of wind on long exposed belts will probably have been considered at the design stage. However, the choice of location for the installation should take account of the possibility of wind effects.

* There are several nucleonic weighers on the market. It is essential that specialized advice is sought from the Radiation Security Officer about the precautions that have to be taken to protect personnel from radiation. This is especially important when the quantity of radioactive isotopes used is relatively large (see section two).

Calibration of belt weighers can be carried out in a number of ways, e.g. with check weights and chains. However, for commissioning purposes the only accurate way to check the calibration is to arrange for the contents of the belt to be weighed on a dormant machine. A suitable motor vehicle can be used to transport the contents to a dormant weighbridge.

4.8 Density measurement

4.8.1 General

Many methods are available for the measurement of density. To produce accurate results it is essential that the most suitable design of instrument is selected for the application and correctly installed. When installing density measuring equipment, the following recommendations should be met.

- (a) With any of the sampling type of instruments it is essential that the installation is arranged to provide a truly representative sample.
- (b) It is essential that the correct materials are used.
- (c) The instrument should be mounted in a position that is free from vibration.

Both temperature and pressure will affect the density of fluids. The effects are likely to be greatest near the critical point of the fluid, and are considerably more significant in the case of gases.

4.8.2 Weighing method

4.8.2.1 General. The density of a fluid can be measured by weighing a fixed volume. Measurement is carried out using a vessel of known volume which is suspended from one end of a pivoted lever, the other end of the lever being restrained by a spring and a means of detecting any movement of the lever due to changes in density is provided. Normally, the detector is a movement transducer (see figure 35).

4.8.2.2 Installation. When installing a density meter, the following recommendations should be met.

- (a) The fluid sample is clean enough to prevent blockages in the sample lines.
- (b) For liquid measurements the instrument is mounted in such a manner to prevent gases entering the measuring vessel.
- (c) The mounting location is free from vibration.
- (d) The sample lines are connected in such a manner to allow free movement of the flexible couplings.
- (e) Provision is made, where appropriate, for the sample line, which takes the sample fluid away from the measuring vessel, to be piped back into the process or away to a suitable drain.
- (f) The instrument is installed with a suitable means to ensure that the temperatures of the sample lines and the measuring vessel are maintained at the same temperature as the process. However, if the temperature of the process fluid deviates from that of the instrument sample fluid, then it is necessary for compensation to be made to the instrument output signal.

4.8.3 Buoyancy method

4.8.3.1 General. The density of a liquid can also be measured by using a method that depends on the buoyancy of a float. In the buoyancy type of instrument the fluid to be measured flows up through a vessel containing a totally submerged buoyancy float tube. When the density of the fluid increases there is a corresponding increase in the upwards thrust on the tube. By detecting the relative movement of the float a direct indication of the liquid density is obtained (see figure 36).

4.8.3.2 Installation. When installing a buoyancy type instrument, the following recommendations should be met.

- (a) The fluid being measured should be free from solid particles and not prone to cause scaling.
- (b) The buoyancy vessel should be mounted in a vertical position.
- (c) The flow through the buoyancy vessel should be regulated to the correct value so that upward thrusts are generated by changes in density and not by changes in flow rate (especially important with high viscosity fluids).
- (d) The instrument should be free from vibration and mounted in a location that is not prone to vibration.
- (e) Access should be provided to the buoyancy tube part of the instrument enabling regular checks to be made to ensure that there is no corrosion and no dirt deposits, etc. as their presence can seriously affect the accuracy of measurement.

4.8.4 Pressure differential methods

4.8.4.1 General. The density of a liquid can be obtained by measuring the pressure at the bottom of a fixed level of the liquid. In order to obtain an accurate measurement the liquid should not be subject to stratification (layering). The liquid in a vessel can be controlled at a constant level either automatically or by allowing it to overflow at a fixed point out of the vessel.

When the level of the liquid is held constant, any variations in the measured pressure at a fixed point in the liquid are due to variations in its density.

This differential pressure measurement can be carried out by any of the means described in 4.3 and 4.5.

4.8.4.2 Installation. When installing a differential pressure density measuring instrument, the head of liquid to be measured should be kept as large as possible in order to achieve accurate readings.

NOTE. For other installation recommendations see 4.5.

4.8.5 Gamma radiation absorption method

4.8.5.1 General. This type of instrument depends for its operation on the relationship between the absorption of gamma radiation in a fluid and the density of the fluid. A gamma radiation source is mounted on one side of the process vessel while the radiation detector is mounted on the opposite side. The amount of radiation received at the detector varies according to the density of the fluid (see figure 37).

