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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

British Standards Institution

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

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 subassembly 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 routeing 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 condensible 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 three.

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 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} Ω) 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.

Adequate illumination for maintenance is needed within the housing therefore additional lighting may have to be provided. Additional heating should be provided when the ambient temperature is low and/or when the humidity conditions are likely to be high. When the ambient temperature is high or where there is a considerable release of heat from the equipment, it may be necessary to provide some form of cooling, e.g. from an air-conditioning system.

5.4.3 The analyser houses can be of substantial proportions, depending upon the numbers of analysers they contain and the houses may be of brick construction, prefabricated from sheet metal or glass reinforced plastics that have been treated with flame retardant additives. The house may form part of a package constructed and tested in a factory, the process analysers, sampling systems, heating, lighting, ventilation and safety devices being built into a transportable unit that is large enough to allow room for a person to walk in. Site installation of such a package then becomes a relatively simple matter of placing the house in position and making the necessary connections to the site facilities and sample lines.

In the case where the building is constructed on site the installation personnel should provide suitable supports on which to erect the analysers. Their tasks may also include the assembly of the sample conditioning systems, and installation of all the equipment such as junction boxes, wiring, lighting and electrical supplies. They should refer to the detailed design drawings and materials lists provided for site guidance as part of the installation documentation.

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 to the process analyser may be necessary.

In many instances a fast circulating loop will be essential to reduce time lags or where it is unacceptable to vent or drain the sample. Plant pressure drops may be used to withdraw the sample from the process line and circulate it through the analyser. If the pressure drop is insufficient or is not reasonably constant, it may be necessary to provide sample pumps for the purpose.

5.6.2 When choosing material and fittings for the sample lines it is essential that due account is taken of the material and piping classification of the process line or vessel from which the sample is drawn. Expert advice should be sought about the use of materials for special or corrosive service, e.g. flue gas, or where there is any possibility that the material of the sampling line could alter the composition of the sample. This is particularly important when the system is required to analyse traces of a chemical component or moisture.

5.6.3 Where plastics or other non-metallic sample lines are used, special care should be taken to provide good supports so that there is no sagging. These sample lines should not be run in the vicinity of hot steam lines or where there is any risk that they will be affected by leaks from process lines, etc.

The layout of a sampling line should be arranged to avoid the formation of high points in liquid lines where gases and vapours could collect, or low points in gas lines where liquid could be trapped. Both will restrict the free flow of 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/repaired?

(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 mounted onto the actuator and valve and connected to it via mechanical linkages.

6.10.2.2 The valve position feedback linkage should be carefully checked to ensure correct fitting and that it is free from mechanical damage.

6.10.2.3 The operating range of the valve with positioner attached should be checked (see **11.4.14**).

6.10.2.4 The positioner should be mounted in such a way to enable easy access to indicators and adjustments when the valve is in situ.

6.10.3 Current to pneumatic converters

Current to pneumatic converters should preferably be independently mounted local to the control valve to enable the valve to be removed for maintenance without disturbing the converter installation and connections and to avoid the effects of vibration.

6.10.4 Booster relays

Where booster relays are used to improve the response time of control valve actuators they should be provided with adequate air supply capacity and venting.

6.10.5 Position indicators

6.10.5.1 All control valves should be equipped with indication of the actual position of the valve, e.g. stem position indication.

6.10.5.2 Where transmitters are used to indicate remotely the position of a control valve, the transmitted signal should be taken as directly as possible from the actual valve position by attachment to the valve stem or shaft.

6.10.5.3 Position sensing switches are sometimes used to indicate remotely the position of a control valve, e.g. in an automatic sequencing or shut-down system.

6.10.5.4 Where the position of a valve is required to be known for safety reasons, i.e. its position is critical to the safety of a reaction or process, then the limit switches or proximity devices used should be specified as having the necessary level of integrity as to be suitable for such applications.

NOTE. BS 4794 : Section 2.20 is a suitable standard for limit switches. The manufacturer's advice should be sought as to the suitability of such devices for these applications.

6.10.5.5 The switches in **6.10.5.3** and **6.10.5.4** are usually mechanically-operated position switches or proximity switches.

6.10.5.6 Limit switches should be robustly mounted in a position on the valve in order to monitor as closely as possible the actual valve position. The switch should be mounted on the correct end of the valve travel and adjusted to the correct detecting position in accordance with the manufacturer's instructions.

6.10.6 Manual handwheels

When a control valve is fitted with a manual handwheel clear indications should be given of the following:

(a) whether the valve is under manual or automatic control;

(b) the position of the valve;

(c) the direction of rotation of the handwheel to open the valve.

NOTE. Special care should be taken when working on or near power-operated valves as these can be set into motion unexpectedly.

Manual handwheels should be easily accessible to the operator.

6.10.7 Capacity vessels

Capacity vessels are sometimes used to assist the air-fail actions of pneumatic actuators. Where such vessels operate as pressure vessels, the design and construction of such parts of the system should comply with the relevant standards for pressure vessels.

6.11 Variable speed systems

6.11.1 Variable speed transmission

There are many different types of variable speed transmission systems that can be used to control process flows by varying the speed of the equipment such as pumps or fans.

These systems are generally fitted between a fixed speed motor and the equipment, the speed of which is to be regulated. They could be in the form of a fluid clutch, variable ratio gearbox, belt-driven cone shaped pulley, etc.

Recommendations for the installation of many of these devices are similar to those of a regulating device, e.g.:

(a) they should be firmly fixed in position and correctly aligned;

(b) control mechanisms should be checked for full and free movement;

(c) mounting and adjustment of auxiliary items should be checked for correct operation for the specific application.

6.11.2 Variable stroke pumps

Process fluid flows are sometimes regulated by controlling the length of stroke from reciprocating piston types of pumps.

Recommendations for the installation of variable stroke pumps are similar to those for variable speed transmission systems described in **6.11.1**.

6.11.3 Variable speed electric motors

6.11.3.1 The speed of a pump, fan, etc. can be regulated by varying the speed of its electric motor.

6.11.3.2 The most common type of variable speed electric motor is the a.c. motor which is powered via a frequency converter. The frequency converter for low power drives is normally provided in a sealed unit. This unit generates heat and should be located where the heat can be dissipated. For high power applications the frequency converter may require forced draught cooling and to protect the equipment the cooling air should be clean and dry.

In addition the following should be taken into account:

(a) because of harmonics generated it may be necessary to use a motor with a higher power rating than that required for a fixed speed application;

(b) it may be necessary to adjust the variable speed unit to match the particular motor to be driven;

(c) stall protection equipment may need to be fitted.

6.11.3.3 Various systems can be used for regulating the speed of d.c. motors.

Section seven. Pneumatic, electrical and hydraulic supply systems

7.1 General

Power supply systems generally used for instrumentation systems and regulating devices, fall into three main categories:

pneumatic
electrical
hydraulic.

In general, the word 'pneumatic' used in this section refers to air; however, if other operating media, e.g. process gases which may be flammable or toxic, are used, special precautions should be taken.

The importance of the correct design and installation of a power supply system to plant operation and reliability cannot be overstressed. Errors in the installation of a power supply system can render the most well designed control system partly or totally ineffective.

7.2 Pneumatic supply systems

7.2.1 Gas quality and operating pressure

7.2.1.1 Compressed air or gas used for supplies to instrument and control systems should be dry, clean and oil-free and, in the case of air, should comply with the following.

(a) The dew point at operating pressure should be at least 10 °C lower than the minimum anticipated ambient temperature.

(b) The air should not contain dust particles larger than 3 μm.

(c) The air should not contain more than 1 p.p.m. mass/mass of oil at 20 °C with the system pressure at 6 bar*.

7.2.1.2 Instrument air should also be free of all corrosive contaminants and hazardous gases, flammable or toxic, which may be drawn into the compressor air intake. If the possibility of contamination exists, the air should be taken from a remote or elevated clean location. Alternatively, the air should be suitably processed.

7.2.1.3 The supply pressure in the plant instrument air header should be suitable to meet the requirements of the control system, usually 6 bar to 7 bar, or should be at least 2 bar above the maximum operating pressure required by any item of instrumentation equipment.

7.2.1.4 The air supply system should be designed to maintain an uninterrupted supply for a predetermined time period (see **7.2.4.2**).

7.2.2 System duplication

7.2.2.1 Air compressors supplying instrument air should have back-up facilities for reliability, either by:

(a) a dual compressor system; or

(b) a standby compressor powered from a different source, e.g. steam or diesel power; or

(c) a cross-over link with the plant air system, which should be suitably conditioned to comply with **7.2.1.1** but which will *not* permit instrument air to be lost to the plant air system.

7.2.2.2 Where two compressors are used, the system should be designed so that either compressor can be isolated for maintenance whilst the other is operating.

7.2.3 Compressors

7.2.3.1 The output capacity of a compressor should be at least 150 % of the total instrument air consumption. Compressors should be suitable for continuous operation, but the design of the compressor/receiver system should ideally be such that the compressor is on load for approximately 50 % of its time in order to increase the long-term reliability of the system and reduce the maintenance costs.

7.2.3.2 The compressor should be capable of delivering air at approximately 2 bar above the pressure for which the air header was designed to work. This is necessary to allow for the pressure drop through the conditioning system, i.e. coolers, driers, filters, etc.

7.2.3.3 Compressors should preferably be of the oil-free type but the lubricated type may be used (sometimes necessary on larger systems) provided the final air quality complies with **7.2.1.1**.

7.2.3.4 A compressor should be supplied with an after cooler and separator to remove most of the free water from the compressed air, and thereby reduce the burden on the dryers.

7.2.3.5 On stop/start compressor systems, a pressure switch should be fitted that controls the duty cycle and hence the receiver pressure. A further pressure switch on the receiver should be included to initiate automatic starting of the standby compressor. Pressure switches used for automatic control purposes should not be used for alarm indication. Separate switches, each with its own isolating valves, should be provided for alarm purposes when required.

7.2.3.6 Continuously running compressors are usually controlled by automatic unloading systems.

7.2.3.7 Facilities should be provided to ensure that cooling water does not flow unnecessarily when compressors are on standby or are shut-down.

7.2.3.8 The noise generated by the compressors should be considered and acoustic treatment applied if necessary to meet the environmental requirements of the plant.

7.2.4 Air receivers

7.2.4.1 For small systems the air receiver is usually integral with the compressor but on larger systems it is usual to employ one receiver served by two compressors. Facilities should be provided to ensure that the receiver remains in service when either compressor is removed for service.

* 1 bar = 10^5 N/m² = 100 kPa.

7.2.4.2 The total air receiver capacity should be sufficient to provide air at an adequately high pressure to ensure continuous operation of the instrumentation for a period of at least 30 min after compressor failure or failure of both compressors on a dual compressor system.

7.2.5 Air dryers

7.2.5.1 Air dryers should be of the adsorptive type, except for very mild climates where the lowest ambient temperature is not likely to be below 10 °C, when a refrigerant type may be considered.

7.2.5.2 Adsorptive type dryers may be of the heat-less or heat-regenerated type and facilities should be provided for automatic regeneration of the desiccant without interruption of the dry air supply. Most systems are designed for automatic regeneration on a time-cycle basis, usually 8 h, but may be automatically initiated by a dew-point detecting device.

7.2.6 Filters

7.2.6.1 Air filters, which should be provided at both compressor inlet (intake filters) and after the dryers (after filters) should comply with the following:

(a) have a high separating capacity;

(b) have a good accumulating ability, i.e. they should be able to collect a large quantity of impurities without any significant decrease in performance;

(c) have a low resistance to air flow.

7.2.6.2 Intake filters are primarily to remove foreign particles and moisture from the incoming air.

They should be carefully positioned to give maximum protection from dust intake and weather conditions, e.g. wind, rain and snow. They should also be easily accessible for maintenance and inspection.

7.2.6.3 The after filters should be capable of removing dust down to a particle size of 3 µm.

7.2.6.4 Oil adsorbers, which may be necessary if the compressor is lubricated, are usually fitted after the compressor and before the dryer.

7.2.7 Cooling water

7.2.7.1 Instrument air compressors are often water cooled. The cooling water is usually initiated by solenoid valves and the flow detected by flow switches which in turn may initiate alarms on low flow or trip the compressor on failure. In addition, temperature switches in the water circuit may be used to detect abnormal flow.

7.2.7.2 Where compressors may be exposed to freezing winter conditions, the cooling water circuits should be heat traced and lagged, especially in systems with 100 % standby, i.e. at least one compressor normally not running.

7.2.7.3 Attention should be paid to the integrity and reliability of the complete cooling water circuit since its loss is the most likely cause of losing all instrument air pressure.

7.2.7.4 Filters should be installed at some point in the cooling water circuit to prevent the deposition of scale, etc. in the compressor cooling surfaces.

They should be of twin design and should be readily accessible for changeover and cleaning.

7.2.8 Valves

7.2.8.1 Isolating valves should be provided in the installation to ensure that all sections of the air supply system can be isolated for maintenance without interrupting the plant operation. In addition, individual isolating valves should be provided for each instrument requiring an air supply.

7.2.8.2 All valves should be easily accessible, capable of tight shut-off and have a low flow resistance.

7.2.8.3 Changeover valves for diverting air services from one dryer to another should preferably be of the ball-valve type.

7.2.8.4 Where ambient temperatures below freezing are expected, consideration should be given to heat tracing the valves and pipework up to the dryer inlet.

7.2.9 Pipework

Recommendations for the design of air supply piping and the sizing of air headers are given in **10.6.2**. After fabrication, air supply piping should be degreased, pressure tested, blown out and sealed until required for service.

7.2.10 Pre-commissioning checks

7.2.10.1 *Compressors.* The manufacturer's pre-start checks and the start-up procedures should be followed.

Small-bore pipes and capillaries, etc. associated with compressors should be checked for leaks or physical damage.

Measuring instruments, pressure and flow switches etc. should be checked for calibration and settings in accordance with section eleven.

All control systems should be checked for correct operation.

7.2.10.2 *Cooling water circuits.* The action and setting of pressure and flow switches and interlocks should be checked for correct operation.

Visual flow indicators should be checked to ensure that they function correctly.

The complete circuits should be checked for leaks.

7.2.10.3 *Air driers.* Heated driers should undergo thorough electrical checks.

Heatless driers should be checked for correct flow of purge air.

The changeover control system should be checked for correct operation.

7.2.10.4 *Air piping and valves.* All air lines should be checked for leaks (see section twelve).

All isolating valves and check-valves should be checked for correct operation.

NOTE. All instruments connected to an air distribution system should be adequately protected by isolation during initial compressor and piping checks.

7.3 Electrical power supply systems

7.3.1 General

This section covers the basic requirements for power supplies to instrumentation systems. The specific requirements for a project would normally be laid down in the project documentation as outlined in section ten.
In addition, reference should be made to the Institution of Electrical Engineers' Regulations for Electrical Installations. However, the following details are given as a guide to be followed in the absence of other information.

7.3.2 Power supply categories

The design considerations for electrical power supplies to instrumentation and control systems should be for the safe and continuous operation of the process plant. On plants where loss of electrical supply to instrumentation and control systems can cause hazards or serious loss of production, it is normal practice to have several separate power supply systems that are each designed to give the required level of reliability.

These power supplies fall into the following categories according to the significance of the apparatus which they supply for the safe operation of the plant:

(a) electrical power supplies that are continuous;

(b) electrical power supplies whose output can be subject to interruption for a short time;

(c) electrical power supplies where longer duration interruption can be tolerated.

It is essential that each instrument and control circuit is connected to the correct integrity of power supply system.

Examples of equipment connected to each power supply type are as follows:

(1) emergency shut-down systems should be connected to type (a);

(2) alarm systems should be connected to type (b);

(3) non-critical analysers should be connected to type (c).

7.3.3 Design considerations

7.3.3.1 Power supply systems should be suitable for the connected apparatus in all respects, i.e. voltage level, voltage stability, frequency, frequency time-keeping and harmonic content.

7.3.3.2 Power supply systems should be designed to afford isolation for maintenance of individual components without affecting the operation of the plant.

7.3.3.3 Power supply systems should be sized initially to have 25 % excess capacity to cater for design modifications. When first commissioned, the system should ultimately be capable of supplying at least 110 % of the maximum design load in order to accommodate later minor additions. Spare circuits should be provided as appropriate throughout the distribution system to permit utilization of the spare capacity.

7.3.3.4 Battery float and boost charging facilities and capacities should meet the requirements of the worst conditions, e.g. minimum and maximum battery room ambient temperatures coupled with the worst simultaneous loading conditions, whilst maintaining the supply within the required parameters.

7.3.3.5 Any float charging system should be so designed that it can maintain full battery charge under all conditions of load.

7.3.3.6 All protective devices should comply with the appropriate British Standards and have proven current/time characteristics.

7.3.3.7 Each circuit, subcircuit and control loop should be individually protected by its own fuse or miniature circuit breaker (MCB). However, where a control loop contains a number of items that can be used independently, consideration should be given to the protection and isolation of individual items.

7.3.3.8 Each shut-down device, system or actuator should generally be individually protected. Where a shut-down system comprises a number of actuating devices and supply failure to part of a system rather than the whole would itself create a hazard, the system rather than the individual items should be protected.

7.3.3.9 Isolation of each individual panel mounted instrument should be provided by a double-pole switch, MCB, disconnecting plug or isolating terminals as appropriate. Supplies to non-critical chart drives only may be grouped (preferably not more than six) to one supply circuit.

7.3.3.10 The local power supply to each item of field mounted equipment should have an individual isolater suitable for the zone classification of the area within which it is installed.

7.4 Hydraulic supply systems

7.4.1 General

7.4.1.1 Hydraulic systems are generally supplied as purpose-built power packs but may be custom-built to a specialized design.

7.4.1.2 The manufacturer of a hydraulic system should be consulted to obtain guidelines for design and installation of the system as there are numerous variations in the features available, such as:

(a) types of hydraulic fluid;

(b) pressure and flow requirements;

(c) speed of response;

(d) power supplies;

(e) standby or back-up systems;

(f) shut-down action.

7.4.1.3 The basis of most circulating hydraulic systems is one or more pumps, an oil reservoir, accumulator and actuators. The accumulator is pressurized with hydraulic fluid by the pumps. The fluid then flows from the accumulator to the actuators as required and returns to the reservoir on a circulatory system.

7.4.2 Hydraulic fluid

7.4.2.1 Hydraulic fluid may generally be of the following types.

(a) *Conventional mineral oil.* This has the advantage of low toxicity but it is a fire risk, particularly at high pressure.

(b) *Synthetic phosphate ester fluids.* These have the properties of resistance to fire but can produce toxic fumes when leaks spray on to surfaces at high temperature.

7.4.2.2 The fluid should have a high viscosity index so as to minimize the effects of temperature. Heating may be required to maintain the viscosity of phosphate ester fluids at low temperatures (e.g. −10 °C).

7.4.2.3 The fluid, O-rings, gaskets and seals of the hydraulic system should be mutually compatible.

7.4.2.4 The fluid may have, depending on the specification, biocidal additives, viscosity index improvers, oxidation inhibitors, corrosion and rust inhibitors, metal deactivators, anti-wear and load carrying agents, foam inhibitors and colouring agents.

7.4.3 Reservoir

7.4.3.1 The reservoir performs the following functions:

(a) it serves as a storage container;

(b) it dissipates the heat generated in the system;

(c) it assists the settlement of solids or contaminants;

(d) it removes entrained air.

7.4.3.2 The reservoir should be designed to hold, between the normal high and the normal low level, sufficient hydraulic fluid to fill the remainder of the system.

7.4.3.3 The reservoir should be located at the highest point in the system to minimize air locks but should be readily accessible. Sufficient vents should be provided at high points to enable the removal of air locks.

7.4.3.4 Inert gas blanketing of the reservoir is desirable to exclude air and thereby reduce corrosion and to prevent a hazardous condition occurring with a combustible hydraulic fluid.

7.4.3.5 If gas blanketing is not used, a permanently open vent should be provided in order to vent gases dissolved in the hydraulic fluid which will be released in the reservoir.

7.4.3.6 Before filling the reservoir the interior should be completely free from foreign matter.

7.4.4 Accumulator

7.4.4.1 The system operating pressure is normally maintained by an accumulator in which an inert gas under pressure is separated from the hydraulic fluid by a membrane or piston. The minimum pressure in the accumulator should be not less than that required to operate any actuator against its maximum load at the required speed, taking into account all pressure losses in the system due to friction, etc.

7.4.4.2 The volume above the high level should be sufficient to empty the drum down to its low level without allowing the system pressure to drop below the minimum operating pressure.

7.4.4.3 The volume between the high and low level should be sufficient to allow normal operation without exceeding these limits.

7.4.4.4 The volume below the low level should store sufficient fluid to move all actuators in the system two full strokes or one full cycle.

7.4.4.5 Gas pressure-type accumulators should comply with BS 5500 and should be provided with a suitable safety valve.

7.4.5 Pumps

7.4.5.1 The normal means of moving the hydraulic fluid around the system is by a pump (or pumps) designed for normal operating flow and pressure.

7.4.5.2 The pump should be capable of passing the flow necessary for the normal requirements of all actuators operating simultaneously plus 200 % of the anticipated leakage.

7.4.5.3 A standby pump should be provided, preferably powered from a different source from the main pump.

7.4.5.4 In the event of total pump failure, the accumulator volume should be sufficient to move all actuators to a safe position.

7.4.6 Filters

7.4.6.1 Although the system should be thoroughly cleaned before commissioning, filters should be used at strategic points in the hydraulic system to remove foreign matter that may occur due to scaling, etc.

7.4.6.2 Filters should preferably be the dual pattern in order to facilitate cleaning without interruption of the system operation.

7.4.6.3 As a minimum, suitable filters should be installed at the pump inlets, the supply line to actuators and the return line from actuators.

7.4.7 Piping

7.4.7.1 The use of stainless steel tubing is preferable on hydraulic systems in order to minimize scale formation.

7.4.7.2 Tubing or piping should be sized according to the requirements of the actuators under emergency conditions.

7.4.7.3 Rigid piping should be firmly clamped to minimize the effects of hammer or vibration.

7.4.8 Flexible hoses

7.4.8.1 Flexible hoses are necessary on actuators to allow relative movements of components and to minimize vibration.

7.4.8.2 The minimum bending radii recommended by the tubing manufacturer should be observed to prevent distortion and subsequent failure.

7.4.8.3 Where there is a potential fire risk, hoses should be of corrugated stainless steel, welded to steel unions or flanges.

7.4.8.4 When installing flexible hoses, a minimum straight length equivalent to twice the outside diameter of the hose (but not less than 25 mm) should be maintained adjacent to each end fitting.

7.4.8.5 Torsional loads should not be transmitted to flexible hose because they may damage the hose or end fittings. Similarly, tensile loads should be prevented.

7.4.8.6 The length of hose should be chosen such that it is not so short that tensile loads are applied, nor should it be so long that excessive sagging results.

7.4.8.7 Elbow couplings, when used, should be fixed to ensure correct alignment of the hose and so avoid side load distortion.

Section eight. Instrument panels

8.1 General

NOTE. This section gives recommendations for the installation of instrument panels, cubicles and consoles.

8.1.1 Categories

Panels fall into two categories:

(a) panels and cubicles mounted in the plant area (see **8.3**).

(b) panels, cubicles and consoles mounted in a control room, computer room or switch house (see **8.4**).

8.1.2 Works inspection and testing

Before the panels leave the manufacturer's premises it should be ensured that:

(a) all mounted equipment carries the manufacturer's certificate of test;

(b) all wiring has been checked for continuity;

(c) all logic switching has been checked using an appropriate plant simulator;

(d) all air lines have been pressure tested.

The customer's responsible engineer should also have completed a check against the specification (see **11.5** for air lines and **11.6** for wiring tests).

8.2 Handling and reception

8.2.1 All panels, cubicles and consoles are normally supplied to site prefabricated and prewired and should be checked against the design specification as soon as possible after receipt.

8.2.2 On arrival at site, crates that show obvious signs of being damaged should not be opened until a representative of the company supplying the panel or his haulage contractor is present, and then only when provided with protection from the weather.

8.2.3 Large panels for assembly on site normally arrive in a coded sequence of crates which should be transported to an allocated area, as close as possible to the final position of the panel, before being opened.

8.2.4 Crates should only be lifted by using such hooks as are provided and spreaders should be used to avoid the possibility of a crate being crushed by its own weight. The slinging of crates using a running eye should never be allowed even to obtain a purchase under the base of the crate itself.

Some panels are not suitable for assembly on site and are delivered as an integral unit. In such instances, they can constitute a handling problem which may be solved by fitting manufacturer's assembly trolleys, skids, etc.

8.2.5 Uncrated panels

Uncrated panels should be carefully lifted using points specifically labelled by the manufacturer and observing the following precautions:

(a) unevenly distributed loads should be balanced;

(b) undue stress in light gauge panelled areas should be avoided;

(c) damage to surface finish by lifting tackle should be avoided;

(d) damage to instruments, etc. projecting from panels should be avoided.

Lifting operations should be under the direction of *one* person (made wholly responsible for the operation) who should ascertain suitable lifting points and sling points.

8.3 Locally mounted panels and cubicles

8.3.1 Location

The duties of the plant operator primarily determine panel location. However, the adverse effects of overhead pipes and services, the possibility of tank overflow and the difficulty of access to the panels themselves should also be considered. Panels should be located as far away as possible from dusty or hot processes and should not stand on or over drains, cable ducts and conduit, piping ducts or runs, or any service other than those used for instrumentation.

8.3.2 Electrical interference

The need to minimize electrical interference from adjacent electrical equipment and cables should also be considered (see section ten). The position chosen should be easily accessible for delivery of the prefabricated panel, i.e. access should not be blocked by plant equipment and permanent or temporary structures.

8.3.3 Support and fixing

When installing panels the maximum allowable floor loading should be checked (this particularly applies to those installed on suspended floors). As methods of construction vary widely, no typical figures can be given and specialist advice should be sought. Where necessary, levelling facilities and/or anti-vibration mountings should be provided.

Panels should always be mounted on a plinth of steel or concrete. Where conditions are likely to be wet, the plinth should preferably be tiled and suitable drainage provided. The plinth should have a minimum height of 130 mm, which should be taken into consideration at the design stage when determining instrument height. The recommended minimum distance from the edge of a concrete plinth is 100 mm for expanding type fixings and 75 mm for embedded bolts.

When making final connections to the panel, care should be taken not to nullify the effects of any anti-vibration mounting. If the panel base is of open construction and the ingress of dust has to be prevented, the panel may have to be mounted on a suitable compressible gasket. With such an arrangement care should be taken to provide adequate bonding and earthing to prevent the existence of a dangerous difference of potential between the panel and earth. In any event, the metalwork of all panels and cubicles should be earthed (see **10.7.5**).

8.3.4 Termination of wiring and tubing

8.3.4.1 The use of terminal rails (electrical and pneumatic) for the connection of input/output signals is strongly recommended, as they facilitate testing and interconnections. On panels with few input/output signals direct connection to instruments may be acceptable. Cables and wiring should be ferruled and identified in accordance with **10.7.4.4**.

8.3.4.2 Where multicore tubing and/or cables are used for field signals, junction boxes and marshalling cubicles should be provided; electrical and pneumatic signals should be separated preferably with dedicated junction boxes. For more complex systems it is advantageous to mount such junction boxes externally to the panel as this allows:

(a) increased flexibility of testing;

(b) simplified changes to the plant control system;

(c) easier changes in the panel position;

(d) less individual multicore cables entering the panel which minimizes cross-over of individual cores at panel termination where space is at a premium.

NOTE. It is necessary that intrinsically safe circuits should in all cases be segregated from other circuits.

8.3.5 Completion

After completion of cable and tube installation all entry holes should be sealed.

8.4 Instrument panels, cubicles and consoles mounted in control rooms, computer rooms or switch houses

8.4.1 General

Panels, cubicles and consoles mounted in control rooms, computer rooms or switch houses will usually be delivered to the site prefabricated, prepiped and prewired. All circuits and equipment will normally have been tested at the manufacturer's works, before despatch, but all tests should be repeated on site after the interconnecting cabling and tubing has been installed between panel sections, consoles, marshalling racks, etc., as applicable.

8.4.2 Location

The location will normally be specified in the original design of the control room in detail and suitable civil works prearranged. Control room panels are usually programmed for delivery after the control room is substantially complete. Liaison with the site engineer is essential to ensure that clear access is available and that the room is weathertight, warm and dry. If the control room is located inside the plant, the installation of mechanical equipment should be programmed to ensure that access for the panel is provided.

If control room walls have to be left unfinished to allow access for the panels, great care needs to be taken to protect the panels and equipment whilst civil engineering work is being completed.

8.4.3 Support and fixing

All support and fixing arrangements should be specified in detail in the original design of the panel. In some cases, however, the size of the complete panel may be such that it is necessary to break it down into two or more sections for packing, handling and transport. In such cases care should be taken during the installation to ensure correct alignment of the sections and correct connection of all cables and pipes between adjacent sections. All interconnected circuits should be tested.

8.4.4 Handling and reception

The recommendations in **8.2** apply but where panels or cubicles are supplied in more than one section and are assembled on site it may require the attendance of the responsible engineer during testing of the circuits.

8.4.5 Environmental considerations

Where a control room, computer room or switch house is situated within the plant it is likely that the room will be air-conditioned or be isolated (by air locks) to prevent entry of hazardous gases and fumes. In such cases all cable and piping entries between cubicles and the plant should be sealed to ensure airtightness at the interface.

It is bad practice to install control room and computer equipment in an unsuitable environment and every effort should be made to ensure the air conditioning, etc. is operating before installing the equipment.

NOTE. For further information on air conditioning see **9.3.2**.

Section nine. Electronic systems

9.1 General

Electronic systems should be installed generally in accordance with the relevant guidelines given in other sections. However, because of the nature of electronic systems, additional requirements apply and in particular those that concern the installation phase of a project are considered.

Examples of such systems are process control computers, shared-display control systems, programmable multi-loop controllers and computer-based data loggers.

9.2 Lifting and handling

9.2.1 On arrival at site all crates should be visually inspected for any signs of damage. Any damaged crates should be opened in the presence of either the supplier or his haulage contractor.

9.2.2 Crates containing computer equipment should not be opened until a suitable environment can be guaranteed (see **9.3**).

9.2.3 Where practicable all major movements of the equipment should be completed before the crates are opened.

9.2.4 Crates should be slung in accordance with the manufacturer's recommendations.

9.2.5 Particular attention should be paid to any warnings displayed on crates such as 'fragile', 'delicate' or 'handle with care'; this is important because some electronic system components are very susceptible to mechanical shock and could sustain damage. Any such crates should be handled with extreme care.