4.8.5.2 Installation. When installing a gamma radiation source and detector, the following recommendations should be met.

- (a) The safety requirements and health regulations applicable for the use of radioactive sources should be met (see the footnote to 4.7.7 and also section two).
- (b) Access should be provided to enable regular inspections of the source to be made.
- (c) The source and detector should be installed in such a position on the process vessel so that the fluid, whose density is to be measured, is always between the source and detector.
- (d) Good mixing of the process fluid should be provided particularly if the fluid to be measured has a tendency to settle in layers, e.g. caustic.
- (e) It is essential to check that the strength of the gamma source is correct for the particular application and that at the commissioning stage adjustments are made to offset the absorption due to the density of the vessel wall material.
- (f) The source and detector should be aligned so that the path between them is uninterrupted by any moving parts, e.g. stirrers.
- (g) For liquid density measurements the source and detector should be located in a position where gas entrainment in the liquid does not occur.

NOTE. Other installation recommendations are similar to those for level measurement using nucleonic techniques given in 4.5.

4.8.6 Ultrasonic method

4.8.6.1 General. The velocity of sound waves in a fluid varies according to the density of the fluid and this relationship can be used to determine the density of the fluid.

In a typical installation an ultrasonic transmitter is mounted on one side of the process pipe or vessel and a detector of ultrasonic waves is mounted on the opposite side. The time interval between transmission and reception of the ultrasonic wave can be used as a measure of the density of the fluid (see figure 38).

4.8.6.2 Installation. When installing an ultrasonic density measuring instrument, the following recommendations should be met.

- (a) There is optimum acoustic coupling between the transmitter/detector and the walls of the pipe or vessel.
- (b) The instrument is mounted where there is good mixing of the process fluid.
- (c) The path of the acoustic waves is arranged so as to avoid any distortions which may be caused by equipment inside the vessel such as stirrer shafts, submerged pumps and internal pipework.
- (d) The instrument is mounted in a position on the vessel where the signal will not be distorted by gas entrainment in the liquid being measured.

4.8.7 Vibrating element (natural resonance) method

4.8.7.1 General. Vibrating element (natural resonance) instruments operate on the principle that if a fluid is contained by, or by part of, a body that is maintained in resonance at its natural frequency, then the frequency of resonance is dependent on the total mass of the system and so will change as the fluid density changes.

The vibrating element is normally in the form of a tube, cylinder or flat plate and all forms may be used for both liquids and gases. The vibrating tube arrangement is mainly used for liquid density measurement since it provides a very clean flow path and is least affected by liquid viscosity. The vibrating cylinder is widely used for gas density measurement since it is able to achieve very high sensitivity whilst still being adequately rugged. The vibrating cylinder and flat plate forms are generally convenient for in-line (insertion) mounting. In general, these instruments are not sensitive to mounting position or normal plant vibration and they can achieve very high accuracy.

4.8.7.2 Installation of instruments for gases. When installing a vibration density meter for use on a gas, the following recommendations should be met.

- (a) The instrument is installed in the gas pipeline in such a manner that the pressure and temperature of the gas in or around the sensing element is the same as that of the gas in the pipeline.

If the bypass installation is used, the density meter body is in close thermal contact with the pipeline. Care should be taken over the siting of any sample lines, isolation valves or filters to ensure that the pressure of the gas in the bypass density meter is the same as that in the gas pipeline.

If an insertion instrument is used, the temperature equilibrium will be ensured and the gas pressure will be within a fraction of a velocity head of the pipeline static pressure.

- (b) The instruments will operate correctly only provided the vibrating elements are kept dry. Hence the meter should be mounted in a situation where condensation will not occur. The instrument should preferably be kept dry during installation. In the case of a bypass instrument, this should be installed only after all pipeline hydraulic testing and cleaning operations have been completed. An insertion meter should be installed only after all pipeline cleaning operations have been completed. If the meter is fitted for hydraulic testing, provision has to be made to clean and dry the instrument after the test.
- (c) Special care should be taken with high pressure installations to ensure that the correct types of seals and fittings are used. Manufacturer's instructions should be carefully followed.

Vortex shedding will occur around insertion meters. Care should be taken to ensure that the mounting arrangement will not allow mechanical resonance to occur at operating flow rates.

4.8.7.3 Installation of instruments for liquids. When installing a vibration density meter for liquid service, the following recommendations should be met.

(a) The instrument should be mounted in a position where errors cannot be caused by gas entering or collecting in the measuring tube.

On bypass density meters, a gas eliminator fitted before the density meter would solve installation problems of this type. Insertion density meters should not be fitted immediately after pipe fittings, e.g. gate valves, where

cavitation can occur, especially when being used on high-vapour pressure products.

(b) The materials of construction of the instrument and associated fittings should be suitable for the fluid being measured.

(c) When using bypass instruments, care should be taken to ensure that the temperature of the liquid in or around the sensing element is the same as that of the liquid in the process.

Section five. Quality measuring instruments

5.1 General

Quality measuring instruments measure chemical and physical properties of process fluids and substances, and are installed either directly in the process line, e.g. chemical probes for pH or thermal conductivity determination, or at a distance and connected by means of sampling systems, e.g. process analysers such as viscometers or chromatographs.

NOTE 1. Further information is given in appendix H. For expert advice and guidance it is recommended that a specialist is consulted.

NOTE 2. Density measurements are described in 4.8.

5.2 Chemical probes

5.2.1 General

There is a wide range of probes available for the measurement of a number of parameters. Installation details are described for some of the more commonly used types.

Because of the nature of construction of the actual sensing elements they are often fitted into an electrode holder which is mounted in a vessel bypass or process line.

The supplier normally specifies in detail all fitting requirements which, because of the delicate nature of the sensing elements, should be followed implicitly.

Clearance for fitting and removal of elements is vital and access for such should be checked.

Where the measuring system is fitted in a bypass it is necessary to ensure that isolating valves and drain valves are fitted to enable removal of the unit for cleaning and maintenance.

5.2.2 Electrolytic conductivity probes

Electrolytic conductivity is a measurement of the total ionic species in solution. In practice this can be related to the ionic strength, total dissolved solids or solution concentration. Measurement of conductivity can be seriously affected by variations in temperature and temperature compensation may be required. Conductivity measuring cells are usually manufactured in four forms:

- (a) platinum, tantalum, PTFE and glass construction;
- (b) stainless steel construction;
- (c) carbon electrodes moulded in resin or plastics;
- (d) electrodeless sensors of various materials.

NOTE. Sensors without electrodes are manufactured in a variety of materials in order to withstand harsh environments such as highly corrosive chemical solutions and abrasive slurries. By virtue of their design and construction maintenance is minimal.

Platinum and glass electrodes are no longer commonly used. Their fragile construction makes reliable industrial application difficult and they also require regular re-platinization resulting in excessive down-time.

Stainless steel and moulded cells are of rugged construction and do not normally require frequent maintenance.

Conductivity cells are produced in a variety of mounting configurations suitable for use in virtually any type of plant fitting.

Particular care should be taken when installing plastic bodied cells to ensure that thread sizes match and there is no confusion between, for example, BSP and NPT threads nor taper and parallel thread fittings. Cells can be irreparably damaged through failure to check on thread details before installation.

During installation care should be taken to ensure that electrodes are free of any grease or dirt, as any such deposit will seriously affect the accuracy of the cell. The manufacturer's instructions for cleaning should be followed.

NOTE. Signal cable installation is important and should be in accordance with section ten.

5.2.3 pH probes

In its simplest form pH measurement provides an indication of the acidity or alkalinity of the measured liquid.

pH measurement requires the use of both a measuring and a reference electrode. In most applications temperature compensation will be required and this is accomplished by mounting a resistance element adjacent to the measuring electrodes.

Electrodes are usually designed for use in a dedicated housing or electrode holder. These units are supplied in a number of mounting configurations to suit particular applications, e.g. dip types for use in open tanks. pH probe systems should have arrangements to ensure that the probes are kept wetted at all times.

pH electrodes may be normally used without prior activation. For precise measurement however the electrodes should be soaked for 12 h in the specified buffer solution. After prolonged storage periods before installation pH electrodes may require rejuvenating in accordance with the manufacturer's recommendations. Measuring and reference electrodes are normally supplied with some form of protection over their measuring surfaces; it is essential that this protection is removed before installation.

For calibration purposes the electrodes are immersed in two known buffer solutions whose value should encompass the required measuring range.

pH electrodes by nature of their construction are very high impedance devices (typically $10^{10} \Omega$) and as a consequence the transmitters, also having a high impedance, require great care when the interconnecting cables are prepared and fitted (see also section ten).