9.2.6 Data memory media such as disks, diskettes and tape cassettes should be transferred directly from their crates to a suitable protective storage area which, ideally, should be a steel cabinet that can be locked. Magnetic storage media are temperature-sensitive and should be stored at a suitable temperature according to the manufacturer's instructions.

9.3 Location and environment

9.3.1 General

Electronic systems are susceptible to the effects of exposure to moisture, chemical attack and dirt. Therefore, particular attention should be paid to the operating environment if their long-term reliable operation is to be assured.

9.3.2 Air conditioning

9.3.2.1 Atmospheric contamination should not exceed the limits specified by the manufacturer. In general this means that a computer room should be completed before the equipment is moved to the room and before it is unpacked. Concrete surfaces below false floors and above false ceilings should be sealed before the room can be considered as being completed and ready to receive equipment.

9.3.2.2 Where the equipment is to be located in a room that is to be held at a positive pressure in order to prevent the ingress of contaminants, prior checks should be made in the room to ensure that an acceptable positive pressure can be maintained indefinitely before the equipment is installed.

In installations where the pressurizing air is unfiltered a check should be made to ensure that the siting of the intake is such that the ingress of contaminated air will not occur. If the pressurizing air is to be taken from a contaminated area then a check should be made with the supplier to ensure that the correct filters have been fitted to the ventilation system.

9.3.2.3 Before the equipment is moved into the room a test should be made to ensure that the air conditioning or ventilation system is capable of dissipating the maximum heat generated by the equipment. This may be done by running portable heaters whose total combined wattage is equal to that of the total heat generated by the system in the computer room and monitoring the temperature at strategic locations. If time is available this test should be run over a period of several days in order to confirm the reliability of the air conditioning/ventilation system under continuous operation.

For these tests to be effective, correct allowances should be made for possible variations in ambient conditions.

9.3.2.4 During the test described in **9.3.2.3** the relative humidity in the computer room should be checked in order to ensure that the equipment operating environment complies with the manufacturer's specifications.

9.3.2.5 Care should be taken to ensure that no item of equipment is exposed to direct or indirect sunlight as this can cause severe local heating problems.

9.3.3 Ventilated environments

In many applications small dedicated systems such as programmable logic controllers or certain elements of larger systems may be installed on panels, in closed cubicles or in wall mounted boxes.

Such equipment is normally designed not to require full air conditioning. However, care should be taken to ensure that adequate ventilation is provided, particularly in the case of closed cubicles and wall mounted boxes. Additionally, in dusty or dirty environments, incoming air should be filtered to prevent fans and heat sinks being rendered ineffective.

In damp environments particular attention should be paid to the seals on doors and covers in order to ensure that they are able to prevent any ingress of moisture.

9.3.4 Vibration

Equipment should not be mounted in an area where it could be subjected to excessive vibration. Particular attention should be paid to electromechanical devices such as disc drives and drum storage devices. Permissible vibration levels should be obtained from the manufacturer.

9.3.5 Magnetic fields

Data memory media such as disks, diskettes and tape casettes should not be stored near, or exposed to, strong magnetic fields, as exposure to such fields can cause data corruption.

NOTE. Magnetic data memory media should not be placed on top of disc drives as these also generate high magnetic fields which can cause partial or complete erasure of the data.

9.3.6 Video equipment location

Video terminals containing cathode ray tube (CRT) displays should be located away from strong magnetic fields as such fields can severely distort the displayed image. Although this is not normally a problem in computer and control rooms, it can be in the case of field-mounted terminals and care should be taken over their location.

9.3.7 Lighting

9.3.7.1 Particular care should be taken to ensure that lighting arrangements do not reduce the visibility of CRT display units. The optimum position will vary depending on the design of the display unit, but in general the unit should be positioned such that the incident light from overhead lighting does not fall across the screen making it difficult to read*.

9.3.7.2 The positioning of lighting units should be such as to allow maintenance staff to have access without having to climb on to the control equipment.

9.3.7.3 When selecting the optimum location of CRT display units, care should be taken to avoid the possibility of sunlight falling on to any CRT displays.

9.3.8 Maintenance access

9.3.8.1 When positioning equipment particular attention should be paid to the manufacturer's recommendation for maintenance access. Provision should be made for power outlets to be located close to the major hardware items in order that power for the test equipment can be provided safely and conveniently.

9.3.8.2 When positioning printing terminals and line printers, space should be allowed for the paper feed bin and paper catcher.

9.3.8.3 Rows of cubicles should be positioned to allow all doors to open fully. Doors should be hung in such a way that they do not impede emergency escape routes.

9.3.9 Radio-frequency interference

The manufacturer should be consulted to determine whether the equipment supplied is susceptible to r.f. interference. If it is, then the use of portable radio transmitters should be banned in the sensitive vicinity of the equipment. Any other possible sources of r.f. interference should be avoided.

9.3.10 Authorized access

On industrial sites it is likely that new equipment attracts attention from unauthorized personnel, particularly when it is located in clean, dry and warm conditions. In order to protect the equipment a security system should be provided to prevent them from gaining access. Such a system should be implemented immediately after the equipment is removed from its crates.

9.4 Earthing

9.4.1 Adherence to design specification

NOTE. For further information on intrinsically safe systems see section three.

9.4.1.1 Correct system earthing is critical to the safe and reliable operation of instrumentation systems and particularly so for computer installations and in distributed control systems. Manufacturers of such systems should therefore specify the system earthing requirements in detail.

9.4.1.2 The size of cable used should be in accordance with the design specification. The use of smaller or incorrect cables could significantly degrade the performance and safety of the earthing system.

9.4.1.3 Earth connections from each individual unit should be connected directly to the system earth bus. It is not recommended to connect to the system earth bus by loop connections between units.

9.4.1.4 During the installation care should be taken to ensure that all parts of the system including cables and joints are adequately protected against the possibility of damage or corrosion.

9.4.2 Integrity of the earthing system

9.4.2.1 Where the system design specifies a separate and dedicated earthing arrangement, care should be taken to ensure that no items of equipment other than those specified are connected to that dedicated earth.

9.4.2.2 Where the system design specifies a single connection from the computer/instrumentation equipment to the main plant earth bus, care should be taken to ensure that no additional items are connected via this single connection to the earth bus.

In such systems a removable link is normally provided to connect the equipment earth to the main plant earth bus. During the installation of the earthing system tests should be carried out at intervals to ensure that with the links removed the two earthing systems remain isolated. On completion of the installation a final test should be carried out again to ensure that the two systems remain isolated. The removable link should be clearly labelled with a warning indicating that it should only be removed following

* Further information may be found in the Chartered Institute of Building Services Technical Memorandum TM6 'Lighting for visual display units'.

disconnection of all supplies to the associated computer/ instrumentation system.

9.4.2.3 Computer/instrumentation earth cable should be clearly identified at its termination points and at regular intervals along its length.

9.4.2.4 In electronic systems where the frame of the system enclosure is earthed via the computer/instrumentation earth, the enclosures should be insulated from structural steelwork or any other plant earth. In such cases care should be taken to ensure that it does not contravene local safety regulations with regard to the relative earthing of adjacent equipment housings.

9.4.3 Earth resistance

9.4.3.1 Where the system design specifies a separate and dedicated earthing arrangement, a maximum earth electrode resistance should be stated in the design. Once the system is installed a check should be made in order to confirm that this figure has not been exceeded.

This check can be carried out by employing two auxiliary or reference electrodes and a megohmmeter as shown in figure 42. By passing an alternating current I between the system electrode and the reference electrode (RE2) and measuring the voltage V between the system electrode and the reference electrode (RE1) the earth electrode resistance can be computed by simply dividing V by I.

NOTE. For additional information on earth electrode resistance measurements see CP 1013 and the IEE Regulations for Electrical Installations (the Wiring Regulations).

9.4.3.2 Where the system design specifies a single connection from the computer/instrumentation system to the main plant earth bus, the recommendations given in **10.7.5.2** should be followed.

9.5 Power supply

9.5.1 Quality of supply

9.5.1.1 A power line disturbance monitor should be connected to the power supply for a period of 1 week to 2 weeks to ensure that the supply meets the minimum requirements laid down in the equipment manufacturer's specification. This test should be carried out immediately after completion of the power supply installation thus allowing the maximum period of time for any necessary modifications prior to the delivery of the computer/ instrumentation equipment.

9.5.1.2 Before connecting the power supply to any item of equipment the information on the manufacturer's data plate on the equipment should be examined in order to ensure that the equipment is compatible with the power supply provided.

9.5.2 Standby or back-up power supply systems

Standby or back-up power supplies such as dual a.c. inverter and battery systems should be tested, where possible, with dummy loads prior to their connection to the computer/instrumentation equipment.

A power line disturbance monitor should be connected to the supply during these tests in order to ensure that the supply remains within the minimum requirements laid down in the equipment manufacturer's specification.

9.5.3 Temporary power supplies

It may become necessary to provide a temporary power supply prior to completion of the permanent supply. Care should be taken to ensure that the temporary supply is secure and meets the system power supply requirement.

9.5.4 Continuity of supply

Whilst most process control systems are provided with power fail/auto restart facilities, it is not recommended that systems be subjected to continual and repeated power failures as such treatment can result in the degradation of system performance. Every effort should therefore be made to maintain continuity of supply once power has been applied to a system.

9.6 Protection

9.6.1 Smoke detection

Smoke detection systems , if specified, should be installed and fully tested by the supplier before the computer/ instrumentation system is left powered up and unattended.

9.6.2 Fire

The fire extinguishing system should be installed and fully tested by the supplier before the computer/instrumentation system is left powered up and unattended.

Where gas flooding systems are employed, installation personnel should be made aware of safety procedures associated with such systems.

9.6.3 Lightning

Lightning protection units should be employed where an electronic system is connected to a data transmission line that may be subject to electrical interference, i.e. lightning. The purpose of such units is to protect the system from high voltage transients that may be induced in the data transmission line.

(a) Lightning protection units should be installed as close as possible to the equipment being protected, and strictly in acccordance with the manufacturer's recommendations.

(b) Care should be taken to ensure that the equipment being protected is earthed through the lightning protection unit.

NOTE. Where the equipment being protected has its electronic components insulated from its metal case then the metal case may be earthed locally.

(c) Input and output cables should always be taken through separate glands and segregated to avoid high voltage transients bypassing the unit.

(d) Particular care should be taken to ensure high integrity of the earthing arrangements of lightning protection units. The effectiveness of the unit is heavily dependent on compliance with the manufacturer's earthing recommendations.

9.6.4 Electrostatic discharges

9.6.4.1 Static charges are transferred to non-conductive surfaces when contact between two surfaces is broken. High static charges can for example build up in printer paper stacks due to the continual making and breaking of contact that the print head makes with the paper. A high static charge may also build up on personnel as they walk around the computer/control room. Static build up is higher when the humidity is low. If such charges are allowed to discharge through the system then an erratic system response or a system failure will invariably occur.

In order to minimize static build up, conductive paths to earth should be provided within the equipment, their effectiveness being dependent on the earthing of the system.

9.6.4.2 If during commissioning the system should fail erratically a thorough earthing check should be made to ensure that a conductive path to earth exists to prevent static build up.

9.6.4.3 In order to minimize the risk of problems due to static electricity, the humidity in the computer/control room should not be allowed to fall below the equipment manufacturer's recommendations.

9.6.4.4 The clothing worn by personnel working on the equipment should not be susceptible to static build up, i.e. nylon overalls, etc. are not suitable.

9.6.4.5 Should problems arise if static is built up when personnel move about then anti-static mats should be placed around the equipment in order to ensure that any static is discharged before contact is made with the equipment.

NOTE. Further information is available in BS 5958.

9.6.5 Electric arc welding

Some types of interface equipment may be susceptible to damage by excessive induced voltages which can be generated by electric arc welding sets, e.g. as a result of poor earth return paths.

To eliminate the possibility of damage from this source the interface equipment should be isolated from plant cables while any electric welding operations are in progress.

9.7 Data transmission systems

9.7.1 Signal cables

Recommendations for signal cables are given in section ten.

9.7.2 Semi-rigid coaxial cables

9.7.2.1 Prior to installation the cable should be checked on its drum with a time domain reflectometer in order to verify that it is undamaged.

9.7.2.2 The cables should be installed in accordance with the manufacturer's recommendations. Particular attention should be paid to the minimum bending radius permitted and the recommended method of securing to the cable tray, etc. Any distortion in the cable due to a too small bending radius or incorrect clamping could render the cable incapable of high frequency transmission.

9.7.2.3 The cables should be spliced and terminated by the manufacturer's representative.

9.7.2.4 Prior to connection to the computer/instrumentation system the installed cable should be checked with a time domain reflectometer in order to verify that the installation has been completed without damage to the cable.

9.7.3 Fibre optic cables

Recommendations for fibre optic cables are given in section ten.

9.7.4 Modems

9.7.4.1 Modems should be connected to the data transmission line and the data source in accordance with the manufacturer's recommendations, taking particular care to ensure that the correct terminals are employed for the particular application.

9.7.4.2 Where applicable the transmit level should be set up in accordance with the manufacturer's recommendations for the specific application.

9.7.4.3 Before commissioning a data transmission link a check should be made on the modem pair to ensure that all loopback facilities are disabled. Should problems be experienced with the link then the loopback facilities may be employed to assist in the diagnosis of the fault (see figure 43).

9.8 Field equipment

Recommendations for field equipment are given in section ten.

9.9 Commissioning

9.9.1 Special test equipment

The manufacturer should be consulted early in the project in order to establish what, if any, special test equipment will be required to commission and maintain the system.

9.9.2 Commissioning spares

An adequate supply of spare parts should be available on site during the commissioning period in order to minimize delays should any equipment fail. Where possible, spare parts should be tested on receipt at site.

9.9.3 System support

9.9.3.1 Complex electronic systems require a high standard of technical support.

9.9.3.2 A full set of documentation including software listings should be available to the commissioning team prior to commencement of commissioning.

9.9.3.3 Valuable time may be saved by having a representative from the manufacturer present during critical commissioning periods.

9.9.3.4 In order to optimize the performance of the commissioning team they should have completed the manufacturer's recommended training courses on the equipment prior to commencement of commissioning.

9.9.3.5 A system log book should be established immediately after the system is first powered up. This log should detail every problem encountered together with its solution, every change or modification made and any other comments pertinent to system performance. This form of record can be a useful diagnostic aid, particularly if intermittent system faults are encountered.

9.9.4 Software

9.9.4.1 All disks, diskettes, etc. supplied by the manufacturer are normally uniquely labelled and dated prior to their shipment. A log should be created referencing these unique labels in order to record software updates or modifications implemented during the commissioning period.

9.9.4.2 A disk/diskette updating procedure should be established in order to ensure that any changes made as the commissioning proceeds are permanently recorded on disk/diskette rather than just in the processors memory.

9.9.4.3 For data security reasons at least two copies of each disk/diskette should be maintained and be accessible to the commissioning team. The second or back-up pack should be clearly labelled 'Back-up'.

9.9.4.4 In addition to **9.9.4.3** a master set of disks/diskettes should be held in a secure location in an area remote from the computer/control room. These masters should be updated at intervals dictated by the rate at which changes are being made. These packs should be clearly labelled 'Master'.

9.9.4.5 Any application disks/diskettes generated on site should be referenced and logged as in **9.9.4.1**.

NOTE. Reference numbers should not be written directly on the cover of floppy diskettes with a pencil or ballpoint pen as the pressure required can cause damage to the recording media and thus corruption of the stored data.

9.9.4.6 Disk packs should be maintained within ± 3 °C of the operating ambient temperature for at least 4 h prior to their use.

9.9.4.7 Should a system crash occur it is important, if the cause of the crash is to be identified, to record various system parameters. This is normally achieved by running a crash dump program prior to restarting the system.

The procedure for running the crash dump program together with the restart procedure should be clearly defined and available to the commissioning team in order to enable a timely recovery from system crashes. Any crash should be recorded in the system log referred to in **9.9.3.5**.

9.9.5 Loop checking

Recommendations for loop checking are given in **11.7**.

Section ten. Piping and wiring

10.1 General

This section gives general guidelines for the design, construction and installation of piping and wiring and should be followed unless overriding instructions are given. Recommendations on the storage of equipment prior to piping and wiring are also included.

10.2 Installation and documentation

Installation should be carried out by skilled personnel using the best engineering practices. Contract documents should contain the following.

(a) The scope of the work to be carried out and demarcation of responsibilities between the parties involved.

(b) The extent of the material to be supplied.

(c) Drawings and documentation giving full details of installation requirements and references to the relevant standards that apply.

(d) Terms and conditions of contract relating to the work on a particular project covering such things as workmanship, tidiness and safety, i.e. when the work is to be carried out by a contractor or subcontractor.

10.3 Installation drawings

10.3.1 Provision should be made on a plant site for a drawing register to be maintained and it is important that only the current editions of drawings which contain the latest revisions are used.

10.3.2 The drawings and documentation covering the instrument installation that are usually provided for a specific project would, for example, comprise the following.

(a) *Engineering flow diagrams.* Schematic drawings of the equipment, piping and control systems making up the plant or process which are sometimes referred to as P and I (Piping and Instrument) diagrams.

(b) *Instrument schedule.* Lists of all instrument items by tag number and providing an index to the applicable purchase order requisitions, specifications and installation drawings.

(c) *Instrument loop schematics.* Diagrams showing the connections between the components of instrument and control loops and identifying pneumatic and wiring connections, terminals, cables and core numbers (as applicable).

(d) *Logic diagrams and control schematics.* Drawings showing the schematic logic of interlock and shut-down systems and special control circuits.

(e) *Instrument location drawings.* Area layout drawings on which are shown the approximate location of instruments, tapping points, panels, control valves, etc. and the proposed routing of air headers, transmission tubing and wiring.

(f) *Instrument installation details.* Hook-up drawings showing piping and mounting arrangements for the various instruments, with an itemized material list for each arrangement.

(g) *Panel layout drawings.* Drawings showing the positions of instruments mounted on panels and overall panel dimensions.

(h) *Panel piping and wiring diagrams.* Panel layout drawings showing the position and connections for incoming multicore tubes and/or cables.

(i) *Control room layout drawings.* Drawings showing positions of control panels and auxiliary racks in the control room and the routing of connection tubes and/or cables.

(j) *Multicore cable and tubing routing.* Overall plot plan showing the approximate locations of the main junction boxes and the routing of the multicores. Where applicable, cable trench cross sections and cable tray layouts are also shown.

(k) *Junction box layouts.* Drawings giving details of individual junction boxes showing the cabling connections, terminal details and identification.

(l) *Cable/tubing schedules.* Lists of all instrument multicore cabling/tubing with lengths, sizes, connection points, core identification and relevant technical information.

(m) *Installation material summary.* Details of the material quantities required for the installation of each instrument and the total quantities ordered or to be provided.

(n) *Instrument specifications.* Technical specifications and design data for each instrument.

10.4 Instrument protection and storage

10.4.1 Instruments and panels that cannot be installed upon delivery should be housed in a properly constructed and heated store and protected from dust and damp. Completion of control rooms should be programmed to permit the installation of panels immediately upon receipt and so minimize handling. If the control room heating system is not in operation, temporary heaters should be installed to ensure that the panels and instruments are kept warm and dry.

10.4.2 Throughout the construction period, instruments that are not provided with housings should be protected by covering with heavy duty plastics bags or where necessary by applying more robust protection.

10.5 Instrument mounting and accessibility

10.5.1 Each instrument or item of equipment to be installed should be inspected to check that its data plate agrees with the specification and that it has been pre-tested (see section eleven). The instrument should then be installed in its intended location, e.g. on brackets, sub-panel, mounting post or process connection, ensuring that it is levelled, vertically plumbed and firmly secured.

In all installations the manufacturer's specific requirements should be rigorously followed.

10.5.2 Where necessary, instruments should be secured to the nearest suitable firm steelwork or masonry so as to be, as far as possible, unaffected by vibration. Process lines or handrails should not be used for supporting instruments.

10.5.3 Instruments should be located so that they do not obstruct walkways or equipment and so that they are afforded the maximum protection from damage that might be caused by passing or falling objects. They should also be clear of drainage points for condensate, water and process fluids from adjacent plant equipment.

10.5.4 All indicating instruments and instruments requiring adjustments should be accessible for servicing from floor level, walkways, permanent ladders or platforms. Orifice plates, line mounted flow transmitters, thermocouples, etc. may be accessed by temporary means if they are less than 6 m above floor level. Above 6 m they should be provided with permanent access.

NOTE. In some instances, portable platform access may be considered suitable.

10.5.5 Post-mounted instruments should be located at a height of between 1.2 m and 1.4 m above floor level on permanent platforms, unless site conditions dictate otherwise, e.g. where vibration could be a problem, a shorter post may be desirable.

10.5.6 All indicating instruments should be readable from floor level or permanent platforms. Gauge glasses should be visible from access ladders and preferably visible from any control valve that controls the vessel level.

10.5.7 When locating post-mounted flowmeters for liquid or steam service, care has to be taken to ensure that the elevation of the orifice installation is suitable so that sufficient slope in the impulse piping is obtainable.

10.5.8 Control valves should be accessible from floor level or permanent platforms. Clearance should be allowed above a control valve to allow for servicing of its actuator and also below for servicing the valve internals, where applicable. Suitable clearances should also be allowed to give access to manual handwheels and valve positioners.

NOTE. For additional considerations for control valve installations, see section six.

10.5.9 Care should be taken in locating tapping points to keep the impulse lines as short as possible, at the same time enabling control instruments to be mounted as close as possible to their associated control valves.

10.5.10 Brackets and supports should be protected against corrosion, e.g. by adequate priming and painting. Where supporting steelwork or cable trays are cut or drilled, the exposed surfaces should also be primed and painted.

10.5.11 Mounting materials containing asbestos or asbestos in non-composite form should not be used as this may present a health hazard.

10.5.12 Mounting materials should be selected so as to prevent electrolytic corrosion.

10.5.13 Care should be taken to ensure that the forces developed by the expansion of piping or vessels will not damage instruments or impulse piping.

10.5.14 All pressure instruments fitted with blow-out vents should be mounted with a clearance of at least 25 mm between the vent and nearest obstructing surface.

10.5.15 On completion of installation, all field mounted instruments, air header isolation valves, tubing and wiring terminations, should be identified by permanent labelling.

10.6 Instrument piping and tubing

10.6.1 General

10.6.1.1 *Classification.* Instrument piping and tubing can be classified according to their service as follows:

(a) air supply piping (see **10.6.2**);

(b) transmission/signal tubing (see **10.6.3**);

(c) process impulse piping (see **10.6.4**).

10.6.1.2 *Routeing and location.* Instrument piping and tubing should be routed bearing in mind the following considerations such that, where possible, they:

(a) are kept as short as possible consistent with good practice and accessibility;

(b) do not obstruct traffic through the process plant;

(c) do not interfere with the accessibility or removal of process equipment, e.g. pumps, motors and exchanger bundles;

(d) avoid hot environments and potential fire-risk areas;

(e) will not be subject to mechanical abuse, e.g. used as a step;

(f) avoid areas where spillage is likely to occur, e.g. from overflowing tanks;

(g) are clear of drainage points of condensate, water and process fluids from adjacent plant equipment;

(h) avoid areas where escaping vapours or corrosive gases could present a hazard;

(i) avoid process piping and are provided with sufficient clearance from piping which may require lagging.

10.6.1.3 *Installation*

10.6.1.3.1 Stainless steel pipes or tubes, particularly those containing flammable, toxic or corrosive materials, should not be located where, in the event of fire, there is the chance of molten zinc falling on to the stainless steel from associated galvanized structures, zinc chromate paint, etc. because of the dangers caused by zinc embrittlement of stainless steel.

10.6.1.3.2 Pipes or tubes installed, but not connected, should have their ends closed to prevent the entry of foreign material either by adhesive tape for short durations or caps/plugs for long periods.

10.6.1.3.3 When instrument pipes/tubes are run parallel to each other, joints should be systematically staggered and neatly offset.

10.6.1.3.4 Horizontal runs of pipes and tubes should be laid vertically one above the other as far as possible and should be run with the minimum number of changes of direction consistent with good practice and neat appearance.

10.6.1.3.5 Unless otherwise specified by the responsible engineer, PTFE tape may be used as a thread sealant for screwed fittings, provided the service operating conditions permit, except on instrument air signal lines which are not protected by a filter (see **10.6.3.1.5**).

10.6.1.3.6 Where modifications are made to existing pipework or tubing systems involving threaded joints, it is essential that traces of previously applied sealant are removed from threads before the connections are remade.

10.6.1.3.7 The number of joints in pipework should be kept to a minimum consistent with good practice.

10.6.2 Air supply piping

10.6.2.1 Typically, air supply piping (½ in nominal bore and above) between the main air header and the instrument air filters will be galvanized steel with screwed fittings. Other materials may be specified during the design phase, such as black steel, ABS or copper. Where other materials are used reference should be made to the British Compressed Air Society's 'Guide to the selection and installation of compressed air services'. Rigid PVC is an unsuitable material.

10.6.2.2 Branch headers should be installed so that they are self draining and have adequate drainage facilities. On small headers this will normally be achieved via the instrument air filter/regulators but on larger headers blow-down valves should be provided at low points.

10.6.2.3 Where the size of instrument air supply piping has not been specified, it should be chosen from table 3; these sizes are based on a minimum pressure of 4 bar at each take-off point.

Table 3. Air header sizing guide

Numbers of users	Line size	Metric equivalent
		mm
1	¼ in n.b.*	6
2 to 5	½ in n.b.	15
6 to 20	1 in n.b.	25
21 to 50	1 in to 1½ in n.b.	40
51 to 100	2 in n.b.	50
101 to 200	3 in n.b.	80

* Nominal bore.

NOTE. A user is an instrument using approximately 0.015 N·m³/min.

10.6.3 Transmission/signal tubing

10.6.3.1 *Pneumatic tubing*

10.6.3.1.1 Tubing is generally used for the transmission of pneumatic signals which are normally in the range of 0.2 bar to 1.0 bar.

10.6.3.1.2 Long pneumatic transmission distances should be avoided.

10.6.3.1.3 The tubing size normally used is 6 mm outside diameter × 4 mm bore.

10.6.3.1.4 Tubing fittings should be compatible with or of the same material as the tubing to which they are connected. Brass fittings are usually used with copper tubing. Care should be taken to ensure that the only fittings used for the installation are those that are required in the design specification.

10.6.3.1.5 PTFE tape should not be used as a thread sealant on instrument air lines downstream of filter regulators, including transmission and controller output signals. Where required, a sealing compound should be used, applied sparingly so that no intrusion of the compound into the air lines occurs.

10.6.3.1.6 All pneumatic signal tubing should be cleaned by blowing through with filtered air before connection to instruments.

10.6.3.1.7 Plastics tubing that is in conduit or closed ducting should not have through-couplings but where these cannot be avoided, they should be made at special junction boxes to be provided for this purpose. The entry to and exit from such conduit or closed ducting, and any joints, should be clean and not have sharp edges or burrs.

10.6.3.1.8 Sufficient slack should be provided in all air tubing to avoid strain on the instrument connections and to facilitate dismantling of the instruments. All control valves and direct vessel-mounted transmitters should have an extra loop in their air tubing to allow maximum flexibility.

10.6.3.1.9 Where permanent enclosures, trunking or conduits are used to contain tubing, adequate spare space should be allowed internally; preferably not more than 50 % to 70 % of the cross-sectional area of the enclosure should be occupied by signal lines. A galvanized draw wire of adequate size should be left in the enclosure to enable additional tubes to be pulled in at some future date. Where condensation is likely to occur in trunking, etc. drain holes at the lowest points should be provided.

10.6.3.2 *Multicore tubing*

10.6.3.2.1 Where a number of tubes are run together on the same route a multicore construction, usually comprising 4, 7, 12 or 19 tubes laid-up and sheathed overall with PVC, is generally more economical.

10.6.3.2.2 Additional mechanical protection may be provided by steel wire or tape. Lead sheathing (or suitable barrier material) should be considered when there is a possibility of solvents or acids attacking the plastics tubing; this is especially the case with underground services where hydrocarbon spillage could occur.

10.6.3.2.3 Multicore tubing should not be bent in a radius less than that recommended by the manufacturer. Normally, this is not less than eight times the overall diameter of the multicore.

10.6.3.2.4 Special care should be taken with multicore tubing having an outer sheathing of PVC when it is being installed at low ambient temperatures. Normally, installation should only take place when the temperature of the multicore cable and the ambient temperature are above 0 °C and have been kept above 0 °C for at least 24 h.

NOTE. Special grades of sheathing are available and should be used for applications where the temperature is likely to remain low for long periods.

10.6.3.2.5 Multicore tubing should be terminated in the field using junction boxes similar to those used for electric cables (see figure 44) but provided internally with bulkhead couplings.

To minimize the length of individually run tubes, the location of junction boxes should be as near as possible to the related instruments.

10.6.3.2.6 An allowance of 10 % to 25 % spare capacity should be provided in each junction box and all spare pneumatic tubing should be connected to the bulkhead couplings.

10.6.3.2.7 In control panels or cubicles, multicore termination should be made direct to bulkhead fittings located on a mounting plate (see section eight).

10.6.3.3 *Types of tubing.* Tubing material should be selected to meet the environmental conditions of the plant. Materials in common usage are described as follows.

(a) *Copper.* Copper is technically the most attractive material, but it is expensive and is sometimes in short supply.

The tubing should be seamless and half-hard annealed (see BS 2871 : Part 2).

Individual copper tubes are usually covered with PVC when laid in the open air or in corrosive atmospheres.

(b) *Aluminium.* Aluminium is less expensive, but has technical disadvantages compared with copper, i.e.:

(1) aluminium joints are more difficult to make and virtually impossible to remake;

(2) aluminium hardens more quickly under vibration;

(3) severe electrolytic corrosion can be expected when aluminium is in contact with other metals;

(4) welding spatter can penetrate aluminium.

It should not be used in Zones 0 or 1 hazardous areas (as defined in BS 5345) unless coated.

In general, aluminium should be used only where corrosion problems prohibit the use of copper tubes.

Aluminium tubing should comply with BS 1471.

Individual aluminium tubes are usually covered with PVC when laid in the open air or in corrosive atmospheres.

(c) *Plastics.* Plastics tubing is low in price and easily installed. Tubes are usually made from nylon, PVC or polyethylene. They do however have severe mechanical limitations and sometimes they are incompatible with certain working atmospheres. Most plastics materials have a low melting point and consequently they should not be installed in the vicinity of hot process lines or equipment operating at high temperatures. They should also be protected from welding spatter.