Where preamplifiers are employed they should be mounted as close to the electrode as is physically possible in order to minimize the possibility of electrical pick-up or microphonically induced electrical noise often encountered when long cables are used for the connection of sensitive high impedance devices.

Particular care should be taken to ensure that moisture cannot enter the cable system. Terminations and all plugs and sockets should be properly sealed to prevent any possible ingress of moisture.

Interconnecting cables are frequently prone to cause problems, hence the need for special care in their installation.

5.2.4 Reduction/oxidation (Redox) probes

The Redox potential is commonly used to determine the reduction or oxidation of an industrial waste during its treatment process by the measurement of the voltage produced. A solution that contains an excess of oxidizing agent has a positive potential, whilst one containing an excess of reducing agent has a negative potential.

The three most common measuring applications are:

- (a) destruction of cyanides;
- (b) treatment of chromates;
- (c) absorption of chlorine in sodium hydroxide.

The measurement of Redox potential requires the use of both a metal and a reference electrode mounted in systems similar to those used in pH measurement, and in general the same installation comments apply.

Depending on the application, silver, gold or platinum electrodes are used. Metal electrodes are generally supplied ready for use but may require degreasing prior to installation. Great care should be taken not to handle the metal billet or pin as this will lead to measuring inaccuracies. After prolonged storage periods before installation, Redox electrodes may become oxidized and should be cleaned as recommended by the manufacturer.

5.2.5 Ion selective probes

Ion selective electrodes for use with such chemicals as ammonia, fluorides, nitrates and chlorides, etc. are widely employed in industrial on-line analysis. They are normally installed in a dedicated ion-selective analyser and form part of that monitoring system.

The electrodes may take the form of glass, liquid membrane or solid state electrodes. In each case the probes should be assembled in accordance with the manufacturer's instructions.

Glass and solid state electrodes are normally supplied ready for fitting and require superficial checking only.

Liquid membrane electrodes are normally supplied in kit form for assembly on site. Great care should be taken in assembly to minimize the risk of premature failure.

5.2.6 Probes for measurement of oxygen in flue gas

Two methods of oxygen measurement are generally used:

- (a) utilizing the paramagnetic property of oxygen;
- (b) using a zirconia sensor to detect the movement of oxygen ions.

The sampling system for the paramagnetic analyser should be very carefully considered at the design stage. Details should be supplied by the system designer and manufacturer and these details should be carefully followed. The position of the sample point is important. The gas sample is aspirated by steam, water or pump and the aspiration system should be checked as soon as completed.

The zirconia probe is fitted into the process pipe or duct and as position is important all details should be settled at the design stage. The probe is part of a package and the detailed installation instructions should be obtained from

the manufacturer. The following recommendations are of particular importance.

- (1) The probe is delicate and brittle, particularly when hot and therefore it is essential that it is not damaged.
- (2) All joints and sealing rings should be properly fitted.
- (3) The probe should be fitted in the correct position relative to gas flow and the deflector should point upstream towards the flow.
- (4) The temperature control system for the probe should be checked out but care should be taken to protect the analyser cell from any external voltages during such checks.
- (5) Where applicable, the cooling air supply should be clean and dry.

5.3 Process analysers

5.3.1 Process stream analysers and their sampling systems are generally complex and it is essential that they are properly applied and installed in order to ensure a high degree of accuracy with trouble free operation. There is a wide range of types and designs that cover numerous different applications in industry. This code deals only with the features that are common to the various installations. The exact requirements for housing, supplies, services, sample conditioning, etc. applicable to each type of process analyser will require individual consideration.

5.3.2 To achieve reliable operation it is essential that attention is given to the following:

- (a) protection against the environment;
- (b) accessibility for maintenance;
- (c) sampling systems;
- (d) distance of the analyser from the process line;
- (e) safety considerations.

Usually these will be considered at the design stage but they should also be borne in mind when installing the process stream analyser.

5.3.3 The installer may be required only to make the piping and electrical connections to a completely assembled and prefabricated analyser house. In other circumstances he may be required to install the analyser in a shelter and pipe up the sampling system. In either case it is essential to pay meticulous attention to details of the installation to ensure that the performance of the analyser is not impaired.

5.4 Mountings and housings

5.4.1 Process analysers may be arranged centralized in groups, or installed in one of the various housings described in 5.4.2 or individually mounted locally. There are a number of advantages in a centralized arrangement but in some circumstances, such as where it is essential to reduce sampling time delays, mounting them locally may have advantages. In the latter case it is important that careful consideration is given to the actual location in the plant

where the process analyser is to be mounted. Any brackets and supports that are used for mounting the analysers should be sturdy and suitably protected to prevent any deterioration if the site atmosphere is likely to cause harmful effects. It is essential to give special consideration to the mounting of process analysers that are sensitive to vibration so that they are either isolated from vibrations by suitable mountings or are located in areas where the level of the vibrations is unlikely to affect the analyser.

5.4.2 Housings for process analysers take a variety of forms depending on the degree of protection required.

(a) *Analyser case*. The enclosure forming part of the instrument.

(b) *Analyser cabinet*. A small simple housing in which analysers are installed singly or grouped together. Maintenance is carried out from outside the cabinet.

(c) *Analyser shelter*. A structure with one or more sides open and free from obstruction to the natural passage of air, in which one or more analysers and associated equipment are installed. The maintenance on the equipment is carried out from within the shelter.

(d) *Analyser house*. An enclosed building or space in which one or more analysers with associated piping, wiring and auxiliary equipment are installed. Either free or forced ventilation is used. The maintenance on the analyser equipment is carried out within the house.

Whichever type of housing is selected it should be constructed of material that is resistant to fire and is impervious to any oils or chemicals that are likely to come in contact with it, both on the outside and on the inside. The housing should provide protection against wind, rain, frost and solar radiation.

5.5 Sample conditioning systems

5.5.1 It is usually necessary to provide a sample conditioning system between the sample take-off point and the process analyser. Sample conditioning systems are designed to remove any undesirable solid or liquid contaminants in the sample and to adjust the temperature and pressure and the flow rate to the values suitable for the analyser. As far as possible the sample conditioning system should have no effect on the chemical or physical property being measured or alter the composition of the sample in any way that would influence the result of the final measurement by the process analyser.

5.5.2 Sample conditioning systems may be supplied complete with the analyser, or assembled in a site workshop or assembled at the location where the analyser is to be used. The components of an assembly may comprise pressure reducers, filters, variable-area flowmeters, coalescers, etc. mounted on a suitable framework. Stainless steel tubing and fittings are often used in the sample conditioning system. Other materials may also be suitable but if in doubt expert advice should be sought. After assembly the sample conditioning system should be pressure tested.

5.6 Sampling lines

5.6.1 Where the sensing device is installed directly in the pipeline no sample loop is required. Where the sensing device is at a distance, sample lines will be necessary to transport the sample to the process analyser with the minimum of delay. If the distance is relatively short and a small amount of sample is required, only a single line from

the sample. Sample lines should be heat traced by steam or electrical power and thermally insulated to prevent changes in physical properties between the sample offtake and the analyser (see section ten).

5.7 Sampling connections

5.7.1 A sampling connection, sensing device or sampling probe installed in a process line should not degrade the pressure rating of the line. Flanges or screwed connections should be of the same rating and material as the process pipework.

5.7.2 Isolation valves capable of tight shut-off should be installed between the sampling connection and the sampling line and preferably should be full bore so as not to impose any restriction on the flow. The valve should have a means of indicating whether it is in the closed or open position.

5.7.3 Any sampling probe, or in-line sensing device, should be correctly positioned across the pipe diameter so that a fully representative sample can be taken.

5.8 Vent and effluent lines

Sample conditioning systems and process analysers may need to be connected to vent and effluent removal lines to remove any unwanted sample. It is most important that great care is exercised in locating the lines that carry the vent gas and effluent liquid so that they are discharged safely and do not cause a hazard to personnel and surrounding plant.

5.9 Manual sampling and calibration connections

A manual sample offtake for laboratory checks should be positioned so that the sample is representative of the liquid or gas entering the process analyser in such a way that the results of the laboratory measurement, and the analyser reading taken at the same time as the manual sample, can be compared without any error being introduced. Calibration facilities to inject a known composition sample may also be required.

5.10 Storage and handling of equipment

5.10.1 As process analysers and their associated equipment are generally high cost instruments it is essential to store them carefully and protect them from the weather when received from the suppliers and prior to installing them on site. Analysers should be carefully handled when being moved so as not to disturb or damage any delicate components which they might contain.

5.10.2 Any special precautions and instructions provided by the manufacturer should be strictly observed. Instruction manuals and any other documents that are attached to, or that accompany, the analyser should be handed over to the technical staff responsible for installation and maintenance.