It should also be borne in mind that in the event of fire the tubing would quickly melt and, therefore, for critical signals other materials should be considered. Some protection can be afforded by installing plastics signal tubing within conduits or ducting, or with other heat insulation.

During installation and handling, care should be taken to avoid deformation of tubing and to ensure that sufficient slack is allowed on bends to prevent straining or flattening of the tubing.

(d) *Stainless steel.* Although relatively expensive, stainless steel tubing is probably the most durable. It will withstand the most arduous service conditions and does not need a protective coating.

The tubing should be seamless and annealed, in accordance with BS 3605. Type 316L is the best in saliferous atmospheres, e.g. offshore, although type 304 may be acceptable for most inland service requirements.

(e) *Alloy.* Alloy tubing, such as cupro-nickel (copper-nickel-iron complying with BS 2871 : Part 2) would also be suitable for applications in marine environments such as offshore or coastal sites.

Cupro-nickel tubing is strong and also ductile; it is easy to handle for installation.

10.6.4 Process impulse piping

10.6.4.1 *General*

10.6.4.1.1 The choice of piping (with pipe fittings) versus tubing (with compression fittings) for instrument process hook-ups is dependent upon the service requirements and is a matter of user preference. The type to be used should be stated in the piping specification for a particular project.

10.6.4.1.2 Generally, tubing is easier to install and is capable of handling the majority of arduous service conditions provided that the tubing and fittings are carefully selected and correctly installed. However, some users believe that piping systems provide greater reliability.

10.6.4.1.3 All impulse piping should be self-draining and in general be run with a slope of not less than 1 in 12. The slope of the impulse pipework should be down from the tapping point for liquids, steam and condensibles and up from the tapping point for gas service unless special provisions are made for venting and tapping.

10.6.4.1.4 Where vents and drains are unavoidable, special attention should be paid to their correct siting to ensure they are at the highest or lowest points of the piping run, e.g.:

(a) vent plugs or valves on high points in liquid-filled lines;

(b) drain plugs or valves on low points in gas or vapour-filled lines;

(c) filling valves or plugs and high and low points where lines are to be filled with sealing fluids;

(d) flushing and neutralizing connections for line and instruments in toxic and/or noxious applications;

(e) rodding-out connections on lines that are prone to plugging or coking.

10.6.4.1.5 Piping/tubing should be jointed by screwed fittings, socket welded fittings, flanges or compression fittings in accordance with the project specification.

10.6.4.2 *Tubing and compression fittings*

10.6.4.2.1 The maximum allowable working pressure and temperature for which tubing and fittings are designed should not be exceeded.

10.6.4.2.2 Tubing should not be used to carry the weight of pressure gauges, seal pots, etc.; these items should be supported by steel piping, nipples and fittings or suitable brackets.

10.6.4.2.3 The tubing material is usually carbon steel or stainless steel, cold drawn, annealed and should comply with BS 3601. Other materials may be considered by the responsible engineer depending on the process service requirements.

10.6.4.2.4 Tubing of outside diameter 10 mm or 12 mm is suitable for most applications. Wall thicknesses should be selected to suit the design working pressure and normally should have a minimum of 1 mm to give the mechanical strength required.

10.6.4.2.5 The body material for compression fittings should be compatible with the process conditions; the compression ring and nut should be compatible with the tubing material.

10.6.4.2.6 When installing tubing and fittings care should be taken to ensure that:

(a) the tubing is cut square to the centreline with a suitable pipe cutter, and deburred;

(b) the tube end is truly circular and without defect;

(c) the compression nut is tightened as prescribed by the manufacturer;

(d) suitable tools are used for tube bending.

10.6.4.3 *Piping*

10.6.4.3.1 Where piping is specified, it should comply with the project piping specification.

10.6.4.3.2 Generally 0.5 in n.b. steel pipe (12 mm) in accordance with BS 3351 is suitable for most services with socket welded, flanged or screwed connections, depending on the project requirements.

10.6.4.3.3 Lined piping, e.g. with PTFE, or plastics pipes may be required for special applications for which no suitable metallic material can be found. These lined pipes are usually factory made to detailed dimensional drawings of the instrument hook-up.

10.6.5 Piping and tubing supports

10.6.5.1 Wherever possible, piping or tubing supports should be kept free from vibrating structures or equipment.

10.6.5.2 Process piping or handrails should not be used to support instrument piping and tubing.

10.6.5.3 Piping and tubing runs should be adequately supported and fixed at distances not exceeding those in table 4.

10.6.5.4 Cable trays, low carbon (mild) steel or angle bar should be used for continuously supporting copper or plastics tubes and the tubes should be secured at 0.5 m intervals.

Table 4. Piping and tubing supports

Size		Maximum distance between supports or clips
Metric	Imperial	
mm		m
Tubing		
10 and less	$^3/_8$ in o.d. and less	0.5 (see **10.6.5.4**)
12	½ in o.d.	1.0
—	Multicore	1.0
Piping		
10 to 20	$^3/_8$ in to ½ in n.b.	1.5
25	1 in n.b.	2.0
40 to 50	1½ in to 2 in n.b.	3.0

10.6.5.5 When approved for a project, a maximum of three plastics or copper tubes may be supported by clipping the tubes to the air header at 0.5 m intervals.

10.6.5.6 Capillaries of filled systems should be run independently of all other lines and should be continuously supported using low carbon (mild) steel angle with clips at 0.5 m intervals.

10.6.5.7 Ladder racks may be used for supporting long runs of multicore tubing.

10.6.5.8 Cable tray material should preferably be hot-dipped galvanized steel, unless otherwise specified by the responsible engineer, and should be run with the breadth of the tray in a vertical plane. Where a short section needs to be run with the breadth horizontal, the breadth should revert to the vertical plane at the earliest possible point. If run in the horizontal plane the tray should be provided with additional supports to prevent sagging (see figure 45 for an example of a tray layout).

10.6.5.9 Trunking or conduit may be used to replace cable tray under certain circumstances, such as where additional protection is considered necessary.

10.7 Instrument cabling

10.7.1 General

This clause gives the basic cabling design and installation requirements for electronic instrumentation systems. The specific design requirements for a project are normally given in the project documentation (see **10.2** and **10.3**). However, the guidance given in **10.7.2** to **10.7.6** is for use when other information is not available.

Where there is a high density of cables, for example in cable tunnels, mezzanine floors and control rooms, low smoke and low toxicity PVC cable sheaths should be used.

Care should be taken to avoid obstruction to cable trunking covers likely to impede cable installation.

Multicore cables should penetrate as far as possible into the plant before rising above ground level. Where possible, above-ground runs should be located away from fire hazards.

10.7.2 Cable classification

Instrument cables fall into three main categories as follows.

(a) *Category 1. Instrument power and control wiring (above* 50 V). This group includes a.c. and d.c. power supplies and control signals including emergency shut-down control circuits.

NOTE. Any cable having a total loading of more than 10 A should be regarded as a power cable and excluded from this classification.

(b) *Category 2. High level signal wiring* (5 V to 50 V d.c.) This group includes digital signals, alarm signals, shut-down signals and high level analogue signals, e.g. 4 mA to 20 mA.

(c) *Category 3. Low level signal wiring (below* 5 V d.c.) This group includes temperature signals and low level analogue signals, e.g. analyser measuring circuits.

10.7.3 Signal cables

10.7.3.1 *Signal segregation.* Only conductors carrying signals of the same category should be contained within any one multicore cable.

In each category, a further segregation is required to ensure that conductors forming part of intrinsically safe circuits are contained within multicore cables reserved solely for such circuits.

High integrity signals, such as data transmission signals from fiscal metering systems or critical shut-down signals, should be contained in separate cables and routed separately from other signals (see also **10.7.4.2.4**).

10.7.3.2 *Signal cable selection*

10.7.3.2.1 Instrument cables should be selected for their duty and should be of sufficient mechanical strength, suitably insulated and with sheathing as required to suit the environment in which they are to be installed.

10.7.3.2.2 A manufacturer's recognized type of instrument signal cable should preferably be used with copper conductors and with insulation of either PVC or polyethylene, generally in accordance with BS 5308 and colour coding is recommended*.

10.7.3.2.3 For permanent installations, solid conductors with a 1 mm^2 cross-sectional area are generally suitable other than in areas where high vibration could be encountered. Solid conductors are simple to terminate and there is no degradation of signal due to broken strands. When stranded conductors are used, crimped connectors should be fitted.

10.7.3.2.4 In order to minimize electrical interference signal wires should be twisted in pairs with a wire braid or aluminized tape screen and PVC sheath.

NOTE. The choice of cables incorporating screens is optional at the discretion of the user as most modern electronic equipment has built-in noise rejection, although screens are sometimes included (particularly wire braid on single pairs) to protect the system against spurious stray currents which could occur on a plant under fault conditions, perhaps by equipment not associated with the instrumentation.

10.7.3.2.5 Additional protection should be provided, if necessary, by steel wire armour and a PVC outer sheath or other forms of cable protection.

10.7.3.2.6 Lead sheathing (or suitable barrier material) should also be considered when solvents or acids are liable to attack the cabling insulation, especially on buried cables that are prone to attack by hydrocarbon spillage. Lead sheathing is applied beneath the outer PVC sheath and should not be regarded as a cable screen.

10.7.3.3 *Multicore and/or multipair cables*

NOTE. For definitions of multicore and multipair cables see BS 5308.

10.7.3.3.1 Where a number of cables run together on the same route it is more economical to use a multicore construction usually comprising 2, 5, 10 or 20 pairs laid-up and sheathed overall with PVC.

10.7.3.3.2 Depending on the type of apparatus to which the multipairs are connected, an overall screen rather than individual screens may be adequate for high level analogue signals.

10.7.3.3.3 When a multipair cable carries signals that might interfere with each other, each pair should have an individual screen. These screens should be individually insulated.

10.7.3.4 *Temperature signal cables*

10.7.3.4.1 Temperature signal cables fall into two main categories:

(a) thermocouple extension and compensating cables;

(b) resistance element cables.

10.7.3.4.2 The cable classification guidelines given in **10.7.2** apply equally to temperature signal cables except that individual screens are normally used in multicore cables.

10.7.3.4.3 Conductors of 0.5 mm^2 cross-sectional area are generally adequate for temperature signal cabling.

10.7.3.4.4 In special applications mineral-insulated metal-sheathed cables are sometimes used and these require special installation precautions (see **10.7.4.3.10** and **10.7.4.3.11**).

10.7.4 Instrument cable installation

10.7.4.1 *Cable routeing*

10.7.4.1.1 The main routeing of instrument signal cables, whether above or below ground, should already have been determined in the design stage taking account of safety, convenience and other factors. In all cases, the shortest practical routes should be selected.

10.7.4.1.2 Site-run cabling should be routed bearing in mind the following considerations, such that, where possible, they:

(a) are kept as short as possible consistent with good practice and accessibility;

(b) do not obstruct traffic through the process plant;

* For an example of colour coding refer to Energy Industries Council Publication no. CCI P/4.

(c) do not interfere with the accessibility or removal of process equipment e.g. pumps, motors and exchanger bundles;

(d) avoid hot environments and potential fire-risk areas;

(e) will not be subject to mechanical abuse, e.g. used as a step;

(f) avoid areas where spillage is liable to occur, e.g. from overflowing tanks;

(g) are clear of drainage points of condensate;

(h) avoid areas where escaping vapour or corrosive gases could present a hazard;

(i) avoid process piping and are provided with sufficient clearance from piping which may require lagging.

10.7.4.1.3 In areas where the foregoing hazards cannot be totally avoided, consideration should be given to installing the cables within metal conduits or trunking. Heat insulation such as mineral wool with outer aluminium cladding may be applied externally to the trunking in order to give additional protection in high fire risk areas.

10.7.4.1.4 Where possible, above ground cable routes should be selected to maximize the physical protection afforded by structural steelwork.

10.7.4.1.5 The layout of cable trays where possible should be such that only the instruments in the immediate vicinity will be affected if a local plant fire damages the signal lines.

10.7.4.1.6 Where signal lines pass through hazardous areas of different classification, e.g. through walls of pump rooms or control rooms, the transition points should be pressure-tight.

10.7.4.2 *Cable separation*

10.7.4.2.1 *General.* Cable separation should be considered on a project basis in order to minimize interference due to pick-up or noise from other cabling. Much depends upon the type of cabling used and the noise rejection capability of the apparatus to which the signal cables are connected (see also **10.7.3.2.4**). In the absence of specific project requirements the recommendations given in **10.7.4.2.2** to **10.7.4.2.5** are a guide to good installation practice.

10.7.4.2.2 *Separation from power cables.* Instrument cables should be routed above or below ground separately from electrical power cables (i.e. a.c. cables usually above 50 V a.c. with a 10 A rating).

Parallel runs of instrument cables and power cables should be avoided; however, where unavoidable, adequate physical separation should be provided. A spacing of 250 mm is recommended from a.c. power cables up to 10 A rating. For higher ratings the spacing should be progressively increased.

Where a cross-over between signal and power cables is unavoidable, the cables should be arranged to cross at right angles with separation of at least 250 mm maintained by positive means.

10.7.4.2.3 *Separation between instrument cables.* Instrument cables should be separated into three groups according to the signal classification (categories 1, 2 or 3, see **10.7.2**). Examples of separation figures are given in table 5.

Table 5. Example of cable separation

Category	Spacing
	mm
1 to 2	200
2 to 3	300
1 to 3	300

Within category 2, analogue signal cables should be laid on the side remote from category 1 cables, i.e. so that analogue signals are furthest from instrument power and control signals. Cable separation should be maintained both for above and below ground installations. The problem of electrical interference becomes more acute where long parallel runs are unavoidable.

10.7.4.2.4 Whenever possible, the cables of emergency shut-down circuits should take an independent route from the cables of other systems which they protect, in order to afford higher integrity.

10.7.4.2.5 Intrinsically safe circuits should be contained in separate cables and terminated separately, otherwise segregation is the same as for other signal cables in the same group.

10.7.4.3 *Cable installation*

10.7.4.3.1 During installation multicore and multipair cables should not be bent in a radius less than the manufacturer's recommended minimum bending radius (normally not less than eight times the overall diameter).

10.7.4.3.2 To avoid risk of damage to the PVC outer sheathing during installation at low temperatures, cables should be installed only when both the cable and the ambient temperatures are above 0 °C and have been for the previous 24 h.

NOTE. Special grades of sheathing are available for use in sustained low-temperature applications.

10.7.4.3.3 Where cables are run through pipes or conduits, the entries and exits should be smooth and free from burrs. Care should be taken when cables are pulled into such conduits to ensure that there is no damage to the cable.

10.7.4.3.4 For metallic conduit, all conduit runs should be mechanically and electrically continuous. Running threads should be secured by locknuts. After conduit is installed, all exposed threads should be painted with a sealing compound.

10.7.4.3.5 Where conduits terminate at cabinets, terminal boxes or trunking, they should be securely locknutted, bushed and ferruled. Sharp edges should be removed and conduits not otherwise connected should be terminated in smooth bushes.

10.7.4.3.6 Conduit or mineral insulated metal sheathed cables should be neatly run, attached to structures and steelwork.

10.7.4.3.7 Care should be taken when PVC conduit or ducting is used that it is not run adjacent to plant or equipment operating at elevated temperatures.

10.7.4.3.8 Conduit junction boxes should be provided at distances not exceeding three random lengths of conduit (approximately 3 m per random length) with not more than two right angle bends occurring in one pull (see figure 46).

10.7.4.3.9 When flexible conduits are necessary, they should be in accordance with BS 731.

10.7.4.3.10 Where mineral insulated (MICC) cables are used, it is essential that all seals be made using the correct components and the methods specified by the manufacturer, and that correct insulation resistance tests are carried out.

10.7.4.3.11 Where mineral insulated cables are not immediately glanded, they should be temporarily sealed after cutting.

10.7.4.4 *Junctions and terminations*

10.7.4.4.1 Cable joints should be made only at appropriate terminals in instruments, junction boxes or approved equipment. No intermediate joints should be made on cable trays, ladder racking or in conduit.

10.7.4.4.2 Field mounted junction boxes should be of robust construction, weatherproof, fitted with hinged gasketed covers and provided with hasps to accept padlocks when specified in the original design. Cable entries should be through the base and sides only. Cable glands should be used to anchor the cable and provide a seal (see figure 48 for an example of field termination of multicore thermocouple extension cables).

10.7.4.4.3 Junction boxes should be selected to give the degree of protection appropriate to the hazardous area within which they are installed and should be suitably certified where required.

10.7.4.4.4 Junction boxes should be fitted with sectional type, screw clamp terminals mounted on rails. Sufficient terminals should be provided to terminate all signal wires (including spare wires) and for connecting the cable screens where appropriate.

10.7.4.4.5 Where specified in the original design, cable glands should be insulated from the junction box to permit the earthing of the cable sheath and/or armour at one point only (see **10.7.5**). In cable terminations where armour/sheath and screen are not earthed, they should be positively isolated from each other.

10.7.4.4.6 All terminations should be made with approved tools. Crimped type terminations should be used for stranded conductors. Where instruments are fitted with flat-headed screw-type terminals, wire ends should be fitted with crimped spades having a retaining lip.

10.7.4.4.7 Sufficient slack wire should be left neatly looped at terminals to permit remaking terminations, alterations and testing.

10.7.4.4.8 Where a termination is made to a measuring element that has to be withdrawn, e.g. a thermocouple, sufficient length of flexible cable should be allowed, if possible, for the element to be withdrawn without electrical disconnection.

10.7.4.4.9 Coaxial and other special cables should be terminated in accordance with the manufacturer's instructions.

10.7.4.4.10 In control rooms, cable clamps can be used to anchor multicores to the panel frame.

10.7.4.4.11 Cables and terminals should be ferruled and identified in accordance with the project requirements. Identification should be clear and wires should carry ferrules bearing the same number as the terminal identification so that there is no confusion as to which terminal a wire belongs*.

10.7.4.5 *Cable tray and supports*

10.7.4.5.1 In the absence of other project requirements, cable tray or ladder rack material should be hot-dipped galvanized steel.

10.7.4.5.2 Cable trays should preferably be run with the breadth of the tray in a vertical plane. Where a short section has to be run with the breadth horizontal, the breadth should revert to the vertical plane at the earliest possible point. If run in the horizontal plane, the tray should be provided with additional supports to prevent sagging (see figure 45 for an example of a cable tray installation).

10.7.4.5.3 Clips, saddles and strapping securing cables to steelwork or trays should be metal, preferably with a plastics coating. The spacing of cable clips should be not more than 250 mm on vertically run or 500 mm on horizontally run cable trays.

Plastics cable ties should not be used.

10.7.4.5.4 Where signal cables are run in trunking, spare space should be left in accordance with the design requirements. Preferably, not more than 50 % to 70 % of the cross-sectional area of the trunking should be occupied by the cables.

10.7.4.5.5 Where condensation is likely to occur in trunking, etc. drain holes should be provided at the lowest points.

10.7.4.6 *Cable trenches.*

10.7.4.6.1 Cable trenches are preferably excavated in open ground, avoiding paved areas and obstructions, both above and below ground, so that reasonable access to the buried cables can be achieved. A minimum clearance of 300 mm should be maintained between cables and parallel runs of underground piping.

10.7.4.6.2 Cables should be buried to a depth of 750 mm (measured from the top surface of the top layer of cables) for uncovered backfilled trenches and to a depth of 450 mm for concrete-covered sand-filled trenches. The cables should be bedded in a layer of soft sand or other suitable cushioning material, extending 75 mm minimum below and above the cables. This layer should be protected by earthenware or concrete cable covers and the trench backfilled and compacted until the ground is restored to its original grade and finish.

* An example of a cable identification system is given in Energy Industries Council publication no. CCI P/7.

As an alternative to earthenware or concrete cable covers, and subject to the responsible engineer's approval, a marker tape may be laid 300 mm above the cable during backfilling. The marker tape should be a minimum of 150 mm wide and manufactured from heavy duty, non-degradable plastics. The tape should be distinctively coloured and clearly marked 'Electric Cables Below'.

10.7.4.6.3 Underground cable routes should be identified by concrete cable markers positioned at 30 m intervals on straight runs and at points where the route changes direction. Where trenches are wider than 1 m, markers should be located on both sides of the trench.

10.7.4.6.4 Cables should preferably be laid in single tiers but, owing to space restrictions, it may be desirable to use multiple tiers, in which case due consideration should be given to heat dissipation.

10.7.4.6.5 Where cables leave trenches they should be protected from fire or mechanical damage by encasing them in metal sleeves which extend to a minimum of 150 mm below ground and 250 mm above. The protecting sleeves should be encased in concrete and after installation a suitable sealing compound should be applied to prevent the ingress of moisture.

10.7.4.6.6 If there is likely to be heavy underground chemical attack, underground cables should have a suitable protective sheath under the outer PVC sheath (see **10.7.3.2.6**). Alternatively, they may be laid in a concrete, crack-free, watertight or acid-resistant trench filled with sand. Because of the cost involved in this arrangement, such trenches should be limited to the distance from the control room to the nearest riser point.

Under adverse conditions it is advisable to install the cables above ground where possible.

10.7.5 Earthing

10.7.5.1 *General*

10.7.5.1.1 All equipment for electrical signal transmission, including enclosures and cable armouring, lead sheathing and screening, should be properly earthed for personnel safety reasons and for obtaining the maximum possible rejection of electrical interference.

10.7.5.1.2 Earthing and bonding should be generally in accordance with CP 1013 unless otherwise specified.

10.7.5.1.3 Special care should be taken when designing and installing instrument earthing systems to avoid the creation of earth loops by permitting earth conductors to contact earthed steelwork or by duplicating earth conductors. Particular attention should be paid to the isolation of earth potential reference busbars in panels, control rooms and out stations.

10.7.5.1.4 The cross-sectional areas of earthing and bonding conductors should comply with CP 1013, but no separate earthing or bonding conductor (i.e. one not contained in a composite cable) should have a cross-sectional area less than the following:

(a) 2.5 mm^2 where installed inside buildings;

(b) 6 mm^2 where installed above ground outside buildings;

(c) 25 mm^2 where buried in the ground.

10.7.5.2 *Control centre earths*

10.7.5.2.1 The instrument equipment earths in each control centre or out-station should be formed into a single earthing system which should be connected to the main earth electrode system of the plant or area at one point only, with the following exceptions:

(a) where there is a mixture of intrinsically safe and non-intrinsically safe systems, a separate earthing system should be provided for each system;

(b) where there is static earthing of equipment chassis, panel frames, etc. this should be connected to the electrical common earth.

An example of a control centre earthing system diagram is shown in figure 47.

10.7.5.2.2 The control centre or out-station earth should consist of a bare copper busbar of at least 75 mm^2 cross-sectional area, mounted on insulators and spaced at least 25 mm from any earthed conducting surface to avoid the creation of earth loops.

10.7.5.2.3 The control centre earth bar should be connected to the main plant earth electrode system by two identical copper conductors of at least 70 mm^2 cross-sectional area. The conductors should be insulated and protected from mechanical damage.

10.7.5.2.4 Each control panel or termination cabinet should be provided with an earth reference bar (or bars) consisting of a bare copper busbar of at least 75 mm^2 cross-sectional area, mounted on insulators in a similar manner to the control centre earth bar (see **10.7.5.2.2**). The panel reference bar should be connected to the control centre earth bar by a single insulated copper conductor of at least 70 mm^2 cross-sectional area.

10.7.5.2.5 If more than one panel reference bar is required, e.g. for separate panel sections, each should be connected individually to the control centre earth bar by a single insulated copper conductor of at least 70 mm^2 cross-sectional area, care being taken to ensure that the components of any one instrument loop are referred to the same earth potential.

10.7.5.2.6 The resistance of any single conductor between the control centre earth bar and its other terminal point in the control centre earthing system should not exceed 0.5 Ω.

10.7.5.2.7 The resistance measured between the panel reference bar and true earth incorporating the conductors and earth electrode should be not greater than 1 Ω or the lowest of the following:

(a) the earth loop impedance requirements of the certification for intrinsically safe circuits;

(b) electrical safety requirements;

(c) computer or other special system requirements.

10.7.5.2.8 With the conductors between the control centre earth bar and the main plant earth temporarily disconnected, the insulation resistance between the control centre earthing conductors and the plant earth system should be not less than 1 MΩ measured at 500 V d.c. applied for at least 1 min.

10.7.5.2.9 The neutral of the secondary winding of all class B and class C isolating transformers, the earth terminations of instruments and the general structural metalwork of panels within the control centre should be directly connected to the control centre earth bar and not to the panel reference bar.

10.7.5.3 *Earthing methods*

10.7.5.3.1 *Power pack.* Transformer laminations and the power pack earth connection should be connected to the electrical power earth.

10.7.5.3.2 *Cable screens.* All cable screens should be earthed at one point only. This should be at the panel reference bar except where the instrument design demands earthing at source, e.g. when earthed tip thermocouples are used, the screen should be earthed at the thermocouple. Continuity of the screen should be maintained throughout the cable run and screens should be isolated from earth at all other points.

NOTE. Intrinsically safe and non-intrinsically safe circuits have separate earthing systems (see **10.7.5.2.1**).

10.7.5.3.3 *Cable screens (telemetry systems).* Cable screens in telemetry systems should be earthed to the appropriate reference bar as follows.

(a) The master control station panel reference bar should be used to earth all protective screens on cabling between the master station and out-stations.

(b) The out-station panel reference bar should be used to earth all protective screens on cabling between out-stations and field equipment.

10.7.5.3.4 *Field mounted instrument enclosures.* All equipment in metal enclosures with a voltage of not more than 50 V a.c. or 110 V d.c. and supported from the (earthed) plant structure should be earthed via metal to metal contact through their supports.

Equipment with higher voltages, or not supported from the (earthed) plant structure should be connected to the nearest plant earth bar by means of 6 mm^2 green/yellow PVC insulated copper wire.

10.7.5.3.5 *Cable armour and lead sheath.* Cable armour should not be used directly as a means of screening cables. It should be used to provide physical protection only. The armour and lead sheath (if used) should be earthed or insulated from earth at junction boxes, field equipment and control room as shown in figure 47.

10.7.5.3.6 *Junction boxes.* All metal field junction boxes should be positively earthed to the nearest plant earth bar using 6 mm^2 green/yellow PVC insulated copper wire.

10.7.5.3.7 *Instrument cable racks, trays and conduit.* Cable racks, trunking trays and conduit should be provided with gaps or suitable insulating spacers to prevent the circulation of induced currents. Each section should be electrically earthed. Fixings to non-metallic structures, e.g. brickwork, should not be regarded as earth connections.

10.7.5.3.8 *Intrinsically safe barrier devices.* Diode shunt barrier devices in intrinsically safe circuits should be bolted directly to the earth potential busbar via their earth connections.

NOTE. The manufacturer's recommendations should be followed and action taken to ensure that the installation complies with the requirements of the certifying authority.

10.7.6 Fibre-optics

10.7.6.1 Fibre-optics are gaining recognition as a means of instrument signal transmission and have the advantage of eliminating problems associated with signal interference and earthing. Special requirements are needed for the installation of fibre-optic transmission systems.

10.7.6.2 The fibre should not be bent more than the specified minimum bending radius.

10.7.6.3 It is not necessary to segregate fibre-optic transmission cables from power cables but they should be installed in a location where they will not be subjected to vibration.

10.7.6.4 Special tools and procedures are required for cutting and attaching couplers to the ends of the fibres.

10.7.6.5 The surfaces on the ends of the fibres should be kept clean and dry.

10.7.6.6 After installation, the continuity and attenuation of the optical transmission system should be checked.

10.7.6.7 Installation of fibre-optic cabling should be strictly in accordance with the manufacturer's instructions, particularly with regard to terminating, jointing and testing.

10.8 Protection from process materials and environmental conditions

10.8.1 General

10.8.1.1 Consideration should be given to the nature of the process fluid being measured and the conditions which may affect the operating characteristics of an instrument. Process fluids which should be specifically considered can be categorized as follows:

(a) corrosive fluids;

(b) viscous fluids;

(c) fluids with high viscosity at low ambient temperatures;

(d) fluids liable to freeze;

(e) fluids with solids in suspension;

(f) condensing vapours.

10.8.1.2 Several methods of instrument protection are available but by careful choice of instrument, special precautions can sometimes be avoided, e.g. by selection of suitable materials or primary elements.

The principal protection systems are:

(a) diaphragm seals;

(b) liquid seals;

(c) purging;

(d) heating;

(e) housing.

These systems are summarized in **10.8.2** to **10.8.7.**

10.8.2 Diaphragm seals

10.8.2.1 Diaphragm seals obviate the need for liquid seals or purges and are to be preferred for many applications. A sealing diaphragm is in effect a diaphragm between the process and the sealing fluid and is usually placed at the point of measurement, thus preventing the process fluid from entering the connecting pipework. The diaphragm and its housing is usually capillary connected to the measuring instrument and is made up as a sealed system filled with an inert fluid such as silicone liquid. Where a remote mounted gauge is required or when the installation is prone to vibration, capillary connected gauges should be used.

10.8.2.2 In the case of differential pressure level transmitters or pressure gauges the diaphragm assembly can be integral with the transmitter or gauge, i.e. without a capillary, provided the operating temperature is within the acceptable range of the instrument.

10.8.2.3 Direct connected diaphragm elements are sometimes used on pressure gauges, i.e. Schaffer diaphragms.

10.8.3 Liquid seals

10.8.3.1 Liquid seals provide a simple method of preventing process fluids from entering impulse lines and are desirable for some applications. In this situation, impulse lines and instruments should be filled with a suitable seal liquid that will not:

(a) solidify;

(b) mix or react with the process fluid;

(c) evaporate under process conditions.

10.8.3.2 The seal liquid should preferably have a higher density than the process fluid.

10.8.3.3 A mixture of water and glycerine in equal volumes is commonly used as seal liquid, but other liquids may be used, depending on process requirements.

10.8.3.4 For instruments with large displacement volumes, seal pots should be installed close to the process connections to provide a buffer volume.

10.8.4 Purging

10.8.4.1 Purging by means of a suitable gas or liquid is sometimes required to prevent corrosive process fluids from entering impulse lines and instruments, or to prevent blockage of process connections and impulse lines arising from solid particles, coking or polymerization of the process fluid.

10.8.4.2 Care should be taken to ensure that the purge lines are connected to a maintained purge fluid supply which is always at a pressure above that of the process fluid, and that the purging medium does not react with the process fluid or affect its characteristics.

10.8.4.3 Each purge line should be provided with a check valve and a constant-flow regulator (preferably with a means of flow indication such as a small variable area meter). Constant flow regulators are necessary to keep the purge flow constant under the following conditions:

(a) variations in purge supply pressure;

(b) variations in process pressure;

(c) an increase in resistance to purge flow, due to partial plugging of lines or connections.