5.11 Testing

5.11.1 It is most important that for testing and for the calibration procedures referred to in 5.12, only instrument technicians who have the specialist expertise in process analysers should undertake this work. Where necessary, appropriate training should be provided.

5.11.2 The process analyser should be tested at the manufacturer's works before delivery to site. Further testing will be necessary after it has been installed to check that the connections to associated equipment, such as recorders, programmers and computer input devices, are correct. Also, all mechanical equipment and connections should be thoroughly tested.

5.11.3 Service and sample connections to analyser houses should be tested in accordance with the general test procedures given in section eleven.

5.11.4 Special attention should be given to the analyser house interlock system (if fitted), particularly to the following items:

- (a) ventilation air flow sensing device;
- (b) any gas detectors that are installed in vent outlets;
- (c) the internal pressure switch;
- (d) audible and visual alarms.

5.12 Calibration and commissioning

Inspection and testing should be so programmed that final calibration and commissioning can be completed just before start-up of the associated plant and thereby avoid a prolonged idle period.

NOTE. Calibration procedures may be found in the manufacturer's literature but reference should also be made to the Institute of Petroleum code of practice for calibrating process analysers.

5.13 Safety

5.13.1 When process analysers are used in connection with flammable and/or toxic materials, great care has to be exercised to ensure that all aspects of safety have been properly dealt with. Reference should be made to section two for advice on personnel safety, and section three for recommendations concerning hazardous areas.

5.13.2 It is particularly important that any purging gas or ventilation air used as part of the electrical safety protective system is drawn from a safe source outside the hazardous area.

5.13.3 Special attention should be paid to the location, inspection, testing and commissioning of all process analysers that form part of a safety protective and monitoring system.

Section six. Regulating devices

6.1 General

A regulating device is the final control element in a process control loop. The most common type of regulating device is the globe type control valve although many other types of control valves are currently in use, such as butterfly valves, ball valves, rotary eccentric plug valves, partial ball valves, diaphragm valves, self-acting regulators, sliding or multivane dampers.

For low pressure drop services in larger pipelines, e.g. above 150 mm in diameter, butterfly valves should be considered for economic reasons.

Control valves are used to vary the area through which a fluid passes and can be operated by a number of different types of actuator. The most commonly used actuators include spring return pneumatic diaphragms, pneumatic pistons, hydraulic pistons, electric motors, electro hydraulic actuators, solenoids and thermally-actuated valves.

Actuators are used to provide the motive force to operate the valve and the motion can be linear or rotational (part turn or multiturn).

Other types of regulating devices include variable speed drives, variable speed gearboxes, power operated louvres, etc.

6.2 Mechanical protection

6.2.1 Special care and protection should be provided to ensure that control valves are not damaged when being transported and installed.

6.2.2 Flange faces should be protected from mechanical damage. This is especially important where plastics bodied valves are used or where the valve has a lined body. In addition, consideration should be given to coating the flange facing of ferrous valves with an easily removed anti-rust compound.

6.2.3 Special care should be taken with lifting equipment to avoid mechanical damage to any of the valve and actuator auxiliary items of equipment, e.g. feedback linkages to external positioners, small bore pipes and pressure gauges.

6.3 Pre-installation checks

6.3.1 Visual inspection

6.3.1.1 Before a control valve is installed it should be carefully checked to ensure that there is no damage and that it complies with the original design specification.

6.3.1.2 The following items should be checked against the valve/actuator data plates:

- (a) tag number;
- (b) body rating;
- (c) body material;
- (d) flange size, facing and rating;
- (e) trim size and material;
- (f) action on supply failure;
- (g) action for control;
- (h) auxiliary items.

6.3.2 Performance checks

6.3.2.1 Performance checks should be carried out to demonstrate that the valve operates correctly for the system specified. These checks should include tests to ensure:

- (a) that the valve moves accurately and smoothly over its full range;
- (b) the speed and direction of movement is correct for the application;
- (c) the valve moves to the correct position in the event of a supply failure.

6.3.2.2 All control valves requiring tight shut-off should be pressure-tested to ensure that the leakage rate is within the design specification.

6.3.2.3 The additional tests described in 11.4.14.2.7 should also be carried out.

6.3.2.4 When the valve and actuator are supplied by different manufacturers, the mechanical fitting of the actuator on to the valve body should be inspected/tested to ensure correct assembly for transmission of maximum actuator power to the valve.