10.8.4.4 Where constant flow regulators are not necessary, fixed restrictions, e.g. restriction orifice plates, should be applied.

10.8.4.5 Care should be exercised in establishing the purge injection point for the installation to ensure that it does not cause induced errors. This is particularly important where impulse lines differ significantly in length.

10.8.5 Heating

10.8.5.1 The heating of impulse lines and instruments should only be considered when other possibilities such as seal liquids cannot be applied. Whatever heating method is used, overheating of the instruments should be avoided and the manufacturer's recommended maximum ambient operating temperatures should be observed.

10.8.5.2 Where heating is necessary, full use should be made of process heat, e.g. by including the first part of the impulse lines (up to the seal) inside the vessel or thermally insulated piping, or by installing protective covers over the process pipe, the impulse lines and the instruments.

10.8.5.3 Where use cannot be made of available process heat, external heat sources should be considered. Steam or electric heat tracing of impulse lines is most commonly used, but hot water or hot oil heating systems should be considered when available for other purposes, e.g. for tank heating or tracing of process piping.

10.8.5.4 Steam tracing is usually carried out using metal tubing, e.g. 12 mm copper. Concealed joints on copper tubing should be hard soldered. Traced lines should be thermally insulated but compression joints should be left exposed.

10.8.5.5 All steam tracing lines should be tested for leaks prior to lagging, preferably at their operating temperature.

10.8.5.6 Steam tracing and condensate return lines applied to instrument impulse tubing should be installed such that instrument maintenance can be carried out with minimum disturbance to the tracing or lagging.

10.8.5.7 Where heating is applied to process liquid lines, care should also be taken to ensure that the process liquid does not vaporize. Steam tracing should be applied over a layer of insulation material if necessary.

10.8.5.8 Electric heating should be used only where compatible with the safety requirements for the specific application. Electric heating should comply with BS 6351.

10.8.6 Housing

10.8.6.1 Under adverse environmental conditions it may be necessary to install the entire instrument in a housing, with or without heating. When fitted, housings should not interfere with free access to instruments and impulse lines.

10.8.6.2 Housings may be of painted steel, fibre-glass or other material which should be fireproof. Covers should be capable of being easily opened and refastened securely. Thermal insulation should be of fire-resisting material and should be fitted inside the enclosure to avoid exposure to damp and subsequent freezing.

10.8.6.3 The design should take into account any need for supplementary heating which may be provided by process fluid, steam tracing or an electrical heater.

10.8.6.4 Electrical heating elements should be thermostatically controlled to prevent overheating of the instruments.

10.8.6.5 Heating elements or tubing inside cabinets or protective housings should be installed in such a way that personnel are protected from physical contact with hot surfaces during maintenance, mounting or removal of instruments.

10.8.7 Solar protection

In geographical areas that are subject to intense solar radiation, instruments should be located in the shade where possible or, alternatively, provided with sun shields or shelters in order to obtain maximum protection from radiated temperatures and avoid possible deterioration of components due to ultraviolet radiation.

Section eleven. Testing, including pre-commissioning

11.1 General

11.1.1 Testing before commissioning

Before commissioning (or start up) of a new installation, the completed instrumentation and control equipment installation should be fully tested to ensure that the equipment is in full working order.

Instrument testing work should be carried out only by personnel that are fully skilled to do the work and, where unfamiliar specialized equipment is being installed, the testing personnel should be given supplementary training on that equipment.

For most plants, instrument testing may comprise several stages as described in **11.1.2** to **11.1.6**.

11.1.2 Inspection upon receipt

A physical check should be made of all instrument equipment when received on site and before the pre-installation testing is carried out.

11.1.3 Pre-installation testing

All instrument equipment should be tested before it is installed to ensure that each individual instrument is functioning correctly and that it is accurately calibrated.

11.1.4 Pressure testing of instrument piping

All piping installations that come within the instrument contract should be tested to ensure that they are pressure-tight under the specified test conditions.

11.1.5 Testing of instrument cables

The interconnecting cabling in electrical and electronic instrument loops should be tested for continuity, insulation resistance, etc. to meet the system requirements. (For hazardous areas see section three.)

11.1.6 Pre-commissioning (including loop testing)

All instrument systems and loops should be tested to ensure that they operate correctly and are ready for commissioning.

11.2 Responsibility for testing and approval

11.2.1 It is assumed that for each plant or section of a plant there will be a responsible engineer for the instrumentation representing the owner who will be responsible for the work carried out on that plant.

11.2.2 The company or subcontractor responsible for the pre-installation testing of instruments should supply a fully equipped workshop for this purpose. Unless otherwise agreed between the responsible engineer and the subcontractor the workshop should have a clean section of bench reserved for electronic instruments and the test equipment which should be isolated from the area set aside for mechanical tests. A list should be drawn up of the test equipment required and agreed with the responsible engineer before any testing is commenced. A list of typical test equipment is given in appendix G.

11.2.3 It is essential that all test equipment should be approved by the responsible engineer and its accuracy should be higher than the accuracies claimed by the manufacturer for all instruments that are to be tested. It is necessary that all test equipment should have a valid calibration certificate issued by a recognized authority and should be periodically re-checked. The interval between checks should be agreed with the responsible engineer.

The test and calibration equipment should be calibrated in the units of measurement selected for and appropriate to the project.

11.2.4 Approval should be obtained from the responsible engineer before electric power or pneumatic supplies are applied to any panel or to any section of plant. On any plant, whether or not it is operating, it is essential to comply with any permit to work procedures that are in force (see section two).

11.2.5 On completion of each test, the stage of the testing procedure reached should be indicated by a temporary label affixed to each instrument or installation.

It is recommended that coloured labels are used to make identification easier. Suggested colours are shown in table 6.

Table 6. Test status colour code

Blue	Pre-installation tested
Yellow	Pressure tested
Green	Cables tested
Red	Pre-commissioned (ready for commissioning)
White	Test failed (written message may be added giving reason for failure)

Such identification should be shown on all components in the loop to enable personnel to see the current status of the installation.

11.2.6 When testing is finished all connections and entries should be sealed temporarily so as to prevent moisture and dirt getting into the equipment.

11.2.7 A record of all test results should be made on a standard form and, when appropriate, approval signatures should be obtained (see **11.8**).

11.3 Inspection upon receipt

Immediately upon receipt on site, each item of equipment should be visually inspected to ensure that it complies with the manufacturer's specification and is free from any defects. If any defects or deficiencies are found these should be reported to the responsible engineer and remedial action agreed before the equipment is put in the stores.

11.4 Pre-installation testing

11.4.1 General

11.4.1.1 Wherever possible, all instruments should be pre-installation tested. The tests should be performed in accordance with the methods given in this section and any adjustments should be carried out in accordance with the manufacturer's instructions.

NOTE. For types of instrument not covered in detail in this code of practice, reference should be made solely to the manufacturer's instructions.

11.4.1.2 All tests should be made so as to simulate as closely as possible the design process values, by using manometers, potentiometers, resistance bridges, dead weight testers, test pressure gauges, etc. and hydraulic, electric and pneumatic supplies connected as appropriate (see **11.4.3**).

11.4.1.3 In general, all instruments should be kept at room temperature for a sufficient time for them to become stabilized before tests are carried out. It is recommended that electronic instrumentation should be energized for 24 h before testing.

11.4.1.4 All shipping stops should be removed from the instruments before proceeding with testing. Miscellaneous components, e.g. charts, mercury and oil, should be correctly installed.

11.4.1.5 The calibration of all instruments should be checked in both the upscale and downscale directions and, if necessary, adjustments made until their readings are within the accuracy limits stated by the manufacturer. The results of each completed test should be recorded on the appropriate calibration sheet (see **11.8**) and witnessed by the responsible engineer.

11.4.1.6 The responsible engineer should be informed immediately and given written confirmation of any defects that cannot be rectified or of any instrument that cannot be calibrated within a reasonable period of time.

The written approval of the responsible engineer should be obtained before any non-standard modifications or adjustments are made.

11.4.1.7 Where the pre-installation test is not specified in the original designer's test schedule, or where circumstances prohibit the prescribed test being carried out, a suitable test method should be agreed with the responsible engineer.

11.4.1.8 When the tests are complete, the instrument should be drained and, if necessary, blown through with clean, oil-free dry air. Where applicable, shipping stops should be replaced. After testing and draining, all connections and entries should be temporarily sealed to prevent subsequent ingress of moisture and dirt.

NOTE. It is essential to drain the liquids used for testing the instruments as a precaution against damage caused by liquids expanding on freezing.

11.4.2 Pre-installation test procedures

11.4.2.1 It is preferable to carry out instrument testing in a calibration workshop, except where instruments form part of an integrated system or control panel in which case tests may be carried out in the control room after installation by using portable test gear and/or simulation equipment.

11.4.2.2 The instrument to be tested should be mounted in the correct plane on a rigid and vibration-free stand or structure.

11.4.2.3 Before commencing any tests, the checks described in **11.4.2.4** to **11.4.2.9** should be carried out.

11.4.2.4 The instrument is not damaged in any way, e.g. damage to doors and linkages. Any such damage should be rectified before any tests are attempted.

11.4.2.5 The data plate on the instrument agrees with the information contained on the instrument specification sheet.

11.4.2.6 The power source available, whether electrical or pneumatic, is that specified for the instrument.

11.4.2.7 Any fuses fitted to electrical components are of the correct rating.

11.4.2.8 A suitable means is available for simulating the required process variable and so that test gauges or meters of sufficient accuracy are available for the tests to be performed.

11.4.2.9 The manufacturer's instruction book is available.

11.4.3 Energy supply source and output

NOTE. The procedures described in **11.4.3.1** and **11.4.3.2** are common to all instruments requiring a power supply source and which generate a signal output.

11.4.3.1 *Pneumatic*

11.4.3.1.1 It should be checked that the air supply for pneumatic instruments is clean, dry and oil free.

11.4.3.1.2 The air supply should be connected and the air supply regulator adjusted to the correct setting (e.g. 1.4 bar for a standard transmitter with an operating range of 0.2 bar to 1.0 bar).

11.4.3.1.3 The output should be connected to a suitable test gauge via a capacity chamber (approximately 0.5 L capacity).

11.4.3.1.4 Care should be taken to ensure that all pneumatic connections are leak-free. If in doubt, the joints should be tested with soap or other suitable solution.

11.4.3.2 *Electric/electronic*

11.4.3.2.1 The power supply specified by the manufacturer of the instrument or shown on the data plate should be connected. Preferably electronic instruments should be left energized for 24 h before beginning calibration tests. Correct polarity of supply should be maintained at all times.

11.4.3.2.2 The output of the instrument should be connected to a suitable test meter, preferably a digital milliammeter or alternatively a digital voltmeter with suitable shunt resistor.

11.4.4 Process variable source

11.4.4.1 *General.* A suitable signal generating source should be connected to the process connection together with a means of isolating and regulating the same, with a suitably accurate indicator. The process variable source will depend upon the type of signal to be simulated and **11.4.4.2** to **11.4.4.8** give examples of methods for generating signals appropriate for the various types of instrument.

NOTE. When an instrument is intended to be used with a process fluid that may present a hazard, suitable safety precautions should be observed and the test method agreed with the responsible engineer, e.g. for oxygen service testing fluids should be oil free. After testing the instrument it should be thoroughly cleaned, dried and sealed together with a moisture absorbent, in a protective polyethylene covering and remain sealed until required for installation.

11.4.4.2 *Pressure*

11.4.4.2.1 A compressed air source can usually be used for pressure ranges less than 7 bar.

11.4.4.2.2 Hand-held pressure pumps may be used for signal generation for pressures less than 1 bar. These are particularly useful where testing is being carried out in the field, e.g. for loop testing.

11.4.4.2.3 Pneumatic calibrators are available with a variety of pressure ranges but generally are not suitable for pressures less than 25 mbar.

11.4.4.2.4 For pressures less than 25 mbar, liquid filled manometers should be used with a suitable precision air reducing valve.

11.4.4.2.5 For pressure ranges greater than 7 bar a hydraulic dead weight tester should be used.

11.4.4.3 *Differential pressure*

11.4.4.3.1 When testing differential pressure transmitters, the variable pressure source is normally connected to the high pressure connection and the low pressure connection should be freely vented to atmosphere.

11.4.4.3.2 After the initial calibration test, for high line pressures and/or high accuracy requirements the high and low pressure sides of the meter element should be subjected, in turn, to a static pressure equal to the maximum expected working pressure. The calibration test should then be repeated to ensure that the results remain within the limits stated in the manufacturer's specification.

NOTE. This test may not be applicable to certain types of instruments and, in case of doubt, advice should be sought from the manufacturer.

11.4.4.4 *Diaphragm sealed instruments.* For external diaphragm-sealed type pressure sensors, it is necessary to fabricate a test rig that comprises a mating flange with a pressure connection to which the pressure sources described in **11.4.4.2** can be attached.

11.4.4.5 *Temperature*

11.4.4.5.1 *Filled systems.* For calibration of thermal systems, a temperature calibration bath equipped with an agitator and a certified thermometer is required. Several types are generally available, the most common are given in table 7.

Table 7. Temperature calibration bath guide

Type	Range
Liquid filled: glycol/water	−40 °C to +5 °C
Water	+5 °C to +95 °C
Oil	−40 °C to +180 °C
Fluidized bed	+50 °C to +1100 °C

Temperature calibration baths are generally suitable for use only in a workshop. If required for use in the field, they should only be used under cover and in a non-hazardous environment.

11.4.4.5.2 *Resistance temperature detectors (RTDs).* For critical applications RTDs can be tested by immersion in a temperature bath and their output measured using a Wheatstone bridge.

11.4.4.5.3 *Thermocouples.* For critical applications thermocouples can be tested by immersion in a temperature bath and their output measured using a potentiometer.

11.4.4.6 *Variable area (VA) flowmeters.* VA meters are usually tested by mechanical means, i.e. the float position is varied by means of a wooden or plastics rod inserted through the bottom connection.

NOTE. The actual calibration required should be checked before testing, as the minimum graduation on a VA meter is usually 10 % flow, whereas the full transmitted output may correspond to 0 % to 100 % flow.

11.4.4.7 *Level displacers.* External cage displacement instruments are generally tested in situ owing to their physical size but alternatively may be tested in a test rig or by the suspended weight method.

(a) *In situ testing.* This is carried out as follows.

(1) A check should be made that the process conditions permit the use of water for calibration.

(2) Where the ultimate service of the instrument is for other than water, the manufacturer's instructions should be followed for compensating for the specific gravity at the operating temperature.

(3) The vessel isolation valves should be checked to ensure that they are completely closed.

(4) A graduated glass or plastics column should be connected parallel to the displacer chamber via the bottom drain connection or gauge tapping.

(5) The top of the displacer chamber should be freely vented to atmosphere.

(6) The level can then be varied by injecting water into the chamber. This is usually achieved by using a water container and a hand pump connected via the bottom drain connection.

(b) *Weight method testing.* This is carried out as follows.

(1) This method involves the substitution of the displacer by calibration weights equal to the resultant

downwards force of the displacer at the required calibration points.

NOTE. The manufacturer's handbook should be consulted for the method of calculation.

(2) This method is generally used for displacers designed for top of tank mounting or with extra large float chambers.

(3) In order to use the weight method it is necessary to fabricate a test rig in the workshop and remove the top section of the instrument, containing the float arm, from the displacer caging.

11.4.4.8 *Process analysers.* Calibration checks are usually carried out on process analysers by injecting known samples into the sample conditioning systems. This should be decided for each type of analyser by reference to the manufacturer's handbook or by consultation with the instrument manufacturer, in which case it should be agreed with the responsible engineer.

NOTE. Complex analyser systems usually require specialist personnel from the process analyser manufacturer to assist in pre-calibration and commissioning. For further information regarding analyser installation or commissioning, see section five.

11.4.5 Calibration test

11.4.5.1 *General.* This procedure is applicable to all instruments (transmitting, receiving and direct reading) other than local pressure gauges, temperature indicators or switches (see **11.4.7** to **11.4.9**).

Where receiver instruments form part of a distributed system and where factory tests have been carried out, the testing procedure should be agreed with the responsible engineer.

11.4.5.2 *Leak test (pressure systems).* A maximum input pressure should be applied to the process connection, the inlet valve closed and the pressure source disconnected. The gauge on the inlet should be watched to ensure that there is no fall-off of pressure over a 3 min period. Where leaks are suspected, these should be eliminated and the test repeated.

NOTE. If this kind of test is performed on a gas system, the gas temperature will change as gas is introduced into the system, especially if high pressures are involved. Thus, the pressure may well rise before full temperature equilibrium is reached. In this case, sufficient time should be allowed for temperature equilibrium to occur before the 3 min inspection period begins.

11.4.5.3 *Calibration*

11.4.5.3.1 The instrument should be checked at zero reading and adjusted if necessary.

11.4.5.3.2 The process input signal should be increased and the corresponding output signal and/or scale readings recorded at 0 %, 25 %, 75 % and 100 % of the instrument range. The readings should always be taken when the signal is rising.

11.4.5.3.3 The process input signal should be decreased and the corresponding output signal and/or scale readings should be recorded again at 100 %, 75 %, 25 % and 0 % of the instrument range. The readings should always be taken when the signal is falling.

11.4.5.3.4 The percentage error calculated from the above tests should not exceed the manufacturer's stated limits for both accuracy and hysteresis.

11.4.5.3.5 Where necessary, adjustments should be made according to the manufacturer's instructions and the tests repeated. Accuracy of readings should be better than, or equal to, the accuracy limits stated in the manufacturer's specification.

11.4.5.3.6 After the tests have been completed, the instrument should be colour coded as given in **11.2.5.**

11.4.6 Controller functional test

11.4.6.1 *General.* This procedure is applicable to discrete analogue controllers, either field or panel mounted, and does not apply to microprocessor type controllers forming part of an integrated system which would usually be factory calibrated and any field tests or adjustments would be subject to special agreement with the responsible engineer (see **11.4.16**).

11.4.6.2 *Receiver controllers (closed-loop method)*

11.4.6.2.1 Receiver controllers, either pneumatic or electronic, should be tested by the closed-loop method. This entails connecting the controller output to the signal input connection via, in the case of pneumatic instruments, a capacity chamber (e.g. 0.5 L) to give the system stability. The steps described in **11.4.6.2.2** to **11.4.6.2.13** should then be performed in order to check the controller alignment and synchronization.

11.4.6.2.2 The controller action should be set to reverse (decreasing output for increasing input) and the auto/manual transfer switch to auto.

11.4.6.2.3 The proportional band should be set to a low value.

11.4.6.2.4 Integral and/or derivative actions (if fitted) should be set to minimum time values.

11.4.6.2.5 The settings of any limits should be checked to allow full scale indication of the calibrated span.

11.4.6.2.6 The set-point should be adjusted to 50 % of scale.

11.4.6.2.7 The controller output should now read 50 % (i.e. 0.6 bar or 12 mA) or, if there is a deviation scale, it should be at null balance point (centre scale).

11.4.6.2.8 The set-point should be moved upscale and downscale whilst observing the output meter. The output meter should continuously track (follow) the set-point and the deviation indication should always read null. Sufficient time (about 3 min) should be allowed at each set-point setting to permit the controller to balance correctly.

11.4.6.2.9 With the controller set-point and output at 50 % as described in **11.4.6.2.7**, the proportional band setting should be moved from minimum to maximum. During this movement, the output and null balance reading should remain constant.

11.4.6.2.10 The auto/manual transfer switch should then be changed to manual, whence it should be possible to vary the output manually from 0 % to 100 % of the output scale.

11.4.6.2.11 In the event of the controller performing incorrectly, adjustments should be made in accordance with the manufacturer's instructions until satisfactory test results are obtained.

11.4.6.2.12 An actuating signal equivalent to 50 % of the instrument range should be applied to the controller and the manual regulator output adjusted to 50 %. The controller set-point should then be adjusted to 50 %, and, by switching the auto/manual transfer switch, 'bumpless' transfer should be confirmed. Where necessary, using the manufacturer's instructions, adjustments should be made to achieve satisfactory 'bumpless' transfer.

11.4.6.2.13 After satisfactory completion of the above tests, the controller action should be returned to the correct mode required for service operation. The controller adjustments should be left with settings of 100 % proportional band and minimum integral and derivative times.

NOTE. The full calibration checking of proportional, integral and/or derivative functions is not normally required but when specified these functions should be checked in accordance with the manufacturer's instructions.

11.4.6.3 *Direct-connected controllers (open-loop method)*

11.4.6.3.1 For controllers connected directly to the process, it is necessary to simulate the process variable as given in **11.4.4.**

A suitable power supply should be connected. In the case of pneumatic controllers, a capacity chamber, e.g. 0.5 L, should be connected to the output to give the system stability. An output indicator should also be connected.

11.4.6.3.2 The controller action should be set to direct (increasing output for increasing input) and the auto/manual transfer switch to auto.

11.4.6.3.3 The proportional band should be set to a low value.

11.4.6.3.4 The integral and/or derivative settings (if fitted) should set to minimum time values.

11.4.6.3.5 The settings of any limits should be checked to allow full-scale indication of the calibrated span.

11.4.6.3.6 The set-point should be adjusted to 50 % of scale.

11.4.6.3.7 The process variable should be increased to 50 % of scale, at which point the controller output should change from minimum to maximum.

11.4.6.3.8 If this does not occur, adjustment should be made in accordance with the manufacturer's instructions.

11.4.6.3.9 When correct changeover occurs, the controller action should be reversed and the operation re-checked to ensure that the controller is correctly aligned. If not, adjustments should be made in accordance with the manufacturer's instructions and the test repeated.

11.4.6.3.10 Having checked the alignment as above, the controller action should be set to the required mode for operation, and the proportional band set to 100 %.

11.4.6.3.11 The process variable and set-point should be set to 50 % of scale.

NOTE. The controller is normally synchronized at 50 % of the output range (e.g. 0.6 bar or 12 mA) and should therefore indicate mid-output range when the set point and the process variable are at mid-scale.

11.4.6.3.12 With the controller set at 50 % of scale as above, the proportional band setting should be adjusted from minimum to maximum, during which the output pointer should remain stationary.

11.4.6.3.13 In the event of the controller performing incorrectly, adjustments should be made in accordance with the manufacturer's instructions and the tests should then be repeated.

11.4.6.3.14 The auto/manual transfer switch should then be changed to manual whence it should be possible to vary the output manually from 0 % to 100 % of the output scale.

11.4.6.3.15 After satisfactory completion of the above tests, the controller action should be returned to the correct mode required for service operation. The controller adjustment should be left with settings of 100 % proportional band and minimum integral and derivative times.

NOTE. The full calibration checking of proportional, integral and/or derivative functions is not normally required but when specified these functions should be checked in accordance with the manufacturer's instructions.

11.4.7 Pressure gauges

11.4.7.1 Pressure gauges should be checked by means of a hydraulic pressure gauge comparator against a standard test pressure gauge.

NOTE. Vacuum gauges require the use of a vacuum test pump.

11.4.7.2 The gauge comparator should be firmly fixed to a bench. A test gauge of range comparable to the gauge under test is fitted to one branch of the comparator. The gauge to be tested is fitted to the other branch and the hand pump on the comparator operated in order to check the gauge against the readings of the test gauge.

Readings should be checked for pressures corresponding to 0 %, 50 % and 100 % of the range of the gauge under test.

Actual gauge readings should be noted for both rising and falling signals.

11.4.7.3 Test gauges should have an accuracy of or better than 0.25 % of full scale and should be periodically checked for accuracy against a dead-weight tester.

11.4.8 Pressure switches

Pressure switches should be tested at their operating point using either a compressed air source or a dead-weight tester depending upon the range of the switch under test. A continuity test-circuit should be connected across the contacts to ensure correct operation.

Care should be taken to ensure that the switch operation is in the correct mode, i.e. with a rising or falling signal according to the instrument specification.

Where the switching differential is stated in the specification, this should also be checked.

11.4.9 Temperature indicators

11.4.9.1 *Local.* Local temperature indicators (dial thermometers) should be checked using a temperature bath as given in **11.4.4.5**. They should normally be checked at approximately 50 % of the range unless otherwise agreed by the responsible engineer.

11.4.9.2 *Remote.* Remote temperature indicators working from RTDs should be checked using a decade resistance box and injecting the appropriate resistance values.

Remote temperature indicators working from thermocouple inputs are tested using a millivolt source. Cold junction compensation should be taken into account.

11.4.10 Temperature switches

Temperature switches should be tested at their operating point using a temperature bath as given in **11.4.4.5**.

A continuity test circuit should be connected across the contacts to ensure correct operation.

Care should be taken to ensure that the switch operation is in the correct mode, i.e. with a rising or falling signal according to the instrument specification.

Where the switching differential is stated on the original design specification, this should also be checked.

11.4.11 Level switches

Float switches should be tested mechanically prior to installation with a continuity test circuit connected across the contacts to ensure correct operation. Care should be taken to ensure that the switch operation mode is correct.

11.4.12 Solenoid valves

11.4.12.1 An appropriate power supply should be connected via a switch.

11.4.12.2 An air supply should be connected to the appropriate port or ports.

11.4.12.3 The operation of the valve should be checked by operating the switch and observing correct changeover action.

11.4.12.4 The tightness of shut-off should be checked by connecting a flexible tube to the outlet port or ports and immersing the free end in water to ensure that the valve closure is bubble-tight at the stated design pressure.

11.4.12.5 Where applicable, electrical and manual reset, override and time delay features should be checked as called for on the valve specification.

11.4.12.6 The resistance of the coil should be checked to ensure that it is as specified.

11.4.13 Flow devices

Flowmeters such as turbine meters and magnetic flowmeters, cannot usually be tested in the field and manufacturers' test certificates are normally accepted. Omission of tests should be agreed with the responsible engineer.

Before installation, the flow device should be checked to ensure that the data and material specification stamped on the data plate or tab handle agrees with the specification.

Orifice plates should be examined for flatness and to ensure that they are undamaged. The bore should be accurately checked to ensure that it agrees with the figure stamped on the tab handle.

11.4.14 Control valves

11.4.14.1 *General*

11.4.14.1.1 These tests may be carried out in the instrument workshop or, as is more often the case, in situ after the valve has been installed in the line. Tests should not be carried out until the valve is in its final operating state, i.e. after line flushing operations have been completed.

NOTE. Where line flushing and hydrostatic testing has occurred with the valve in situ, the valve packing should be checked and replaced if damaged.

11.4.14.1.2 The valve and data plate should be checked to ensure that they agree with the control valve specification.

11.4.14.1.3 A check should be made that, where specified, a lubricator is fitted and that it is charged with the correct lubricant.

11.4.14.2 *Diaphragm actuated valves without positioners*

11.4.14.2.1 A note should be made of the dry operating range (bench-set) of the diaphragm actuator from its data plate or specification sheet.

11.4.14.2.2 A suitable regulated air supply together with an accurate test gauge should be connected to the diaphragm case connection.

11.4.14.2.3 The air pressure should be increased to load the diaphragm and the valve spindle position from the valve stem position indicator should be checked against the appropriate air pressure signal. The travel should be checked at the following positions: 0 %, 25 %, 75 % and 100 % of the valve stroke.

11.4.14.2.4 Where necessary, the valve spring tension nut should be adjusted to obtain the correct start point and a retest made.

11.4.14.2.5 Where necessary, the speed of operation from fully open to fully closed should be checked to ensure that it is within the limits stated on the specification sheet.

11.4.14.2.6 Where necessary, the hysteresis should be checked by using a micrometer dial indicator clamped to the valve stem and repeating the travel test with rising and falling signals at 0 %, 25 %, 75 % and 100 % of the valve stroke. The hysteresis should be within ± 5 % of the valve stroke unless otherwise specified in the original design specification.

11.4.14.2.7 When tight shut-off is an important criterion, a test rig should be fabricated comprising a blind flange on the valve outlet fitted with a 6 mm bleed pipe and a suitably rated isolation valve from the centre of the flange. The open end of the bleed pipe should be immersed in a container of water so that discharge bubbles can be observed.

NOTE. For precautions to be taken when pressure testing see **2.19**.

The specified signal corresponding to the valve closed position under normal operating conditions should be applied to the valve actuator and, if necessary, adjustments made to the valve, until the leakage bubble-rate is within the specified tolerance.

11.4.14.2.8 Where an air failure lock-up relay or other accessory device is incorporated, it should be checked for correct operation in accordance with the instrument specification.

11.4.14.3 *Diaphragm-actuated valves with positioners*

11.4.14.3.1 Where the positioner is fitted with a bypass valve (normally omitted on split-range service*), the valve should be switched to the bypass position and a variable air supply connected with test gauge to the signal input connection.

11.4.14.3.2 A note should be made of the dry operating range (bench-set) of the diaphragm actuator from its data plate or specification sheet.

11.4.14.3.3 The air pressure should be increased to load the diaphragm and the valve spindle position from the valve stem position indicator should be checked against the appropriate air pressure signal. The travel should be checked at the following positions: 0 %, 25 %, 75 % and 100 % of the valve stroke.

11.4.14.3.4 Where necessary, the valve spring tension nut should be adjusted to obtain the correct start point and a retest made.

11.4.14.3.5 Where necessary, the speed of operation from fully open to fully closed should be checked to ensure that it is within the limits stated on the specification sheet.

11.4.14.3.6 Where necessary, the hysteresis should be checked by using a micrometer dial indicator clamped to the valve stem and repeating the travel test with rising and falling signals at 0 %, 25 %, 75 % and 100 % of the valve stroke. The hysteresis should be within ± 5 % of the valve stroke unless otherwise specified in the original design specification.

11.4.14.3.7 When tight shut-off is an important criterion, a test rig should be fabricated comprising a blind flange on the valve outlet fitted with a 6 mm bleed pipe and a suitably rated isolation valve from the centre of the flange. The open end of the bleed pipe should be immersed in a container of water so that discharge bubbles can be observed.

NOTE. For precautions to be taken when pressure testing see **2.19**.

The specified signal corresponding to the valve closed position under normal operating conditions should be applied to the valve actuator and, if necessary, adjustments made to the valve, until the leakage bubble-rate is within the specified tolerance.

11.4.14.3.8 The operating range of the positioner, input and output, should be recorded.

11.4.14.3.9 An air supply should be connected to the positioner supply connection and adjusted to 0.4 bar above the maximum operating rate of the actuator.

11.4.14.3.10 If fitted, the positioner bypass valve should be switched on.

11.4.14.3.11 A variable input source should be connected to the positioner signal connection.

11.4.14.3.12 The actuator should then be checked for travel, with rising and falling signals at 0 %, 25 %, 75 % and 100 % of the valve stroke, against the appropriate air pressure signal. If necessary, adjustment should be made in accordance with the manufacturer's instructions, and a retest made.