6.4 Control valve installations

When designing control valve installations for isolation and bypass the following should be observed.

- (a) Isolation valves, bypass valves or handwheels may be needed in order that control and shut-down valves can be tested and/or maintained while the plant continues production.
- (b) Each installation has to be considered on its own merit and the individual requirements should take the following into account.
 - (1) Frequency of testing or repair.
 - (2) Expected failure mode of control valve.
 - (3) Normal operating procedures for plant running, e.g. continuous or batch.
 - (4) Can plant be controlled manually while control valve is being tested/repared?
- (c) When a manual bypass is used, the control valve should be fitted in the straight-through path.
- (d) Manual isolation valves in series with control valves should be of the line size and should introduce negligible pressure drop or flow disturbance in the fully open position.
- (e) The bypass valve should be of similar flow capacity to the control valve and should be suitable for fine manual adjustment.
- (f) Where required, vent or drain valves should be provided adjacent to the control valve together with the provision for flushing and purging, as shown in figures 39, 40 or 41. On multiple control valve installations each control valve should be fitted with its own isolation, bypass and vent valves.

NOTE. Figure 39 shows an arrangement for a control valve with downstream side connected to atmosphere.

Figure 40 shows an arrangement for a control valve when both sides of the valve could become pressurized.

Figure 41 shows an arrangement for some applications such as highly toxic or extremely high pressure installations.

On some installations the isolation, bypass and vent valves may be automatically operated.

(g) In steam lines the upstream side of the control valve should be adequately provided with steam traps to prevent carry-over of condensate.

6.5 Access for testing and maintenance

In order to ensure that there is adequate access for testing and maintenance the following should be taken into account.

- (a) Control valves should be installed so that they are easily accessible for in situ testing and maintenance from the floor or permanent access platform.
- (b) Valve position indicators, signal gauges, positioners, etc. should be clearly visible from the floor or permanent access platform.
- (c) Adequate space should be left above the control valve where lifting equipment is required to remove the valve or actuator for maintenance.
- (d) Adequate space should be allowed below the control valve to facilitate in situ servicing of the valve internals where access is from the bottom.
- (e) When thermal insulation is required around a control valve, it should be fitted in such a manner to allow easy removal for control valve maintenance.
- (f) When a pipeline is heat traced it may also be necessary to heat trace the control valve to prevent static fluids from solidifying. Heat tracing may be required on a control valve to prevent freezing which could be caused by pressure changes or changes in other process conditions across the control valve. (It may also be required to prevent condensation in wet gases.) The heat tracing should be fitted in such a manner to enable easy removal for control valve maintenance. It should not be capable of providing enough heat to damage components of the control valve.

6.6 Environmental protection

Control valves and auxiliary items should be protected from adverse environmental conditions, such as the following:

- (a) excessive heat;
- (b) corrosion;
- (c) vibration;
- (d) falling debris;
- (e) mechanical damage;
- (f) leakages from other pipelines or plant items.

Control valves should be installed so that any leakages onto other equipment are minimized, e.g. gland leaks.

In addition to selecting the correct design of control valve for the application, it may be necessary to apply acoustic insulation to the control valve and its associated pipework to reduce the emitted noise level.

6.7 Piping

6.7.1 Control valve installations in process piping

6.7.1.1 Pipework on either side of the control valve should be permanently supported.

6.7.1.2 When the control valve body is of a smaller nominal size than the line, its connection to the line should be made using taper pieces/reducers.

6.7.1.3 The surface finish on the control valve flange faces should be the same as that on the pipe flange faces. Joints, which should be of the correct material, should not protrude into the pipeline.

6.7.1.4 Before installing the control valve it may be necessary to remove items such as plastics inserts that have been intended for protection during transport.

6.7.1.5 If it is desirable to achieve close conformity between design conditions and actual valve flow characteristics, the pipe should have no bends or obstructions for five pipe diameters upstream and downstream of the valve and no sharp bends for 10 diameters.

6.7.1.6 Piping should be arranged to allow easy removal and replacement of the control valve and flange jointing materials and, where required, space should be left for in situ replacement of the actuator and trim.

6.7.1.7 Piping runs should be constructed in such a manner that they do not apply excessive stress to control valve bodies. The piping should be built up progressively to include the control valve (or a replacement spool piece), rather than leaving a space for the control valve to be fitted into later.

6.7.1.8 Where a control valve has to be welded into a pipeline, special care should be taken to ensure that the maximum temperature of the control valve components is not exceeded during the welding operation.

6.7.1.9 The attitude in which a control valve and its actuator is mounted should be in accordance with the manufacturer's instructions. For high temperature applications it may be preferable to mount the actuator below the pipeline to reduce its temperature.

6.7.1.10 The control valve should be installed so that it is not fitted into a lute in the pipeline.

6.7.2 Protection during pipeline cleaning and testing

6.7.2.1 If pipelines are to be flushed, steam cleaned or chemically cleaned, control valves should be removed and replaced by spools, unless the materials of the control valve are suitable to withstand the cleaning operation without damage.

6.7.2.2 During pipeline pressure testing, control valves should be put into the fully open position (or bypassed) to avoid excessive differential pressure across the valve.

6.8 Control valve bodies

6.8.1 General

Different types of control valves sometimes need different arrangements for installation and testing. The installation should comply with the manufacturer's instructions but some specific recommendations for the more commonly used valves are given in 6.8.2 to 6.8.4.

6.8.2 Globe valves

A globe valve should be installed so that the fluid flows through it in the direction specified by the manufacturer. (The flow characteristics may be altered if the valve is reversed. The fluid pressure drop across the valve plug can affect the power needed from the actuator to move the valve.)

6.8.3 Butterfly valves

Butterfly valves are often supplied as a 'wafer' type of body that is clamped between pipeline flanges. Special care is needed to avoid damage to the valve body faces and disc during transport and installation, particularly if the disc or body is coated.

If the valve is fitted with a power-fail open type of actuator the disc may protrude outside the valve body. The valve should be locked in the closed position or be fitted with short spool pieces on each side to avoid damage during installation.

6.8.4 Ball valves

The torque required to move a ball valve varies with pipeline conditions, e.g. operating pressure and temperature. When testing actuator power and speed these variations should be taken into account.

6.9 Control valve actuators

6.9.1 Diaphragm actuators

Diaphragm actuators can be used with or without a positioner. The positioner normally requires an air supply that has to be filtered and regulated to the correct pressure. The actuator stem should preferably be mounted in a vertical position.

For high temperature applications it may be preferable to mount the actuator underneath the final control element.

6.9.2 Piston actuators

Piston actuators can be either pneumatic or hydraulic. In each type the fluid pressure can be varied on both sides of a piston attached to the final control element stem or shaft.

The force produced by the actuator depends upon its supply pressure. The actuator should therefore be connected to a supply system that will maintain the pressure for which the actuator was designed.

6.9.3 Power cylinders

6.9.3.1 Power cylinders are used to provide greater thrust, longer strokes or faster responses than other types of actuators, e.g. as may be required by very large control valves, dampers and louvres. The operating medium may be pneumatic or hydraulic.

6.9.3.2 If the power cylinder is not coupled directly onto the final control element then linkage between the two should be as direct as possible.

6.9.3.3 Linkages should be fitted in a manner that minimizes the effects of hysteresis. They should be fitted to allow for any possible movement of the power cylinder relative to the plant pipework and space should be provided to accommodate this movement.

6.9.3.4 Where movement is transmitted via wire ropes swivels should be fitted.

6.9.3.5 All connecting mechanisms should be checked for correct alignment.

6.9.4 Electric actuators

6.9.4.1 Electric motors are sometimes used with a gearbox system to operate control valves. These could be for linear or rotary operation of the final control element.

6.9.4.2 The electric actuator is normally supplied already fitted to the control valve.

6.9.4.3 The actuator electrical supply should be checked to ensure the correct voltage and phase rotation.

6.9.4.4 The motor case should be connected to earth.

6.9.4.5 All cable entries should be glanded and control circuit housings should be completely sealed.

6.9.4.6 The gearbox system should be checked to ensure the correct quantity and type of lubricant.

6.9.4.7 It may be necessary to check/adjust the limit switches on each end of the motor travel and the torque cut-out switch, if fitted.

6.9.4.8 When putting into service, the position of the handwheel clutch mechanism should be checked.

6.10 Auxiliary equipment

6.10.1 General

Control valves can be fitted with many additional items to enhance their performance. It is essential for the correct operation of the control system that the auxiliary items are robustly mounted and correctly adjusted in accordance with the manufacturer's instructions.

Advice on the correct installation of some of the auxiliary items commonly used is given in 6.10.2 to 6.10.7.

6.10.2 Positioners

6.10.2.1 Control valve positioners may be an integral part of an actuator or an additional item of equipment that is