11.4.14.4 *Other actuators*

11.4.14.4.1 Control valves with other types of actuators, e.g. piston operators, air cylinder operators, electro/hydraulic or electric motor operators, should be tested for stroking and failure action in accordance with the manufacturer's instructions.

11.4.14.4.2 Where limit switches or torque switches are fitted, these should be checked, using a continuity test set, for correctness of setting and for operation. On motorized valves, care should be taken to check the setting of the limit switches before switching on the actuator.

11.4.15 Safety valves

11.4.15.1 *General*

11.4.15.1.1 The testing of safety valves is sometimes outside the scope of work of the instrument department and the following tests are given as a guidance for use when required. All test methods should be agreed with the responsible engineer before being put into operation.

NOTE. Boiler safety valves are usually tested in situ after mounting on the boiler. These valves are sealed to prevent unauthorized interference and reference should be made to BS 6759 : Part 1.

11.4.15.1.2 It is important that safety valves are stored in a secure warehouse with the valves standing vertically. When received, the valve blanking plates should be checked for damage that could have allowed the passage of foreign material into the inlet nozzle and the body cavity.

11.4.15.1.3 Before testing, it should be ensured that the valve agrees with its specification sheet, that the data plate on the valve is correct and that the direction of flow is clearly marked on the valve body.

11.4.15.2 *Test rig*

11.4.15.2.1 Safety valves are normally tested in a workshop which should be equipped with a suitable test rig. The test rig should be constructed of such materials that there is no possibility of the formation of rust or scale which could be blown through into the valve under test. A suitable nozzle with gaskets, adaptor flanges and bolts or clamps should be incorporated so that the relief valve under test may be mounted rigidly in a vertical position.

11.4.15.2.2 Compressed air is preferred as a test fluid but bottled inert gas may be used if air is not available at the required pressure. The test fluid should be filtered to ensure that no particles of foreign matter are passed through into the valve under test.

* For such valves see the manufacturer's instructions.

If a test gas other than air is used, the test rig should be installed in a freely ventilated location.

11.4.15.2.3 For high pressure duties, hydrostatic testing may be required using a purpose built test rig which should be operated in accordance with the manufacturer's instructions. On hydrostatic test rigs, all piping and fittings in contact with water should be of stainless steel.

11.4.15.2.4 To control the test pressure, a precision reducing valve and a test pressure gauge (minimum 150 mm diameter) with resettable maximum pointer should be provided on the inlet side. The reducing valve and gauge ranges should be selected to cover the range of safety valve set pressures to be tested.

11.4.15.3 *Test procedure*

11.4.15.3.1 Safety valves should be tested immediately prior to installation. If installation is deferred, the protective flange covers should be refitted and the valve stored in a vertical position. When required for service, the valve should be retested.

11.4.15.3.2 All tests on safety valves should be recorded on the check sheet (see **11.8**) and the signatures of witnesses should be obtained as required.

11.4.15.3.3 The safety valve tests are:

(a) popping and reseating; and

(b) the seat leakage test.

11.4.15.4 *Popping and reseating*

11.4.15.4.1 Before popping the safety valve, ensure that the outlet test flange has not been fitted and that the valve outlet is unobstructed.

11.4.15.4.2 The inlet nozzle should be wiped clean prior to testing.

11.4.15.4.3 The safety valve cold set pressure should be ascertained and entered on the test record sheet. This pressure should be found on the valve data plate or on the valve data sheet.

11.4.15.4.4 The test pressure should be increased slowly until the safety valve is observed to pop and the pressure (as indicated by the maximum pointer on the test gauge) should be noted on the test record sheet. If the difference between the measured popping pressure and the cold set pressure is outside acceptable tolerances, the valve setting should be adjusted in accordance with the manufacturer's instructions.

11.4.15.4.5 The test pressure should then be lowered and the reseating pressure noted and checked to ensure that it agrees with the safety valve specification.

11.4.15.5 *Seat leakage test.* The seat leakage test should be in accordance with BS 6759.

11.4.16 Microprocessor systems

Microprocessor based control systems are not covered in this section except in so far as the tests detailed can be applied to components of a system.

On site, check-out and pre-commissioning would usually be carried out by specialist personnel from the equipment manufacturer or, alternatively, if other qualified and experienced personnel are used, then the manufacturer's instructions should be followed.

Every input and output signal should be checked through from its field initiation point to control room display unit or vice versa. All control functions should be checked for operability in accordance with the manufacturer's stated performance characteristics.

All checks should be recorded on loop test sheets and the forms described in **11.8** may be used as applicable.

All test methods should be agreed with the responsible engineer.

11.4.17 Special control systems

The procedures for the testing of complex control systems, e.g. multi-fuel combustion controls, should be agreed with the responsible engineer before the work begins. Moreover, complex interlocking and shut-down systems with many inputs and outputs require a carefully planned testing procedure which should be formulated and also agreed in advance.

Testing of emergency shut-down systems should involve physical operation of the actual shut-down devices, on both inputs and outputs.

11.4.18 Emergency shut-down systems

A specific procedure should be agreed in advance with all parties prior to testing of the emergency shut-down system. This procedure should cover, but not be limited to, the testing of each individual function, the sequence of functions, and the logic of the interaction.

A certified record of all tests should be kept.

11.4.19 Alarm systems

The alarm should be energized and the 'test', 'accept' and 'reset' buttons operated to ensure that all display windows are functional and that the alarm sequence is operational. In particular, displays using two or more lamps in parallel per window should be checked to ensure all lamps illuminate.

The display facia should be checked to ensure that window colours and engravings are correct and located in the correct positions.

11.5 Pressure testing of instrument piping and tubing

11.5.1 General

11.5.1.1 The object of this phase of the testing procedure is to ensure that all instrument piping and tubing is pressure-tight under the specified working/testing conditions.

11.5.1.2 The pressure testing of any equipment fabricated on site, e.g. cooling chambers, capacity pots and catch pots, should be witnessed by the responsible engineer unless this requirement has been waived, in which case the responsible engineer should be provided with test certificates.

11.5.1.3 The instrument piping and tubing to be tested can be classified in the following categories:

(a) air supply piping (see **11.5.2**);

(b) transmission signal tubing (see **11.5.3**);

(c) process impulse piping (**11.5.4**).

11.5.1.4 The pressure testing of air supply piping, transmission tubing and process impulse pipework on a given loop should be completed before the final loop testing. Thus, if the transmitter has to be disconnected for loop testing, only one connection has to be rechecked.

11.5.2 Air supply piping

11.5.2.1 The testing of the main instrument air header from the source up to and including the first isolation, i.e. branch shut-off valves usually on the pipe track, is not included in this procedure.

The tests described in **11.5.2.2** to **11.5.2.6** assume that the instrument air compressors and driers have been commissioned and an instrument air supply established at the specified working conditions, i.e. clean, dry and oil-free. If the permanent air supply has not been established an alternative source of clean, oil-free, dry air or nitrogen should be used. This can be obtained either from storage cylinders or an oil-free compressor with dryer.

11.5.2.2 Branch air lines to individual instruments should be disconnected immediately upstream of and adjacent to the instrument air filter regulator and blown through with clean air until clear of all foreign materials. The tubing downstream of the filter regulator should be blown through before connection to the instrument.

11.5.2.3 The open end(s) should be blanked off and a suitable test pressure gauge connected into the system.

11.5.2.4 The isolation valve immediately upstream of the piping to be tested should be opened and when the line is pressurized it should be closed. This test should have a duration of 10 min and the test gauge should be observed in order to detect leakage. In addition, all joints should be checked for leaks by the application of soap or similar solution, and leaking joints remade as necessary.

11.5.2.5 On completion of the test, the line should be reconnected and the joint(s) that have not previously been proven should be checked with soap solution.

11.5.2.6 The pipe should then be colour coded as given in **11.2.5**.

11.5.3 Transmission signal tubing

11.5.3.1 Each individual tube should be disconnected at both ends and blown through with clean, oil-free, dry air.

11.5.3.2 The tubes should be blanked off and pressurized to 1.4 bar from an existing air supply, via a pneumostat or bubble bottle. After pressurizing, the bubble rate should be less than one bubble in 10 s. If an air supply is not readily available, the tubes may be pressurized using a foot pump and with a manometer connected into the system. With the pressure source isolated, the reading should remain constant for a period of 10 min.

The tube should then be reconnected and, when an air supply is established, the joints that have not previously been proven should be tested with soap solution. This may be achieved by setting the transmitter/controller outputs to maximum.

11.5.3.3 Underground tubing should be tested before trench backfilling is commenced.

11.5.3.4 The tubing should then be colour coded as given in **11.2.5**.

11.5.4 Process impulse piping

11.5.4.1 After fabrication, where practicable, process impulse piping should be disconnected at both ends for flushing and testing.

11.5.4.2 The line should be first flushed with water, then one end should be blanked off and the other end should be connected to a hydraulic pump with a suitable test gauge fitted. The line should then be pressurized to the test pressure of the associated process line or vessel. The line should then be isolated from the pressure source and the pressure should remain constant for a period of 10 min.

NOTE. Test pressure is normally 1.5 times normal working pressure.

11.5.4.3 After testing, the lines should be reconnected to the instrument manifold and all manifold valves should be checked for tight shut-off.

11.5.4.4 For close coupled instruments, e.g. line mounted differential pressure cells, the pipes should be disconnected at the instrument only and tested up to the initial isolation as in **11.5.4.2**.

11.5.4.5 During hydraulic tests on the main process line, instruments should be disconnected to ensure that initial isolations are leakproof. During flushing, all installed instruments should be positively isolated from the process line. Instruments fitted with manifolds should have their bypass lines open.

11.5.4.6 It should also be ensured that all instrument pressure tappings have been drilled through the pipe wall.

11.5.4.7 All instrument equipment and piping that has been hydrostatically tested with water should be thoroughly dried out on completion of the test.

11.6 Testing of instrument cables

11.6.1 Immediately after cables are laid and *before* connection, all thermocouples, electrical and electronic instrument wiring should be checked for polarity, continuity and insulation resistance between conductors and between conductors to earth. These tests should be carried out before final loop 'power off' tests.

NOTE 1. Attention is drawn to the need to perform continuity and insulation resistance checks in accordance with Part 6 of the IEE Regulations for electrical installations (15th edition) or the rules and regulations with which the installation has to comply.

NOTE 2. Severe damage may be caused to barriers and electronic equipment if inadvertent insulation testing of cables is carried out *after* connection.

Underground cables should be tested before trench backfilling is commenced.

11.6.2 Tests on instrument cables for loop impedance, inductance, capacitance, etc. should be carried out, where required, in accordance with BS 5345 : Part 4 in order to determine their suitability for inclusion in intrinsically safe circuits.

11.6.3 Coaxial cables used for data-highways should be tested using sine-wave reflective testing techniques.

11.6.4 After all tests have been completed the cables should be colour coded as given in **11.2.5**.

11.7 Pre-commissioning (including loop testing)

11.7.1 General

11.7.1.1 The object of loop testing is to ensure that all instrumentation components in a loop are in full operational order when connected together and are in a state ready for plant commissioning.

11.7.1.2 The procedure to be adopted in carrying out these tests is described in **11.7.1.3** to **11.7.1.8** but, in general, the completed instrument loop should be tested as one system and, where necessary, adjustments should be made to calibrations. Associated alarms and trips should be checked during loop testing.

11.7.1.3 As a prerequisite to testing the equipment, inspection and testing of the associated pipework, wiring, mounting, etc. should be carried out to ensure that the installation is complete, is generally acceptable and has been carried out in a professional manner and in accordance with this code of practice.

Checks for mechanical/electrical completeness should be carried out using the first part of the instrument loop check sheet given in **11.8**.

11.7.1.4 Loop testing of remote control loops is a two-man operation, one man in the field and one man in the control room. Both men should be provided with adequate means of communication, i.e. field telephones or radio transceivers as approved by the responsible engineer.

NOTE. Attention is drawn to the possibility of r.f. interference from such equipment, which may affect the accuracy of certain electronic equipment and systems. In case of doubt, the advice of the manufacturer of the equipment and systems should be sought.

11.7.1.5 The instrument engineer responsible for loop testing should give adequate notice to representatives of other engineering disciplines where the tests require to be interrelated.

11.7.1.6 Loop testing should not be carried out on electronic equipment until an adequate warm up period has elapsed. Where possible, the equipment should be energized for at least 24 h before testing.

11.7.1.7 In most instances, the responsible engineer will witness the final loop tests and countersign the test certificates.

11.7.1.8 Upon completion, one copy of the test certificate for every installation, recording all results, should be made available to the responsible engineer. The certificates for any tests not witnessed should be accompanied by the responsible engineer's written confirmation that witnessing has been waived.

11.7.2 Loop testing procedure

11.7.2.1 The loop should be inspected and air/electrical supplies set where appropriate. In particular it should be checked that the control valve air supply pressures are set in accordance with the manufacturer's specification.

11.7.2.2 For electronic loops, a check should be made that the polarities are correct. The loop impedance should be measured and the necessary compensating adjustments made.

11.7.2.3 Each loop should be tested from the field signal input through to the receiving instrument and, in the case of controllers, the output should also be checked through to the final control element operation. During a loop test all ancillary items in the loop should be tested, e.g. signal convertors and alarm switches.

11.7.2.4 Before loop testing, all components should be checked for correct zeroing and adjustments made if necessary.

11.7.2.5 To carry out a loop test, it may be necessary to isolate the transmitter (or input device) from the process and to connect in a process signal simulator (see **11.4.4**). Signals should be generated equivalent to 0 %, 50 % and 100 % of the instrument range and the loop function checked for correct operation at each point in both rising and falling modes.

If errors in overall loop calibration are detected, repeat tests should be carried out on individual items of the loops as in **11.4**.

11.7.2.6 For controller applications, the controller should be switched to manual mode and, by applying the appropriate signals, it should be ensured that the control valve or valves stroke correctly. Valve positioner gauges should also be checked during this stage.

11.7.2.7 Alarm and trip actions should be checked by varying the actuating signals and adjusting as necessary.

11.7.2.8 Locally mounted controller or transmitting-only loops should be tested in a similar manner to that described in **11.7.2.4** and **11.7.2.5** omitting transmitter and/or auto/manual checks as necessary.

11.7.2.9 After each loop is satisfactorily tested, the controller should be switched to manual and checked for the following:

(a) correct action selection;

(b) 100 % proportional band;

(c) minimum integral action;

(d) minimum derivative action.

The controller should then be colour coded as given in **11.2.5**.

11.7.3 Temperature loops (thermocouple and resistance thermometer)

11.7.3.1 Thermocouples and resistance thermometers should be removed from their wells and checked to ensure that they are not damaged. The resistance of each resistance thermometer should be measured at ambient temperature and both resistance and temperature should be noted. For temperature loop simulation, signals from resistance thermometers are simulated by decade boxes and signals from thermocouples by the use of precision millivolt signal generating sources.

11.7.3.2 After testing, all thermocouples/resistance thermometers should be replaced in their thermowells and reconnected. It is important to ensure that the element is 'bottomed' in the thermowell and that the polarity of the thermocouple connections is correct.

11.7.3.3 For galvanometer deflection type instruments using thermocouples, compensating lead resistances should be adjusted if necessary.

11.7.3.4 Where a two-wire resistance thermometer system is employed, 'make-up' resistance should be adjusted.

11.7.3.5 For three and four-wire resistance thermometer installations, care should be taken to ensure that the connections are correct.

11.7.4 Process analysers and associated equipment

11.7.4.1 Process analysers should be checked according to manufacturer's instructions and/or by agreement with the instrument engineer (see also **11.4.4.8**).

11.7.4.2 Trips and alarms not previously covered in the loop tests, e.g. initiating devices that stop/start pumps, should be checked in conjunction with the instrument engineer.

11.7.4.3 All systems should be checked for fail safe operation which will include the checking of burn out features on thermocouple installations.

11.7.5 Preparation for commissioning

Upon completion of loop testing the installation should be made ready for process commissioning. All extra work such as setting zero elevations and suppressions, filling liquid seals, adjusting purge rates etc. should be completed.
It should be checked that all accessories such as charts, ink, fuses and safety-glasses are fitted.

11.8 Check sheets

11.8.1 The results of all calibration checks and loop tests should be recorded on suitable check sheets, signed by the instrument engineer responsible for testing and countersigned by the responsible engineer.

11.8.2 Completed examples of calibration and check sheets and a test report* are shown in appendices B to E.

* The sheets shown form part of the Energy Industries Council Procedure CCI P/1.

Section twelve. Commissioning and acceptance

12.1 General

Commissioning is the bringing on-stream of a process plant and the tuning of all instruments and controls to suit the process operational recommendations.

It is recommended that this section is used to form the basis of a plant instrumentation commissioning and acceptance procedure.

12.2 Ready for commissioning

A plant, or section of a plant, is considered to be ready for commissioning when the following conditions are satisfied:

(a) all instruments have been installed in accordance with the fully approved drawings and other relevant documentation prepared and supplied by the plant designer or contractor (see section ten);

(b) the installation has been checked for mechanical/electrical completeness (see section eleven);

(c) all line flushing operations and pressure tests have been completed;

(d) all signal loops have been fully tested for electrical or pneumatic integrity (i.e. instrument pre-calibration and loop testing) as described in the pre-commissioning procedure (see section eleven);

(e) the settings and set-points of all controllers and alarm initiators have been adjusted to estimated values and the correct operation of all instruments has been demonstrated to the satisfaction of the client's responsible engineer (see section eleven);

(f) the labelling of all instruments and connections has been completed to the satisfaction of the responsible engineer;

(g) the site or area has been cleaned up, i.e. all surplus materials and tools have been removed, and all painting and thermal installation work has been completed, unless otherwise agreed by the responsible engineer;

NOTE. Before commencing work in or adjacent to a live plant, on any area not yet commissioned, it is essential that permit to work procedures in force are complied with (see section two).

12.3 Commissioning

12.3.1 General

All pertinent documents including flow diagrams, flow data, schedules of safety valve settings, alarm settings, and controller set-points, should be available at all times for use by the commissioning engineers.

During the plant commissioning period, specialist and instrumentation engineers should be on standby, or on call, until the official handover and acceptance of plant has taken place.

Stores and workshops should be available during the commissioning period. Consumable spares should be available at all times.

During commissioning, all errors, omissions and alterations to the installation, whether due to design changes or for any other reason, should be carefully noted and remedial action agreed in writing with the accepting authority before work commences.

12.3.2 Preliminary checks

As a prerequisite to instrument commissioning, the commissioning engineers should ascertain, as a minimum, that:

(a) all instrument electrical power supplies are fully functional, including any emergency standby supplies;

(b) all instrument air supplies are available;

(c) all liquid seals are installed and filled in accordance with the design requirements;

(d) all control valve lubricators have been charged with the correct lubricant;

(e) all protective heating systems, e.g. heat tracing and heated enclosures, are working, where required;

(f) the control room environment is satisfactory and in a finished state;

(g) control room air conditioning systems are fully operational and are maintaining correct temperature and humidity conditions;

(h) all cable entries to control rooms have been sealed.

12.3.3 Commissioning procedures

12.3.3.1 *General.* Instrument commissioning should be carried out on a loop-by-loop basis and should be fully co-ordinated with the plant start-up operations.

Before commissioning an instrument loop, all instrument zeros should be checked and adjusted where necessary, i.e. for both transmitting and receiving instruments.

Commissioning falls into several main phases as described in **12.3.3.2** to **12.3.3.5**.

12.3.3.2 *Measurement systems*

12.3.3.2.1 All instruments requiring power supplies should be energized, e.g. remote transmitters.

NOTE. Electronic instruments should preferably be energized for at least 24 h before commissioning is commenced in order to provide an adequate warm-up period. Where the warm-up period is not allowed, settings may need to be checked and readjusted at a later stage.

12.3.3.2.2 Pressure sensing systems or impulse lines should be pressurized by gradually opening the process block valves at the primary sensing points. Bleed/vent valves should be opened as necessary during pressurization in order to eliminate air, unwanted gases or condensate from the process sensing lines.

12.3.3.2.3 Differential pressure systems, e.g. flow and liquid level, should also be pressurized as described in **12.3.3.2.2**, taking care to observe the correct valve opening sequence in accordance with the manufacturer's instructions.

12.3.3.2.4 Read-out instruments (indicators and recorders) should be observed to check that sensible readings are being obtained.

12.3.3.2.5 Recorder chart drives should be energized and recording mechanisms should be in operation.

12.3.3.3 *Control systems*

12.3.3.3.1 Before attempting to commission a control loop, it should be ensured that the air/power supplies are available, as required, at all loop components, e.g. controller and control valve positioner, if fitted.

12.3.3.3.2 The initial stages of plant commissioning is usually accomplished with controllers switched to the manual bypass mode and with control valves manually bypassed in the field by operation of bypass valves, by operation of manual hand wheels, or by manually derived signals from the controller.

12.3.3.3.3 When a control valve is on manual bypass in the field, it is first necessary to pressurize the control valve actuator by a remote signal derived from the controller in manual mode and then to bring the control valve into operation by removing the manual override constraints.

12.3.3.3.4 With the controller still in the manual mode, the responsiveness of the system may then be checked by varying the remote manual signal and observing the response on the read-out instrument, taking care to avoid causing upsets which may be detrimental to process operations.

12.3.3.3.5 Once the system is seen to respond correctly and the required process variable reading is obtained using remote manual control, the controller set-point should be aligned with the process variable and the controller may then be switched to auto in order to bring the controller on-stream.

12.3.3.3.6 The controller responses, i.e. proportional, integral, and derivative actions, should then be adjusted to obtain optimum settings to suit the automatic operation of the plant.

NOTE. For methods of controller tuning, reference should be made to manufacturers' literature or other publications on this subject.

12.3.3.4 *Alarm systems.* Alarm annunciators should be energized and the test button/s operated to ensure that all display windows are functional.

Alarm sensing primary elements should be commissioned, one at a time, as given in **12.3.3.2.**

After commissioning, the alarm settings should be checked to ensure that they are operating at the values specified at the original design stage.

12.3.3.5 *Shut-down systems*

12.3.3.5.1 Shut-down systems should have been fully checked out at the plant pre-commissioning phase (see section eleven).

12.3.3.5.2 Before attempting to commission a shut-down system on a plant it is essential to formulate a commissioning procedure in conjunction with the process operation personnel, and reach written agreement regarding operation of any inhibit switches.

12.3.3.5.3 Often a plant is commissioned with a limited number of shut-down inhibit switches, relative to that part of the plant being commissioned, in an override position, as it is sometimes impracticable to have function trips in operation when attempting to commission the plant.

Usually it is not permissible to have more than two or three inhibit switches in operation at the same time.

12.3.3.5.4 The primary measuring instruments associated with shut-down systems should be energized and commissioned as described in **12.3.3.2** and once the plant is on-stream the inhibit switches should be, step-by-step, changed to auto operation as soon as possible.

12.3.3.5.5 Before overriding any of the shut-down systems it is necessary to obtain the written agreement of the plant operation supervisor.

12.4 Acceptance

12.4.1 All instrumentation should be complete and shown to be working to the satisfaction of the plant owner before the plant take-over and acceptance certificates are prepared.

12.4.2 When requested, the acceptance procedure should provide for the hand over of all drawings, data sheets, check lists, test results, operating and maintenance instructions/manuals, quality assurance/quality control reports, as-built drawings, etc. prepared during the original design and the construction of the plant.

12.4.3 The Final Acceptance Certificate should be issued and certified only when all control loops and individual instrument systems have been demonstrated to work satisfactorily and have been formally accepted by the plant owner.

12.4.4 If, at the moment of final acceptance, certain items are still pending due to unforeseeable reasons, they should be carefully listed and agreed between the parties involved. Agreement should also be reached concerning the method of completing the work and the time for its completion.

Appendices

Appendix A. Explanation of marking and labelling of equipment in hazardous areas

A.1 General

It is essential that information on labels that are attached to equipment, and in any associated documentation, enables the equipment to be installed and operated safely.

A.2 Certification of apparatus

It is the legal responsibility of both manufacturer and user to comply with specific safety requirements. The usual method of demonstrating compliance with safety requirements is to obtain certificates from an independent recognized authority. The principal certifying authorities in the UK are given in table 8 (see also 3.2.3).

Table 8. Principal UK certification authorities

Group I (coal mining) apparatus	Group II (non-mining) apparatus
Health and Safety Executive HSE(M) Harpur Hill Buxton Derbyshire SK17 9JN	Health and Safety Executive BASEEFA Harpur Hill Buxton Derbyshire SK17 9JN

A.3 The certificate

The certificate issued by the certifying authority to the manufacturer gives details of the representative sample of the apparatus submitted to the authority to certify that it has been found to comply with the relevant standard. In the case of the authorities listed in table 8, this is usually a British or European Standard.

The certificate will basically deal with matters concerning protection within the hazardous area but it might not deal with any other aspects of the design, e.g. it may not indicate the degree of protection against dust, liquids or resistance to corrosion. The manufacturer will usually provide other information on these aspects.

A.4 The licence

Certification authorities, BASEEFA in particular, control the use of their certification mark by granting an 'A' licence. A manufacturer without such a licence may not apply the BASEEFA mark.

Licence holders can be asked at any time to supply apparatus or parts of apparatus being manufactured for checks and tests by the certifying authority, to establish that the apparatus or parts comply with the certified design. In addition, the holders of a BASEEFA licence are subject to periodic visits by representatives of the certifying authority who will examine any certified apparatus that is in the process of manufacture or assembly in order to verify that the quality and safety of the product meets the certification requirements. The BASEEFA licence is subject to renewal at intervals of 3 years and if there is any doubt about the manufacturer's ability to produce good quality equipment in accordance with the certification documents, it is unlikely that the licence will be renewed.

Details of the licence marks are as follows.

FLP — *HSE mining mark.* From January 1971 Group I products only. Health and Safety Executive (Mining), Buxton

Ex — *BASEEFA mark.* Group II products only. BASEEFA, Buxton

Ex — *Community mark.* In addition to the certifying authority mark if the product is certified to the harmonized standards reflected in EEC directives 76/117/EEC and 79/196/EEC

A — *Trade agent mark.* Used by BASEEFA in addition to the certification authority marks and community mark shown above

A.5 Certification terms

NOTE. Any of the seven types of certificate described in (a) to (g) may be the subject of either prime certification or of supplementary certification.

Prime certificates result from new submissions made for the certification of electrical apparatus, components or systems.

Supplementary certificates result from submissions for variations of certified electrical apparatus, components or systems.

For the purposes of certification the following descriptions apply.

(a) *Component approval.* Certification that a component is suitable for use in apparatus or in association with apparatus demonstrates that it complies, in whole or in part, with the requirements of a standard that is *not* one of the harmonized standards to which reference is made in the directives, e.g. BS 229, BS 889 and BS 4683. In this case certification can be obtained but the component will *not* bear the BASEEFA mark or the community mark. The certificate number is usually a four figure number prefixed BAS and suffixed U, e.g. BAS4126U. The certificate is valid for 3 years but is not subject to the licensing conditions.

NOTE. For group I (coal mining) apparatus the term 'component acceptance' is used.

(b) *Certificate of assurance.* Certification of apparatus which, in whole or in part, complies with one of the harmonized standards to which reference is made in the relevant EEC directives. The apparatus will bear the BASEEFA mark but *not* the community mark. The certificate number is usually a five figure number prefixed BAS.EX, e.g. BAS.EX81181. The use of the BASEEFA mark is subject to the licensing conditions, the licence being valid for 3 years.

(c) *System certificate of assurance.* Certification of an interconnected intrinsically safe system which, in whole or in part, complies with a standard that is not one of the harmonized standards to which reference is made in the EEC directives of SFA3012.

(d) *Component certificate.* Certification of a component as suitable for use in association with apparatus certified to standards that are harmonized to standards to which reference is made in the EEC directives, e.g. BS 5501 (EN 50). The apparatus bears the community mark but does *not* bear the BASEEFA mark. The certificate number is usually a six figure number prefixed BAS.EX and suffixed U, e.g. BAS.EX813091U. The certificate is valid for 3 years but is not subject to the licensing conditions.

(e) *Certificate of conformity.* Certification of apparatus to harmonized standards to which reference is made in the EEC directives, e.g. BS 5501 (EN 50). The apparatus bears the BASEEFA mark and the community mark. The certificate number is usually a six figure number prefixed BAS.EX, e.g. BAS.EX813182. The use of the BASEEFA mark is subject to the licensing conditions, the licence being valid for 3 years.

(f) *System certificate of conformity.* Certification of an interconnected intrinsically safe system to a harmonized standard to which reference is made in the EEC directives, i.e. BS 5501 : Part 9.

(g) *Inspection certificate.* Certification that apparatus meets the equivalent safety requirements of apparatus that has a certificate of conformity. This would be used where apparatus does not meet the constructional requirements of BS 5501 (EN 50) but has been shown to offer a degree of safety at least equivalent to them.

(h) *Trading agents.* A trading agent who does not manufacture equipment is not permitted to hold a certificate or licence in the name of his Agency. The Agency is allowed by the manufacturer of the equipment, subject to the approval of BASEEFA, to have the name or trade mark of his Agency shown on the equipment. The trading agent is not allowed to make any changes or modifications to the equipment as supplied by the manufacturer. However in order to allow the Agency to be identified the label, in addition to those indicated in **A.4**, can be marked with the letter 'A' surrounded by a circle.

(i) *Foreign standards.* Equipment certified by CENELEC countries prior to harmonization, or by other countries (such as the USA) may not comply with the requirements of CENELEC harmonized standards.

If such equipment is used the engineer is responsible for ensuring that it meets all the necessary requirements but if any doubt arises professional advice should be sought.

Appendix B. Instrument pre-installation calibration sheet

An example of an instrument pre-installation calibration sheet is as follows.

INSTRUMENT PRE-INSTALLATION CALIBRATION SHEET

CLIENT: XYZ LTD PLANT: SOLVENT RECOVERY
CLIENT'S PROJECT No.: 6789 PROJECT No.: 123 – 456

INST. TAG No. PT-306 SERVICE STRIPPING COLUMN OVERHEAD

TYPE: PRESSURE TRANSMITTER MODEL No.: 11 GM SERIAL No.: 1234
MANUFACTURER: FOXBORO ORDER No.: L-456-J20 SPEC. NO.: SL-456-J301
SIGNAL RANGE: 0.2 – 1 barg. DIAL/CHART RANGE: 0 – 10 barg.

PHYSICAL CHECK:

PROCESS CONN. CORECT	☑	PNEU./~~ELECT~~. CONN. CORRECT	☑
BODY MATERIAL CORRECT	☑	RANGE/SPAN CORRECT	☑
ELECT. SUPPLY SETTING CORRECT	N/A ⊟	AIR SUPPLY SETTING CORRECT	☑
GENERAL CONDITION SATISFACTORY	☑	ANCILLIARY EQUIPMENT SUPPLIED	☑

SHIPPING STOPS REMOVED ☑

CALIBRATION CHECK:

MAKER'S QUOTED ACCURACY ± 0.5 % F.S.*

INPUT		READING OR OUTPUT					
		RISING			FALLING		
% SPAN	ACTUAL	ACTUAL	% SPAN	ERROR %	ACTUAL	% SPAN	ERROR %
0	barg. 0	barg. 0.2	0	0	barg 0.2	0	0
25	2.5	0.398	24.75	−0.25	0.399	24.875	−0.225
75	7.5	0.797	74.625	−0.375	0.798	74.75	−0.25
100	10	1.0	100	0	1.0	0	0

CONTROLLER CHECK: N/A
CONTROL MODE-PROPORTIONAL ☐ INTEGRAL ☐ DERIVATIVE ☐
ON-OFF ☐ DIFF. GAP ☐
CONTROLLER ALIGNMENT CORRECT ☐ AUTO/MANUAL CORRECT ☐

SETTINGS: N/A
CONTROL ACTION – DIRECT ☐ REVERSE ☐ DIFF. GAP ____ %
ALARM SETTING ____ TIME DELAY SETTING ____
LIMIT SWITCH SETTING - HIGH ____ LOW ____
OUTPUT LIMIT SETTING - HIGH ____ LOW ____

CORRECTIONS: N/A
AUTOMATIC TEMPERATURE CORRECTION RANGE ____
S.G./DENSITY CORRECTION SETTING ____
ZERO ELEVATION/SUPPRESSION SETTING ____
THERMO-COUPLE BURNOUT DRIVES UPSCALE ☐ DOWNSCALE ☐

SHIPPING STOPS REFITTED ☐

*ANCILLIARY EQUIPMENT LIST: 1. SNUBBER
2. AIR SET

REMARKS: MAXIMUM HYSTERESIS = 0.125% (MNFRS. QUOTED FIGURE IS 0.15%)

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* F.S. = Full Scale

INSTRUMENT TAG NO. PT – 306

Appendix C. Pressure indicator calibration check sheet

An example of a pressure indicator calibration check sheet is as follows.

CALIBRATION CHECK SHEET					PRESSURE GAUGES * ~~DIAL THERMOMETERS~~				
CLIENT: XYZ LTD					PLANT SOLVENT RECOVERY				
CLIENT'S PROJECT No: 6789					PROJECT No. 123 – 456				
TAG No.	RANGE bar g.	CHECKED	WITNESS	DATE	TAG No.	RANGE	CHECKED	WITNESS	DATE
PI - 1	0 - 10	[signature]	[signature]	18/3/85					
PI - 2	0 - 20	[signature]	[signature]	18/3/85					
PI - 3	0 - 10	[signature]	[signature]	18/3/85					
PI - 4	0 - 30	[signature]	[signature]	18/3/85					
PI - 5	0 - 5	[signature]	[signature]	18/3/85					
ETC.									
*DELETE AS APPLICABLE									
					PI/~~TI~~* CHECK SHEET SHEET No. PI – 1				

Appendix D. Alarm system check sheet

An example of an alarm system check sheet is as follows.

ALARM SYSTEM CHECK SHEET

CLIENT: XYZ LTD PLANT: SOLVENT RECOVERY
CLIENT'S PROJECT No.: 6789 PROJECT No. 123 – 456

INST. TAG No. XA – 101 LOCATION MAIN CONTROL PANEL

ANNUNCIATOR TYPE ICS – 20 SIZE 5 WIDE X 4 HIGH SERIAL No. 12345
MANUFACTURER I.C.S. ORDER No. L-456 – J21 SPEC. No. SL-456- J707

GENERAL CHECK:

GENERAL CONDITION SATISFACTORY	☑	AUDIBLE ALARM OPERATES	☑
ENGRAVING CORRECT TO SPEC.	☑	ACK. & TEST BUTTONS OPERATE	☑
ELECT. SUPPLY SETTING CORRECT	☑		☐
ALARM SEQUENCE CORRECT	☑		☐

ALARM LOOP CHECK:

POINT No.	ALARM No.	ALARM ACTUATOR CHECK: TAG No.	DESCRIPTION	ALARM SETTING	OPERATION CORRECT	INSTALL'N CORRECT	ALARM OPERATION CORRECT
1-1	LAH-101	LSH-101	C302 STRIPPER BOTTOMS	HIGH	✓	✓	✓
1-2	PAH-101	PSH-101	C302 O/HEAD PRESSURE	8·0 barg	✓	✓	✓
1-3	TAH-101	TSH-101	C302 O/HEAD TEMP.	220°C	✓	✓	✓
1-4			↓				
1-5							
2-1							
2-2							
2-3							
2-4							
2-5			ETC				
3-1							
3-2							
3-3							
3-4							
3-5							
4-1							
4-2							
4-3							
4-4							
4-5			↓				

REMARKS:

CHECKED BY: [signature] DATE 18/3/85 WITNESSED BY: [signature] DATE 18/3/85

ACCEPTED BY: [signature] FOR XYZ LTD DATE 18/3/85

ALARM SYSTEM No. XA- 101

Appendix E. Instrument loop check sheet

An example of an instrument loop check sheet is as follows.

INSTRUMENT LOOP CHECK SHEET

CLIENT: XYZ LTD PLANT: SOLVENT RECOVERY
CLIENT'S PROJECT No.: 6789 PROJECT No.: 123 – 456
LOOP No. FRC-309 SERVICE STRIPPING COLUMN REFLUX
LINE OR EQUIPMENT No. C-302 PIPE I.D. 6.060"

MECHANICAL/ELECTRICAL CHECKS

MEASURING ELEMENT:	INSTALLATION CORRECT	☑	LOCATION CORRECT	☑
	ISOLATING VALVES CORRECT	☑	MATERIALS CORRECT	☑
	TAPPING(S) POSITION CORRECT	☑	ORIFICE DIAMETER 91.11 mm	
IMPULSE CONNECTIONS:	CORRECT TO HOOK-UP	☑	MATERIALS CORRECT	☑
	PRESSURE TESTED	☑	TEST PRESSURE 20 bar g.	
	STEAM/ELECT. TRACED	☑	LAGGED	☑
FIELD INSTRUMENT(S):	INSTALLATION CORRECT	☑	AIR SUPPLY CORRECT	☑
	WEATHER PROTECTED	☑	POWER SUPPLY CORRECT	N/A –
PANEL INSTRUMENT(S):	INSTALLATION CORRECT	☑	AIR SUPPLY CORRECT	☑
	SCALE/CHART CORRECT	☑	POWER SUPPLY CORRECT	N/A –
CONTROL VALVE~~(S)~~:	INSTALLATION & LOCATION CORRECT	☑	SIZE & TYPE CORRECT	☑
	STROKE TESTED	☑	POSITIONER CHECKED	☑
	LIMIT SWITCH(ES) SET	N/A –	I./P. TRANSDUCER CHECKED	N/A –
AIR SUPPLIES:	CONNS. CORRECT TO DWGS.	☑	BLOWN CLEAR & LEAK TESTED	☑
TRANSMISSION-PNEU:	LINES INSPECTED, BLOWN CLEAR & LEAK TESTED	☑		
-ELECT: N/A	INSULATION CHECKED-CORE TO CORE	–	CORE TO EARTH	N/A –
	CONTINUITY CHECKED	–	LOOP IMPEDANCE CHECKED	–
	EARTH BONDING CHECKED	–	ZENER BARRIERS CORRECT	–
TEMPERATURE LOOPS: N/A	T/C OR R/B CHECKED	–	CABLE TO SPECIFICATION	N/A –
	CONTINUITY CHECKED	–	LOOP IMPEDANCE CHECKED	–
GENERAL:	SUPPORTS CORRECT	☑	TAGGING CORRECT	☑

CHECKED BY: [signature] DATE 18/3/85 WITNESSED BY: [signature] DATE 18/3/85

LOOP TEST:

MEASUREMENT	TRANSMITTER INPUT	TRANSMITTER OUTPUT	LOCAL INST. READING	PANEL INST. READING	
	0	0.2 bar g	0	0 (0-10J)	
	50%	0.6 "	50.1 %	7.1	
	100%	1.0 "	100 %	10	

CONTROL	CONTROLLER OUTPUT	TRANSDUCER OUTPUT	VALVE POS'NR OUTPUT	CONTROL VALVE POSITION	
	0		0.2 bar g	CLOSED	
	50%		0.6 "	50% OPEN	
	100%		1.0 "	100% OPEN	

REMARKS:

CHECKED BY: [signature] DATE 18/3/85 WITNESSED BY: [signature] DATE 18/3/85

ACCEPTED BY: [signature] FOR XYZ LTD DATE 18/3/85

INSTRUMENT LOOP No. FRC-309

Appendix F. Safety valve test report

An example of a safety valve test report is as follows.

SAFETY RELIEF VALVE – TEST REPORT

CLIENT: XYZ LTD PLANT: SOLVENT RECOVERY
CLIENT'S PROJECT No.: 6789 PROJECT No.: 123-456

VALVE DATA
TAG No.: PSV-101 SERVICE: C-302 STRIPPER COLUMN
TYPE: CONVENTIONAL MODEL No.: 26HA21 SERIAL No.: 4567
MANUFACTURER: FARRIS ORDER No.: L-456-J22 SPEC No.: SL-456-J901
INLET SIZE: 1½" x 300# ASA OUTLET SIZE: 3" x 300# ASA ORIFICE SIZE: H

OPERATING DATA
SET PRESSURE: 10 barg BACK PRESSURE: 0.7 barg
SPRING SET PRESSURE: 9.3 barg OPERATING TEMP.: 220°C

PHYSICAL CHECK
BODY MATERIAL CORRECT: ☑
CONNECTIONS CORRECT: ☑
SPRING MATERIAL CORRECT: ☑
NOZZLE MATERIAL CORRECT: ☑
DISC MATERIAL CORRECT: ☑
BELLOWS MATERIAL CORRECT: N/A ☐
LIFTING LEVER – OPEN: N/A ☐
– PACKED: ☐
SCREWED CAP: ☑
TEST GAG: ☑
LOCKING DEVICE: N/A ☐

TEST RESULTS	UNITS	SPECIFIED VALUE	TEST RESULT	REMARKS
COLD SPRING SET PRESS.	barg.	9.486	9.485	2% TEMP. CORR'N
RESEAT PRESSURE	barg.	9.1	9.106	
SEAT LEAKAGE RATE (ANSI B147.1 (API 527)) *	bbls per m.	20	15	

GENERAL REMARKS

CHECKED BY: [signature] DATE 18/3/85 WITNESSED BY: [signature] DATE 18/3/85
ACCEPTED BY: [signature] FOR XYZ LTD DATE 18/3/85

* bbls = bubbles

SAFETY RELIEF VALVE
TEST REPORT No.: PSV-101

Appendix G. List of test and calibration equipment

The following is an example of test and calibration equipment which may be required for on-site instrument testing and pre-commissioning.

This list is not exhaustive and the requirements for a specific project should be reviewed.

The test and calibration equipment should be calibrated in the units of measurement selected for the project.

All test equipment should be approved by the responsible engineer.

(a) *Pressure test and calibration equipment.* The following equipment may be required.

(1) Portable manually operated hydraulic pump (bucket pump).

(2) Low pressure, hand-held pressure pump (ranges up to 1 bar).

(3) Vacuum pump, manually operated.

(4) Dead-weight tester.

(5) Pressure gauge comparison test pump.

(6) Precision air filter/regulator sets (two sets minimum).

(7) Liquid filled manometer (ranges less than 25 mbar).

(8) U-tube manometer (ranges approximately ± 25 mbar).

(9) Precision inclined manometer (ranges less than 10 mbar).

(10) Precision sealed mercury manometer (ranges less than approximately 1000 mbar).

(11) Certified test gauges, 0.25 % accuracy or better.

(12) Portable pneumatic calibration boxes (two boxes minimum).

(13) Portable air compressor (where air is not available).

(b) *Temperature test and calibration equipment.* The following equipment may be required.

(1) Thermostatically controlled temperature bath(s).

(2) Thermostatically controlled oven for checking cold junction compensation.

(3) Sets of standard (precision) mercury in glass thermometers.

(4) Precision potentiometer and millivolt generator.

(5) Precision Wheatstone bridge incorporating a detachable resistance box where resistance thermometers are to be installed, accurate to 0.05 % on any resistance value.

(6) Decade resistance box accurate to 0.1 %.

NOTE. All test instruments should be provided with test leads complete with test probes, clips and distribution terminals.

(c) *General electronic/electrical test and calibration equipment.* The following equipment may be required.

(1) Digital voltmeters (a minimum of two, portable) with an accuracy of ± 0.1 % of range or better and with a discrimination of 10 μV or better, and incorporating an internal calibration/standardizing feature and 0.1 % calibration resistors.

(2) Precision millivolt, volt and milliamp source measuring device.

(3) Portable multimeters.

(4) Insulation resistance testers.

(5) Stop-watch and relay contact timing device.

(6) Dual-beam oscilloscope.

(d) *Instrument manufacturer calibration and test equipment.* The following equipment may be required.

(1) For specific instruments and systems the manufacturers often provide dedicated calibration or test equipment which can include any combination of the devices in (a), (b) and (c). The use of these is recommended to simplify connections and signal compatibility.

(2) For many microprocessor-based 'smart' instruments, hand-held calibrators, programmers or communicators are available to ensure proper setting of the instruments.

Appendix H. Further reading

H.1 Government regulations and recommendations

Health and Safety at Work, etc. Act 1974

The Factories Act 1961

The Electricity Regulations 1908 and 1944

The Construction (General Provisions) Regulations 1961

The Safety Signs Regulations 1980

The Mines and Quarries Act 1954

Notification of Accidents and Dangerous Occurrence Regulations 1980

Mineral Workings (Offshore Installations) Act 1971

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

The Ionizing Radiations (Sealed Sources) Regulations 1969

The Ionizing Radiations (Unsealed Radioactive Substances) Regulations 1968

The Asbestos Regulations 1969

Protection of Eyes Regulations 1974 Certificate of Approval No. 2 (F2489)

Health and Safety Commission

HSC3 The Health and Safety at Work, etc. Act 1974 Advice to employers

HSC5 The Health and Safety at Work, etc. Act 1974 Advice to employees

Health and Safety Executive

Memorandum on the Electricity Regulations (HSW 928)

Guidance Note GS4 Safety in pressure testing 1976

Guidance Note GS5 Entry into confined spaces 1977

Guidance Note GS8 Articles and substances for use at work — guidance for designers, manufacturers, importers, suppliers, erectors and installers 1977

Guidance Note GS15 General access scaffolds 1982

Guidance Note GS16 Gaseous fire extinguishing systems: precautions for toxic and asphyxiating hazards 1984

Guidance Note GS24 Electricity on construction sites 1983

Guidance Note PM32 The safe use of portable electrical apparatus (electrical safety) 1983

HS(G) 12 Off-shore construction — health, safety and welfare

HS(G) 22 Electrical apparatus for use in potentially explosive atmospheres

HS(R) 5 The notification of accidents and dangerous occurrences

HS(R) 6 A Guide to the HSW Act

HS(R) 7 A Guide to the Safety Signs Regulations 1980

HSE 246 Noise, code of practice: reduction of exposure of employed persons

Safety precautions relating to intense radio-frequency radiation. HMSO.

Protection against ultraviolet radiation in the workplace. HMSO.

H.2 Miscellaneous regulations and recommendations

American National Standards Institute (ANSI)

ANSI B147/.1 Commercial seat tightness of safety relief valves with metal to metal seats

ANSI MC 96.1 Temperature measurement, thermocouples

American Petroleum Institute

API RP 550 Manual on installation of refinery instruments and control systems

British Approvals Service for Electrical Equipment in Flammable Atmospheres

SFA 3012 Intrinsic safety

Energy Industries Council

CCI P/1 Instrumentation installation testing procedure (prepared by EIC Contractors' Committee on Instrumentation)

CCI P/4 Colour coding of cables

CCI P/7 Cable identification system

EEC Directives

73/23/EEC Low voltage directive

76/117/EEC Electrical equipment for use in potentially explosive atmospheres

79/196/EEC Electrical equipment for use in explosive atmospheres (special directive)

84/47/EEC Commission directive adapting council directives 79/196

Institute of Petroleum

Code of practice for calibrating process analysers

Petroleum measurement manual
Part V Automatic tank gauging 1982
Part VII Density
Section 2. Continuous density measurement 1983

Model code of safe practice in the petroleum industry
Part 1. Electrical safety code (reprinted in 1982 to include 1975 revision of Chapter 3 (Instrumentation))

Institution of Electrical Engineers

IEE Regulations for electrical installations (fifteenth edition) (The Wiring Regulations)

Oil Companies Materials Association

INP-3 On-line analysers

Oil and Chemical Plant Constructors' Association
(Now part of the Engineering Equipment and Materials Users' Association)

Code of practice for site radiography

National Federation of Building Trade Employers

Construction safety (2 volumes)

Site safety supervisors' compendium

Royal Society for the Prevention of Accidents

The safe use of electricity: a guide for industry and commerce

The Chartered Institution of Building Services

Technical memorandum six — lighting for visual display units. 1981

Miscellaneous

Cornish, D.C., Jepson, G. and Smurthwaite, M.J. *Sampling systems for process analysers.* 1981. Butterworth Press

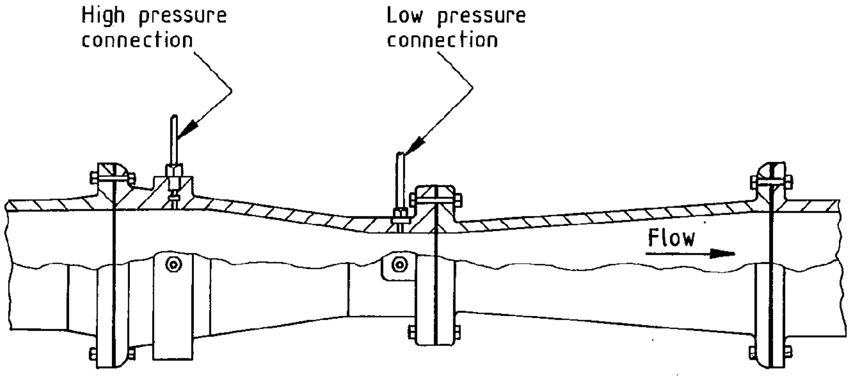


Figure 1. Tapping point location on a Venturi tube

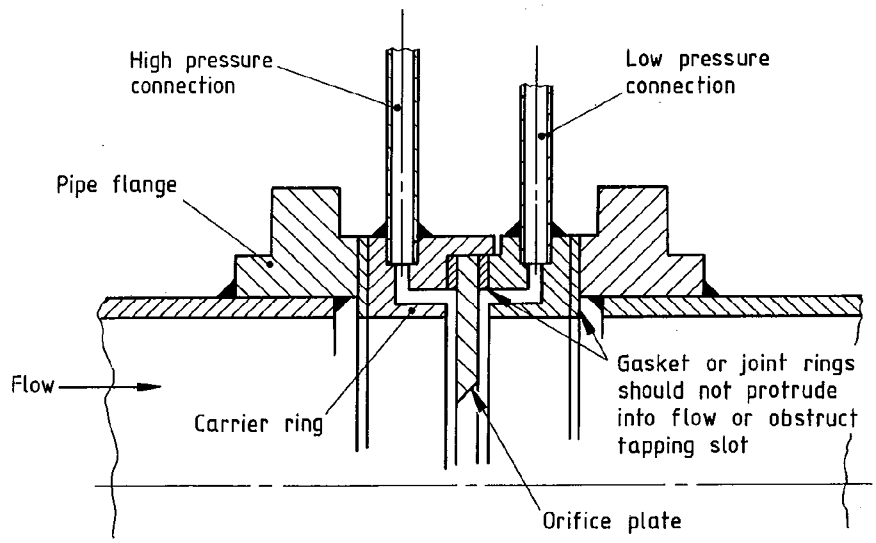
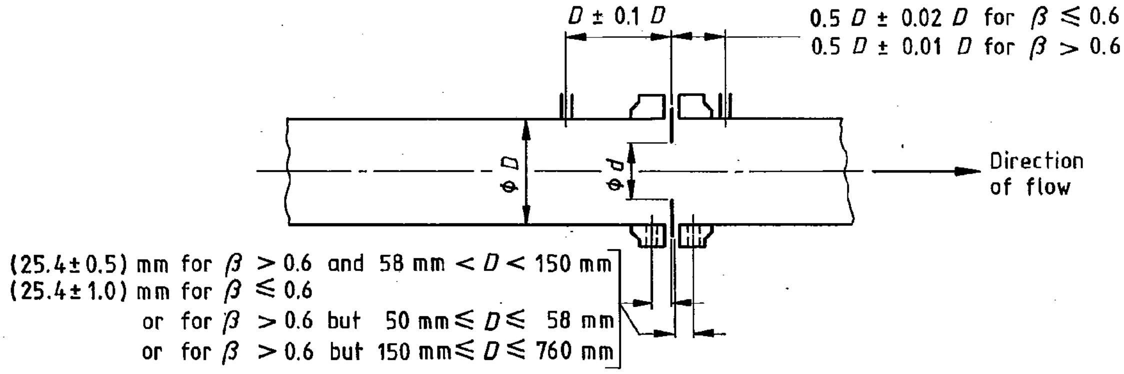


Figure 2. Tapping point location on an orifice plate carrier ring



NOTE. β is the diameter ratio, $\beta = \frac{d}{D}$.

Figure 3. Tapping point locations for flange-mounted orifice plate

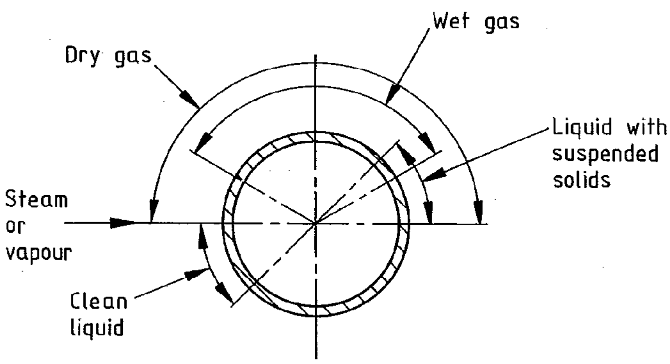
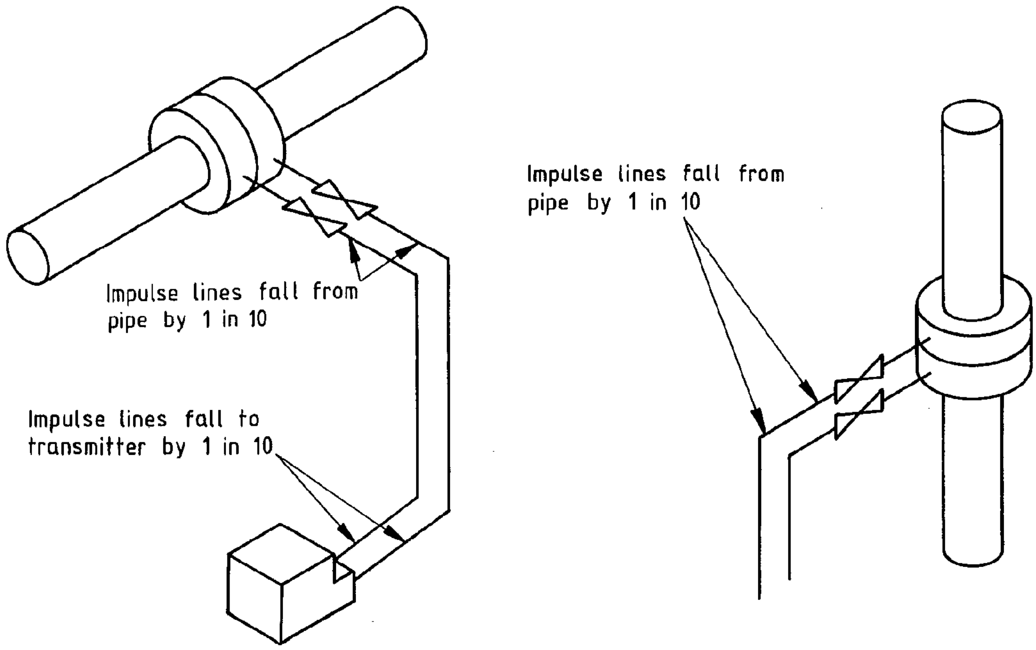
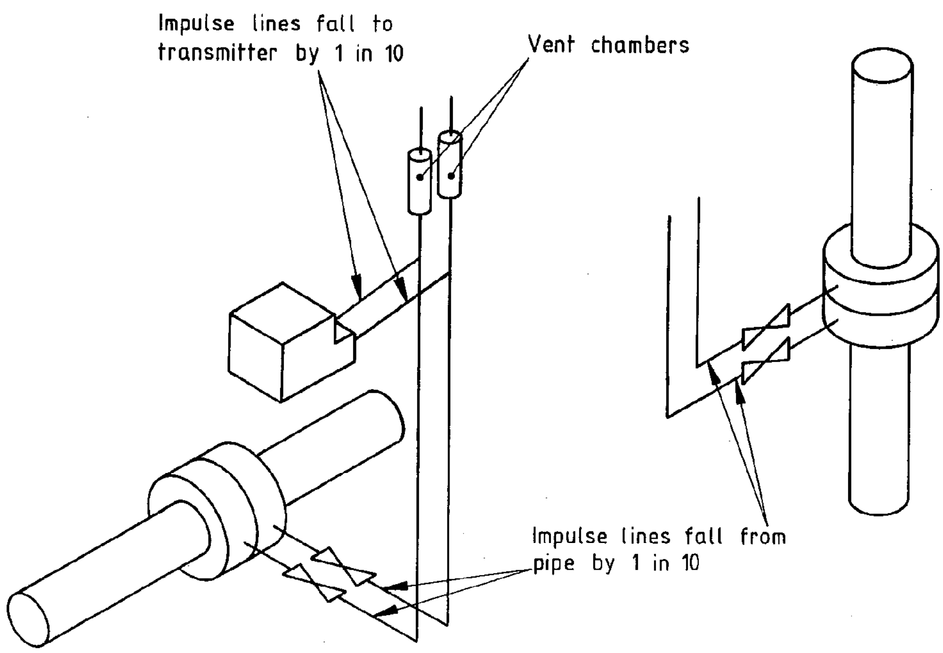


Figure 4. Radial location of tappings on a horizontal or sloping pipe

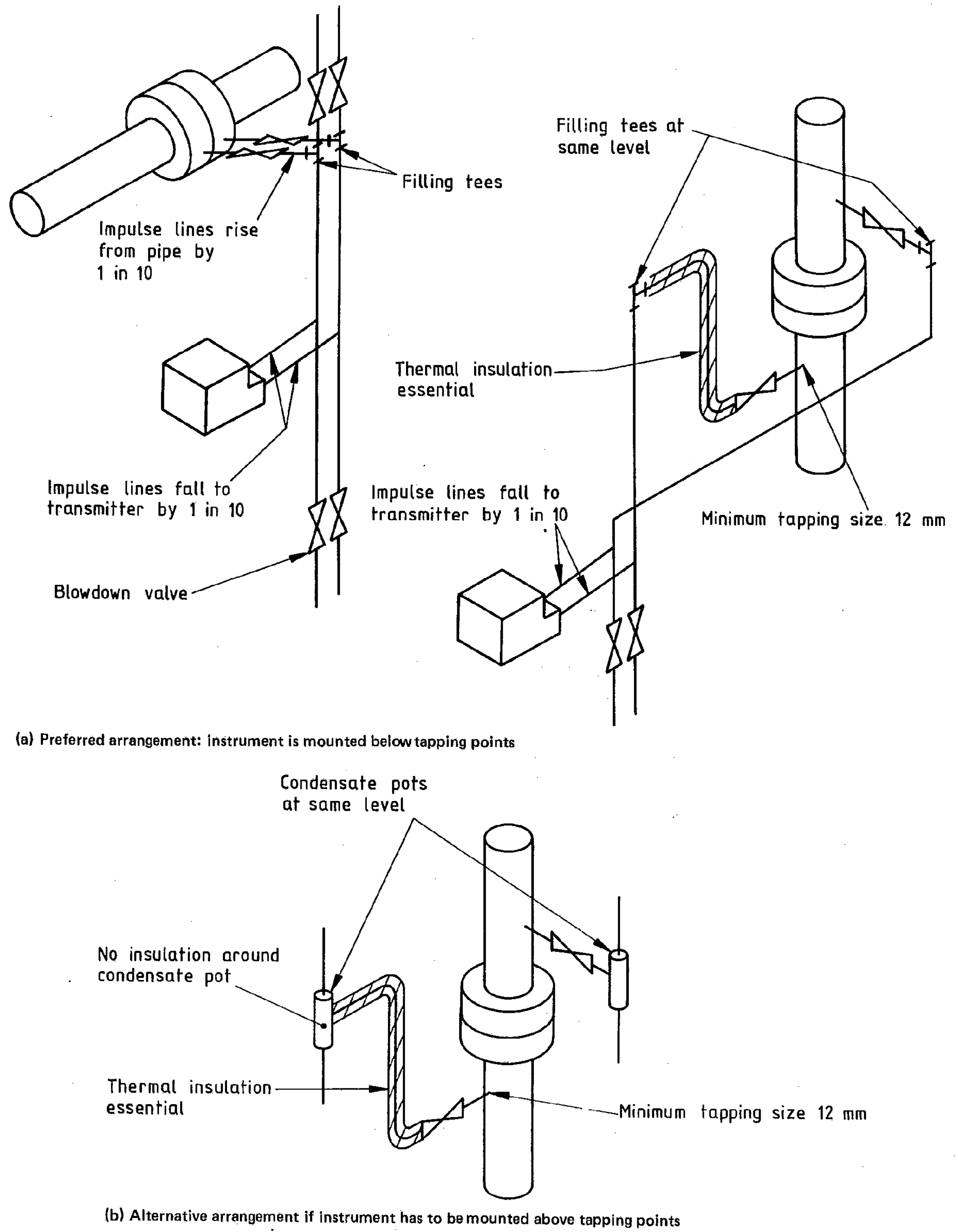


(a) Preferred arrangement: instrument is mounted below tapping points



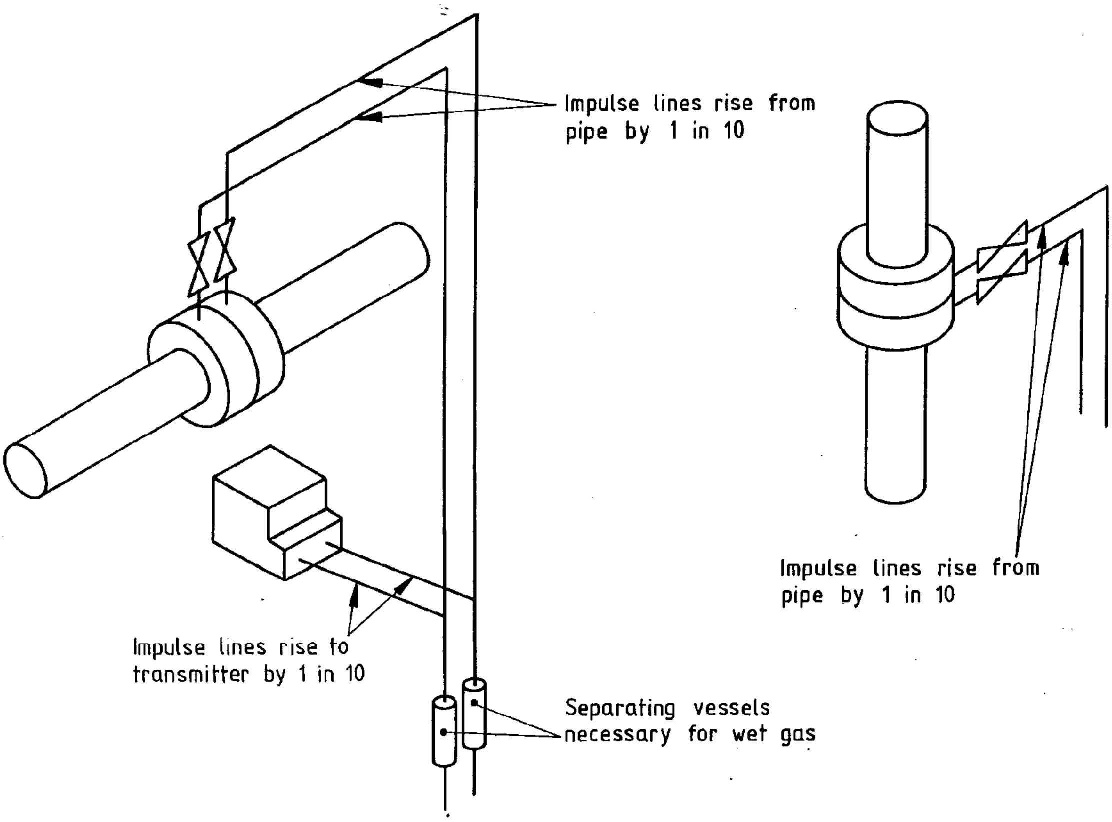
(b) Alternative arrangement if instrument has to be mounted above tapping points

Figure 5. Impulse pipework connections for measurement of flow of liquid

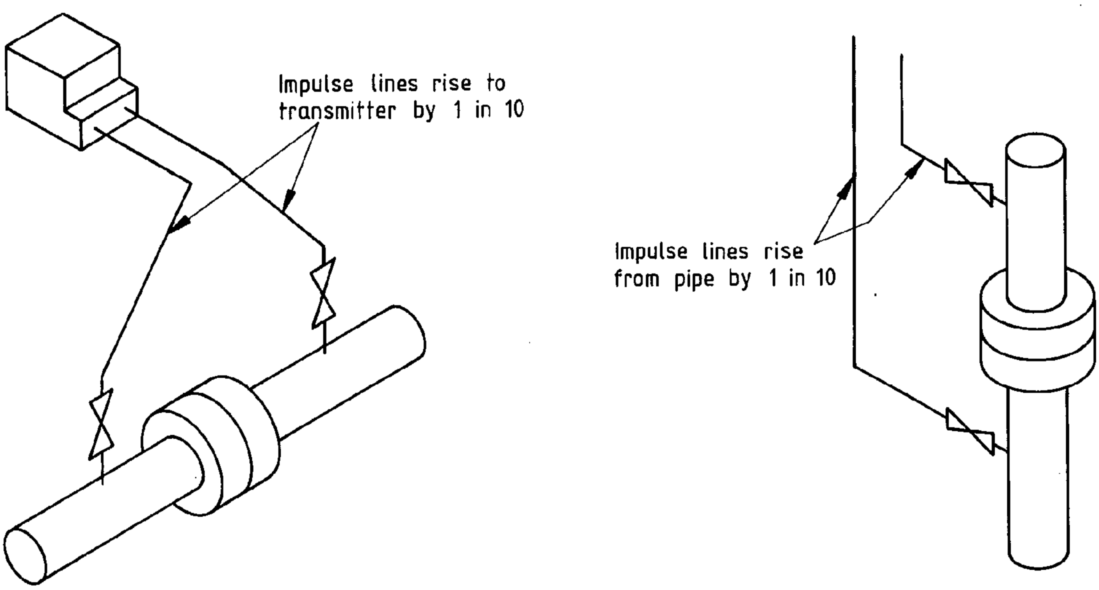


NOTE. Pipes marked to slope downward in direction of arrow.

Figure 6. Impulse pipework connections for measurement of flow of steam or condensing vapour

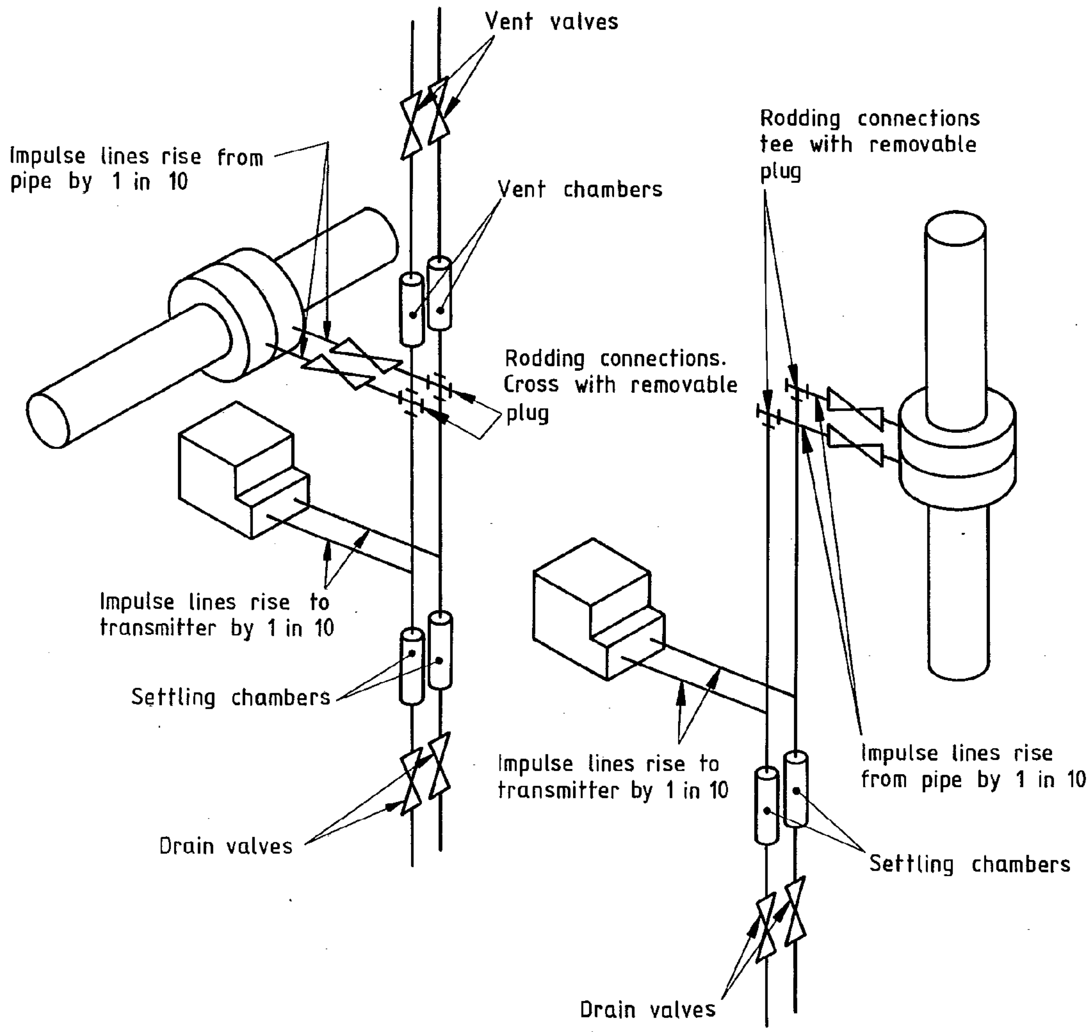


(a) Preferred arrangement: instrument is mounted below tapping points



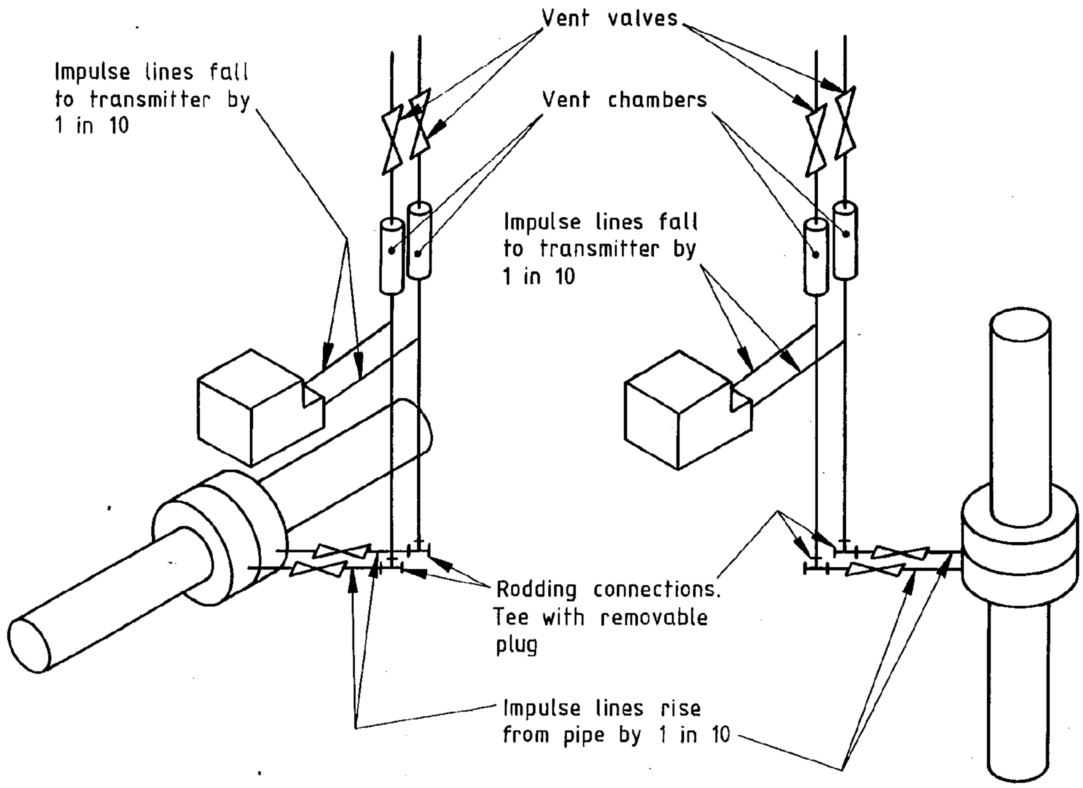
(b) Alternative arrangement if instrument has to be mounted above tapping points

Figure 7. Impulse pipework connections for measurement of flow of gas



(a) Preferred arrangement: instrument is mounted below tapping points

Figure 8. Impulse pipework connections for measurement of flow of liquid with suspended material



(b) Alternative arrangement if instrument has to be mounted above tapping points

Figure 8 *(concluded)*

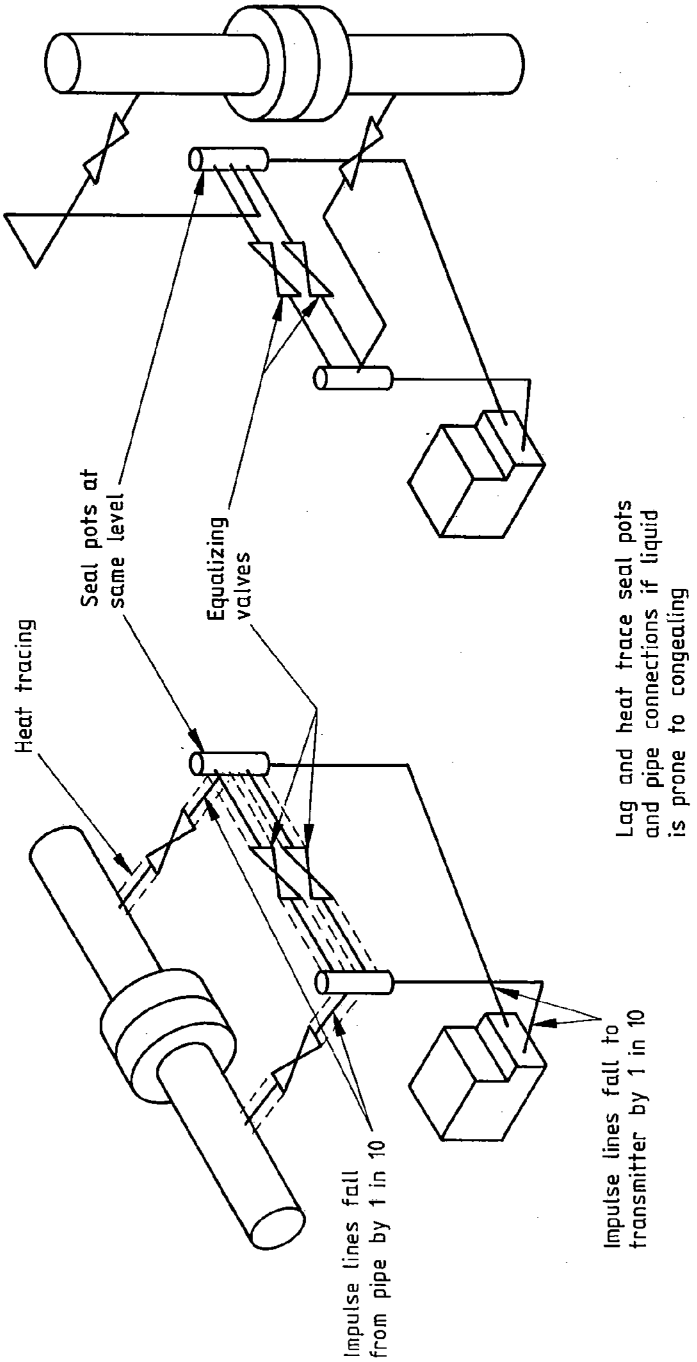


Figure 9. Impulse pipework connections for measurement of flow where seal pots are used

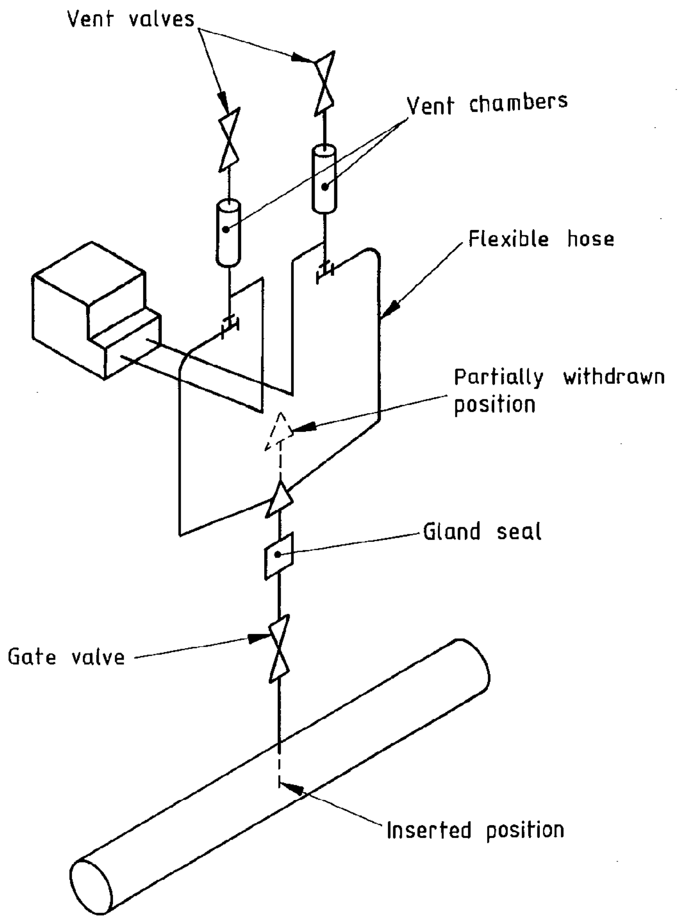
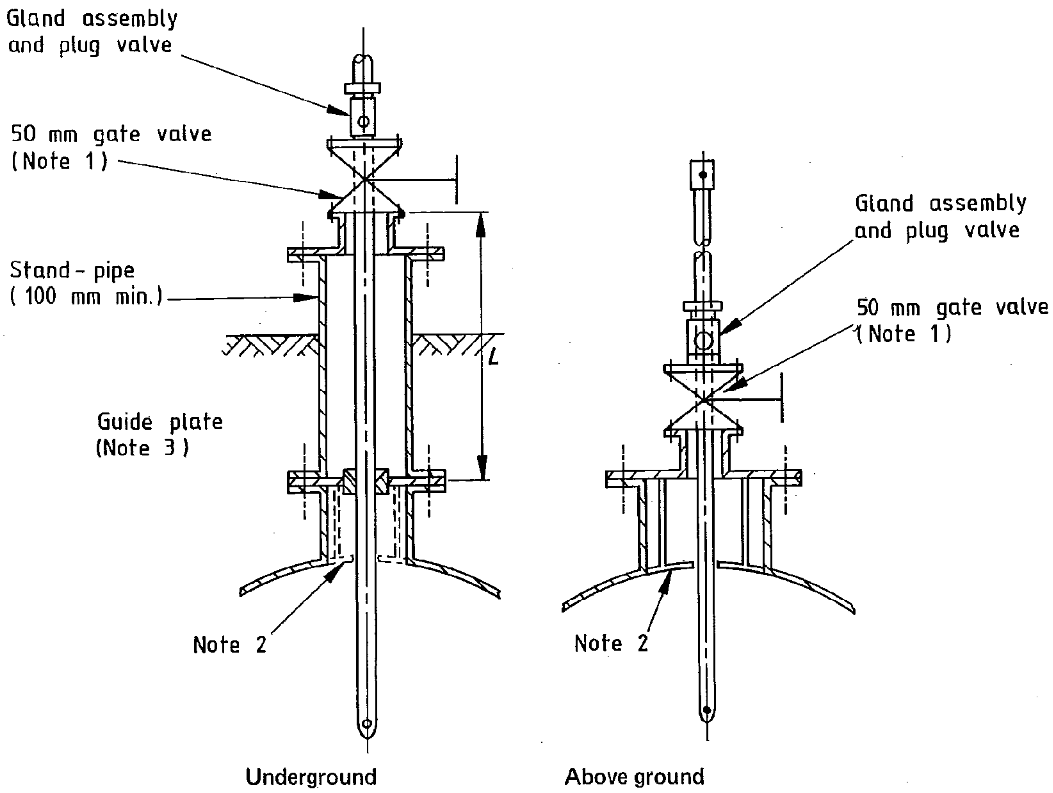


Figure 10. General arrangement of pitot tube installation for measurement of liquid flow



NOTE 1. Gate valve and standpipe, etc. to be as specified.

NOTE 2. False wall required for nozzle diameters of 150 mm and above.

NOTE 3. Guide plate required when *L* is 1 m or more.

Figure 11. Detailed arrangement of pitot tube

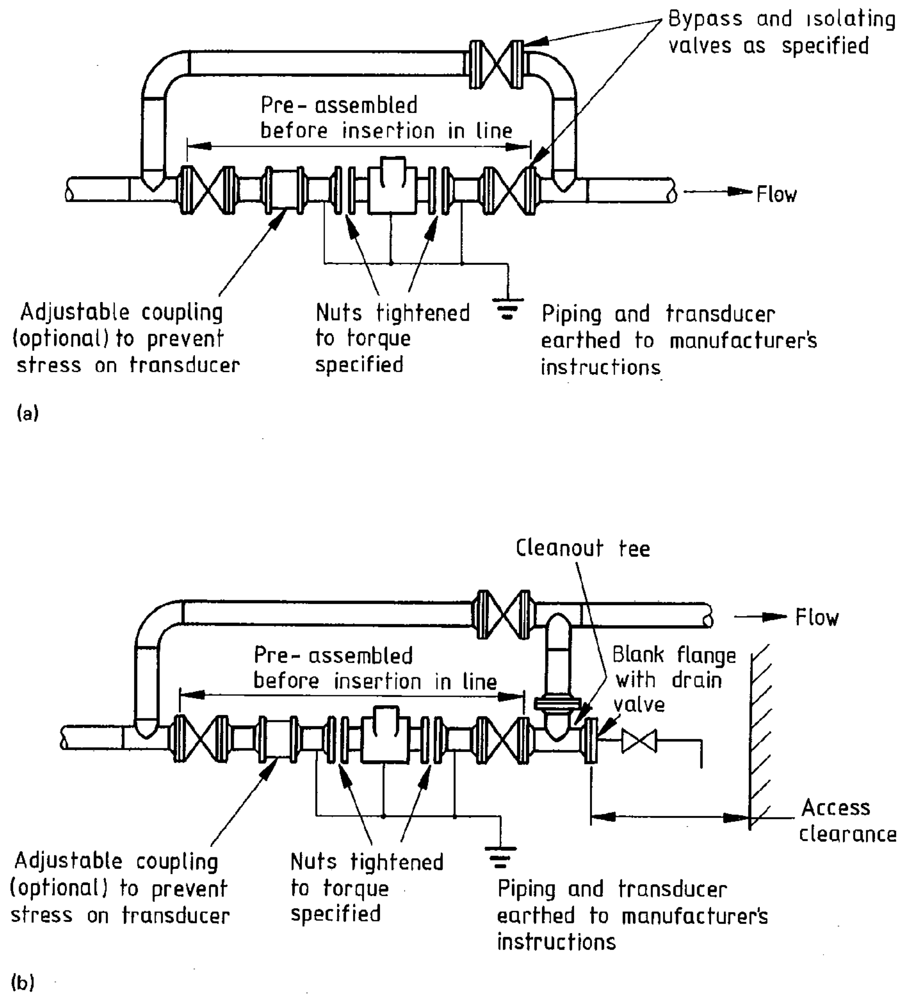
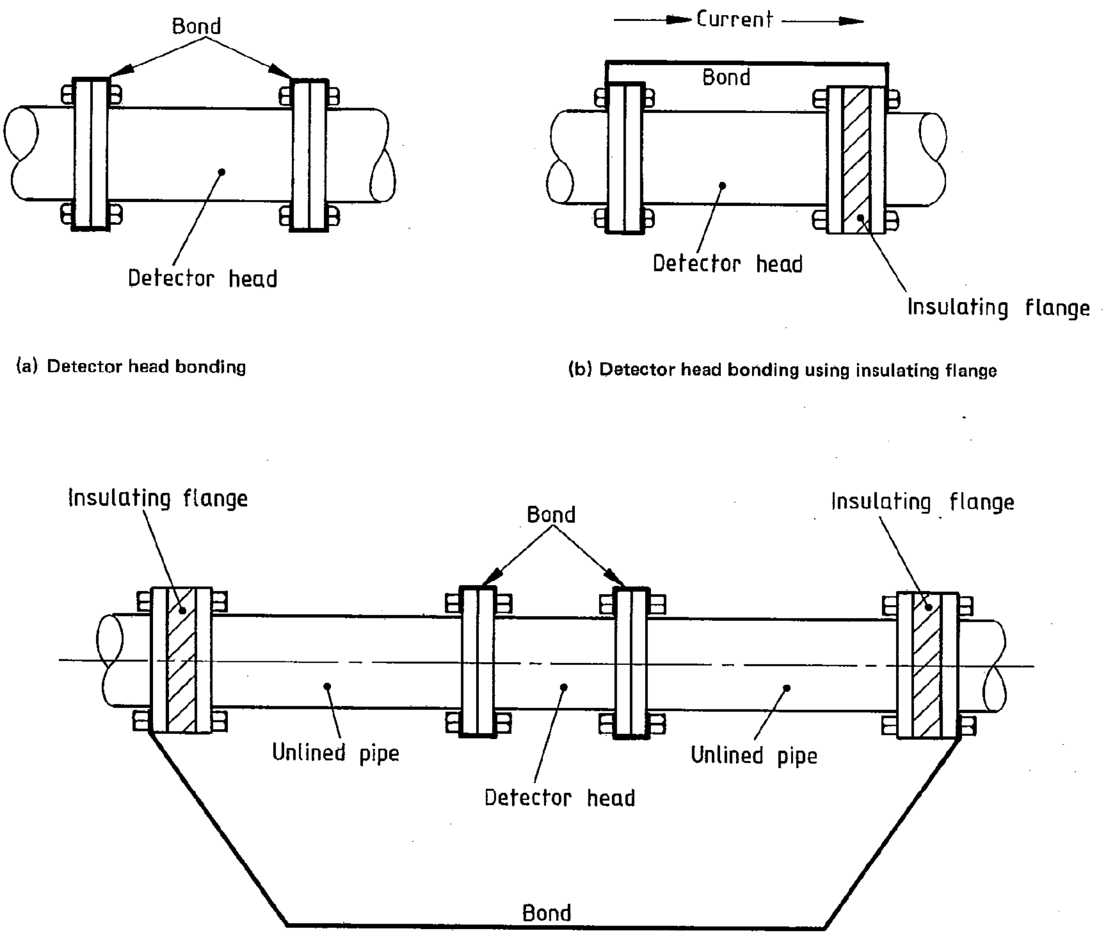


Figure 12. Electromagnetic flowmeter installations



(a) Detector head bonding

(b) Detector head bonding using insulating flange

(c) Detector head bonding using unlined pipe sections

Figure 13. Cathodic protection for electromagnetic flowmeters

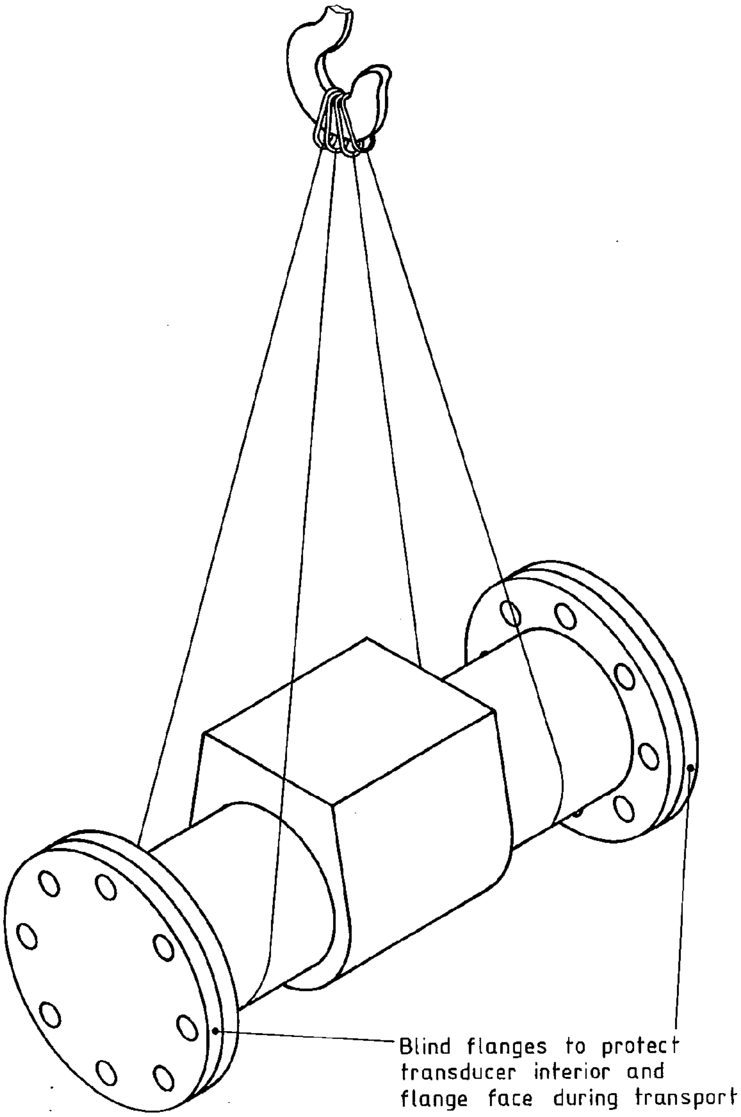


Figure 14. Correct way for lifting an electromagnetic flow transducer

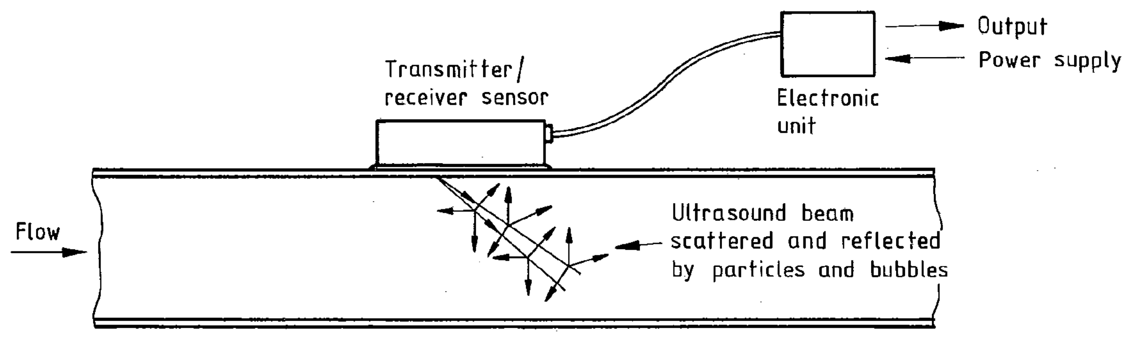
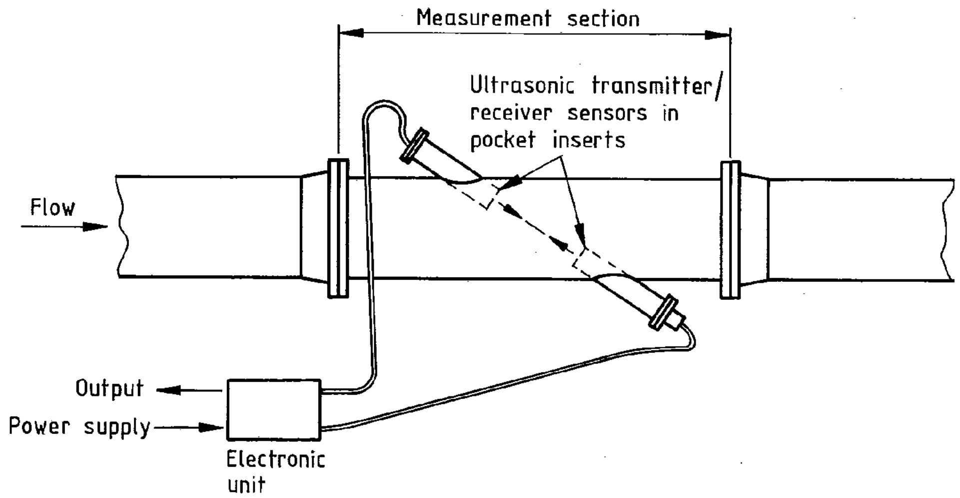
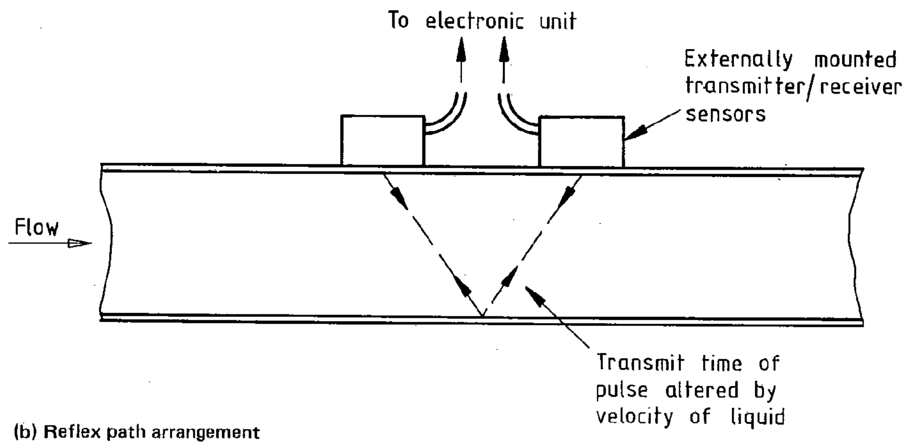


Figure 15. Ultrasonic doppler flow measurement

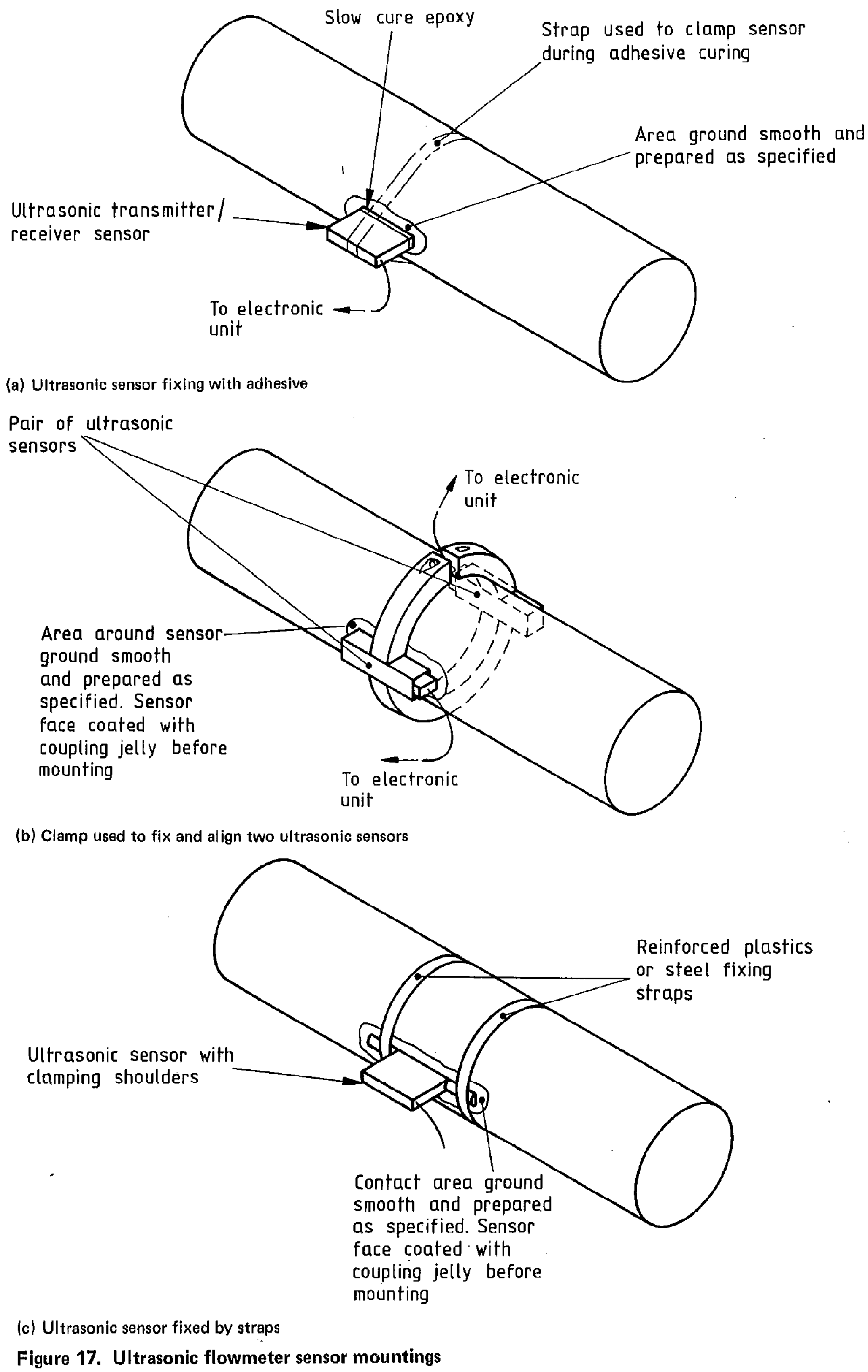


(a) Direct path arrangement



(b) Reflex path arrangement

Figure 16. Ultrasonic transit time flow measurement



(a) Ultrasonic sensor fixing with adhesive

(b) Clamp used to fix and align two ultrasonic sensors

(c) Ultrasonic sensor fixed by straps

Figure 17. Ultrasonic flowmeter sensor mountings

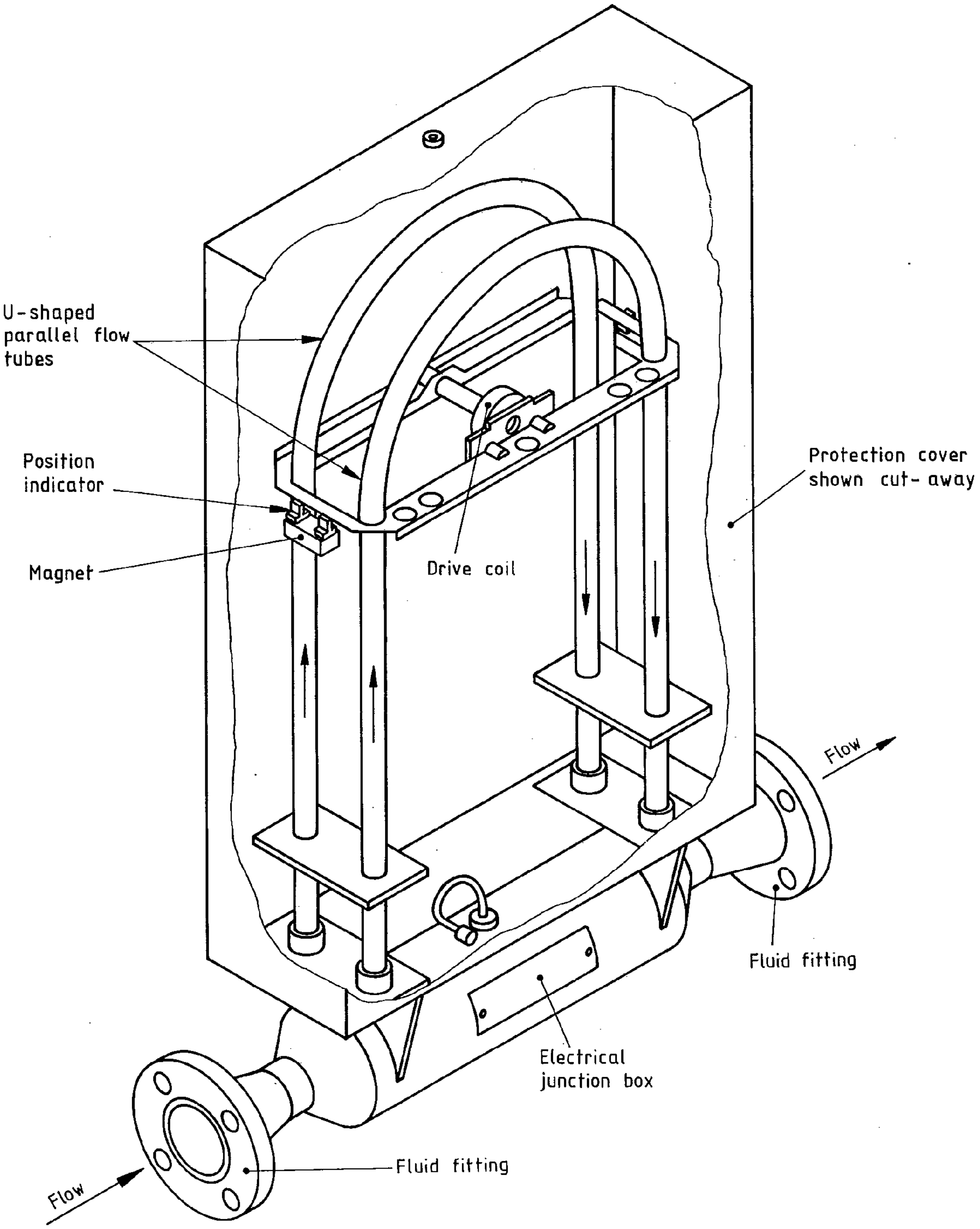


Figure 18. Coriolis mass flowmeter

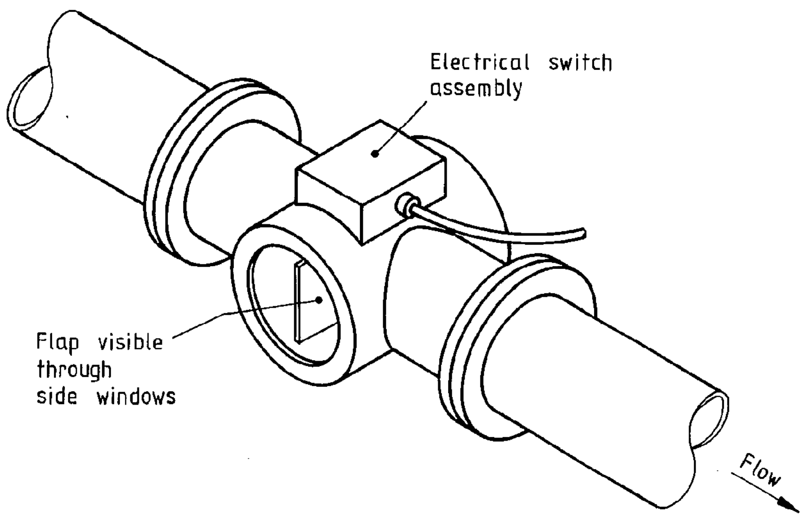
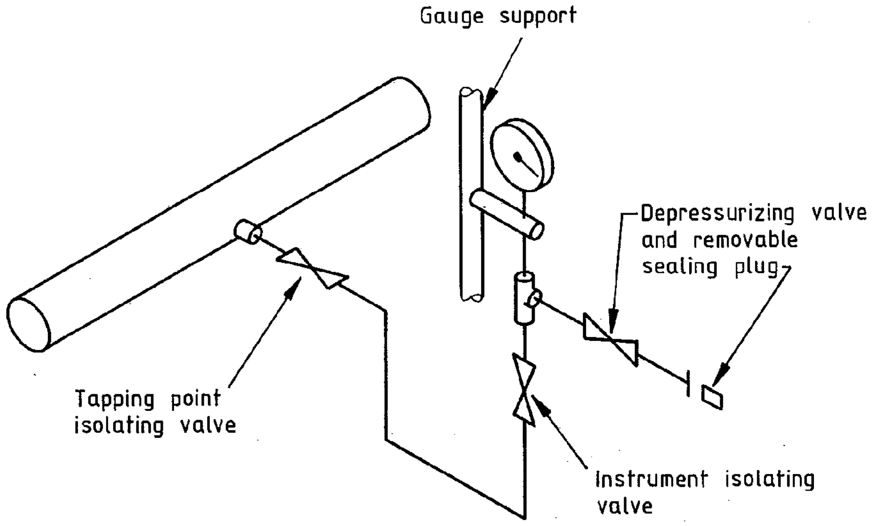
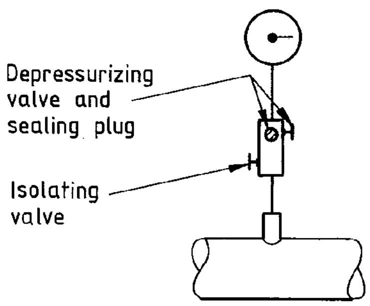


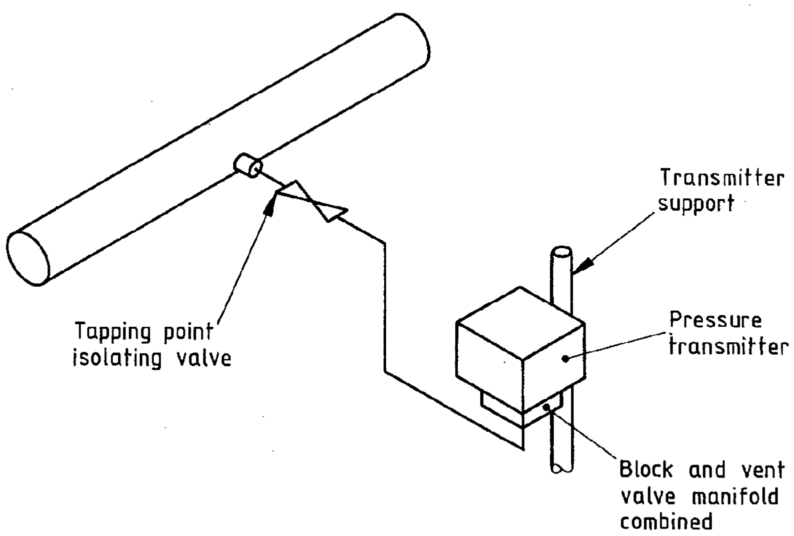
Figure 19. Flap type flow switch



(a) Basic indicator hook-up

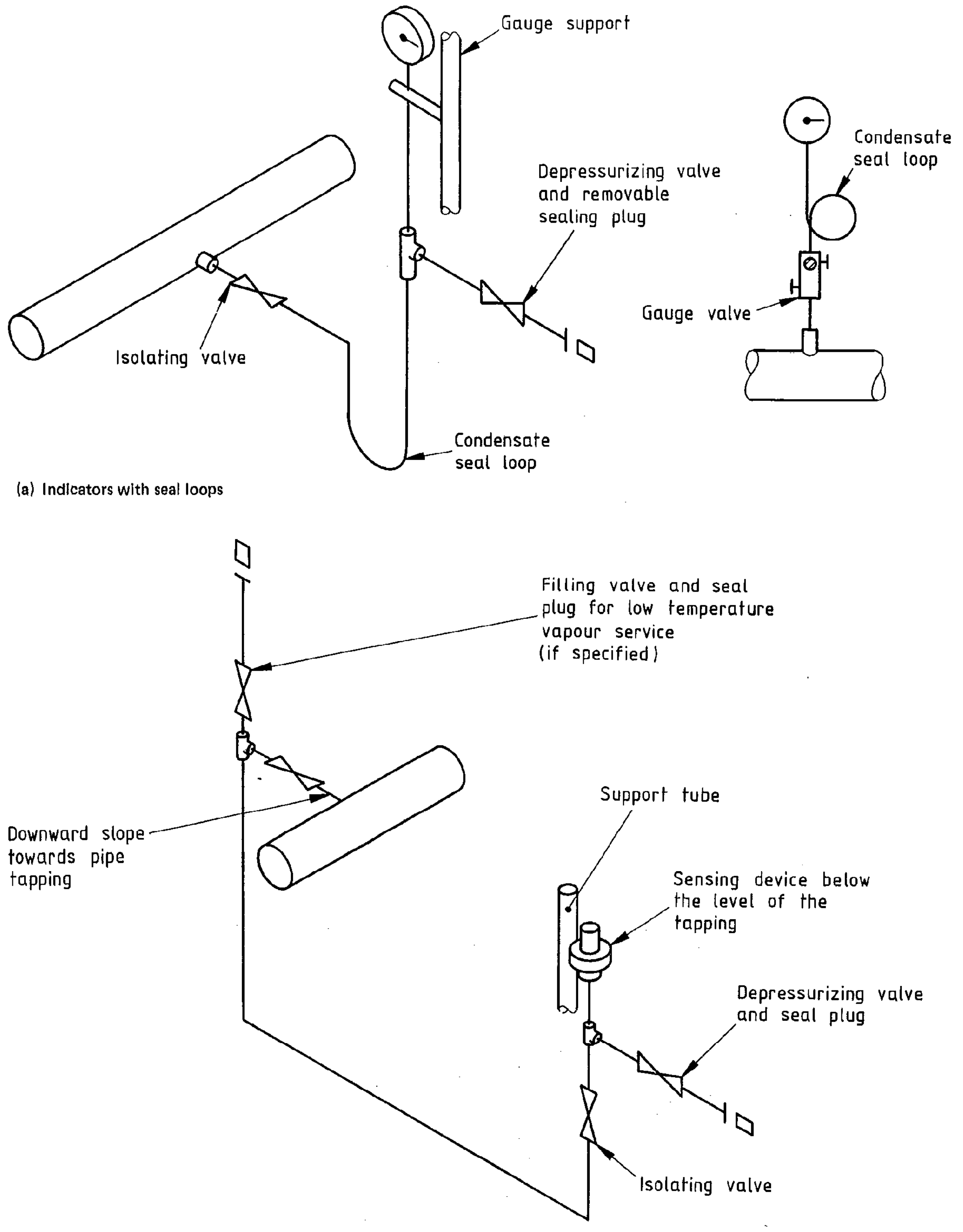


(b) Pressure gauge and gauge valve



(c) Pressure transmitter with combined block and vent valve block

Figure 20. Pressure indicator or transducer hook-ups



(a) Indicators with seal loops

(b) Transducer or pressure switch with filling tee

Figure 21. Pressure indicator or transducer with condensate seals for hot vapour or steam service

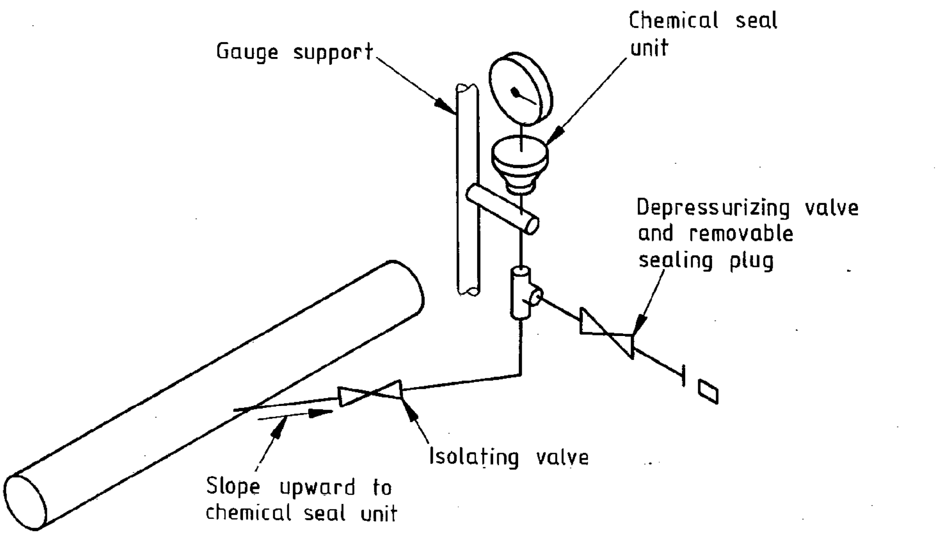


Figure 22. Arrangement of pressure gauge with chemical seal

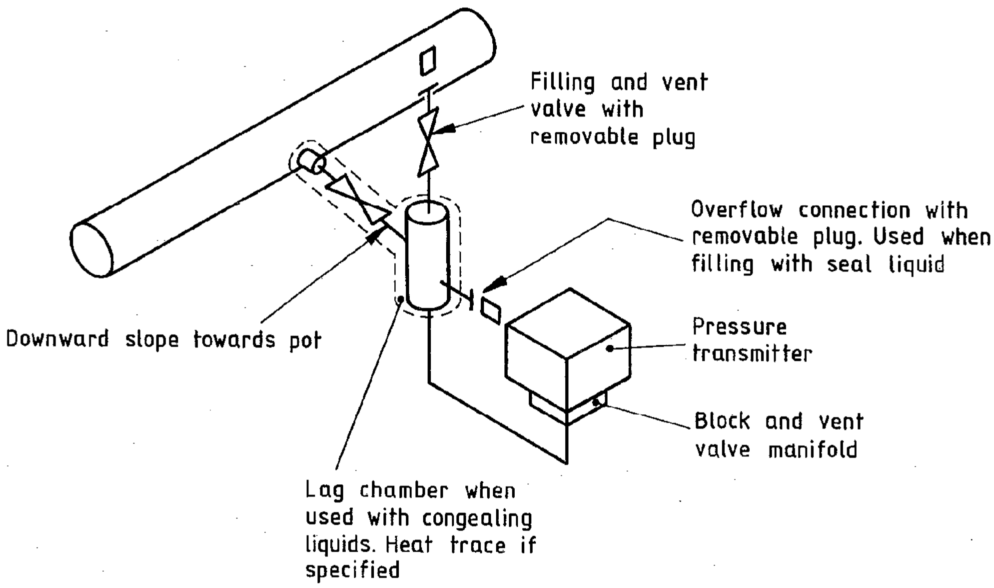


Figure 23. Pressure gauge with seal pots

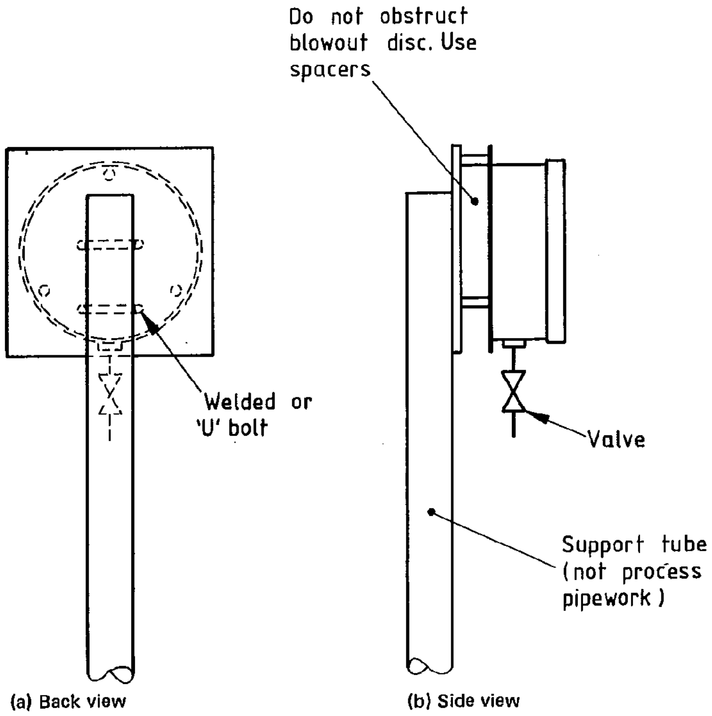


Figure 24. Independent support for pressure gauges up to 150 mm (6 in) in diameter

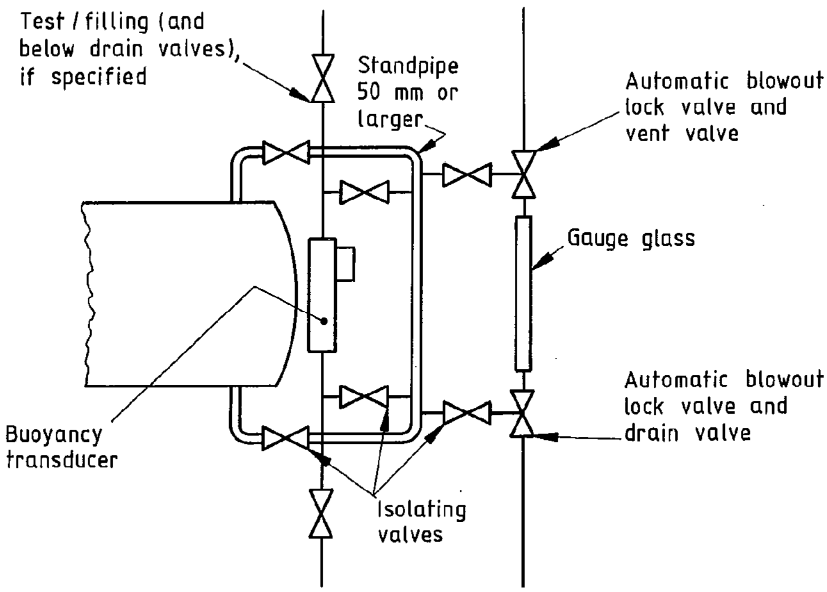


Figure 25. Level measurement on a vessel using a standpipe

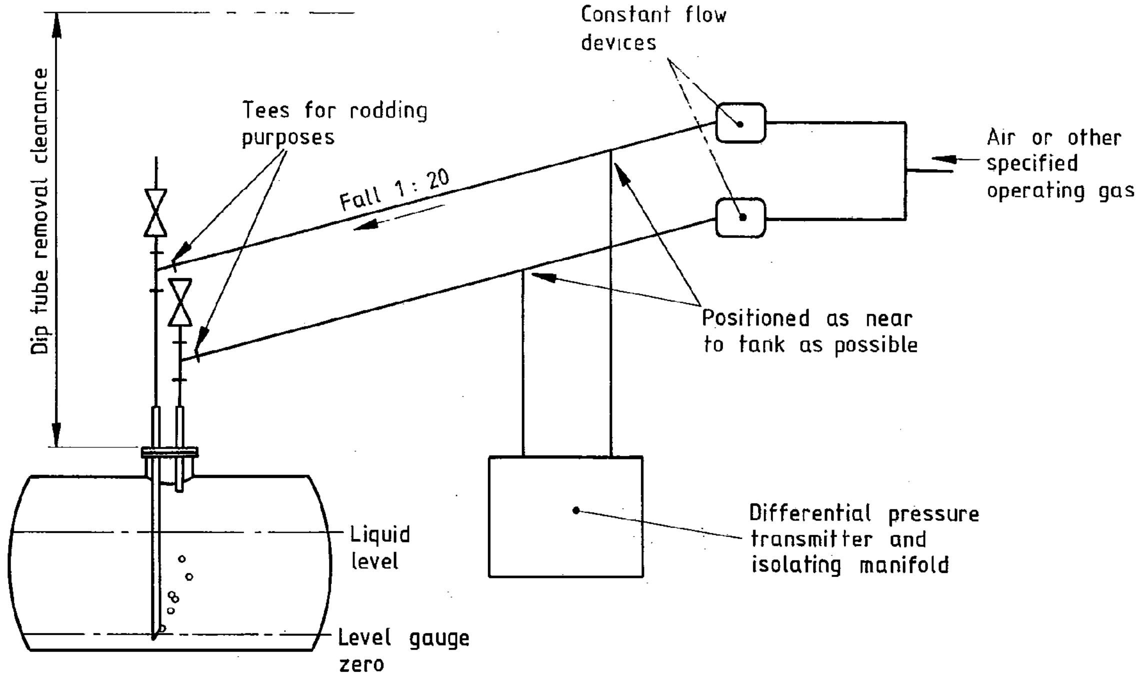


Figure 26. Level measurement using purged dip tube

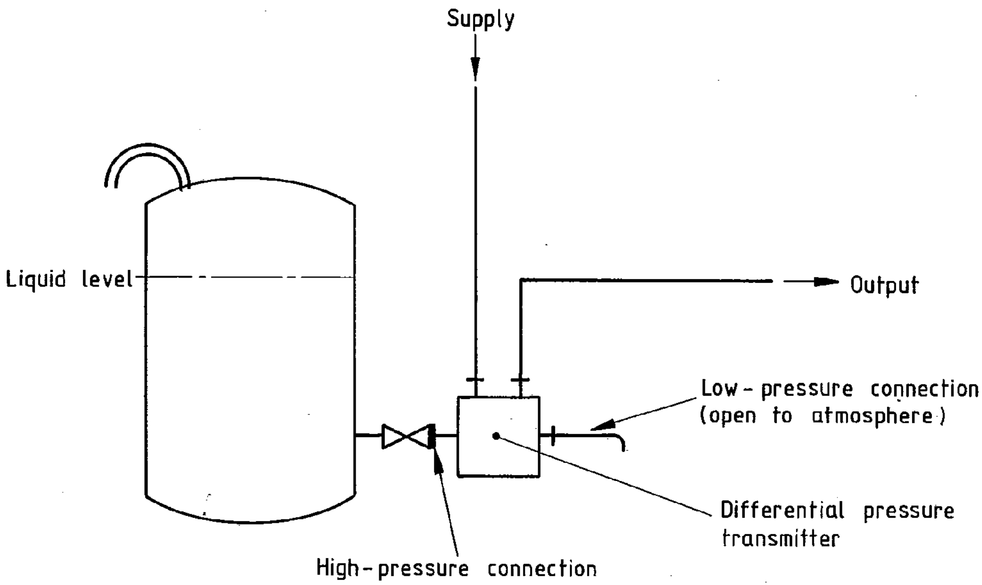


Figure 27. Level measurement using differential pressure transmitter on vented tank

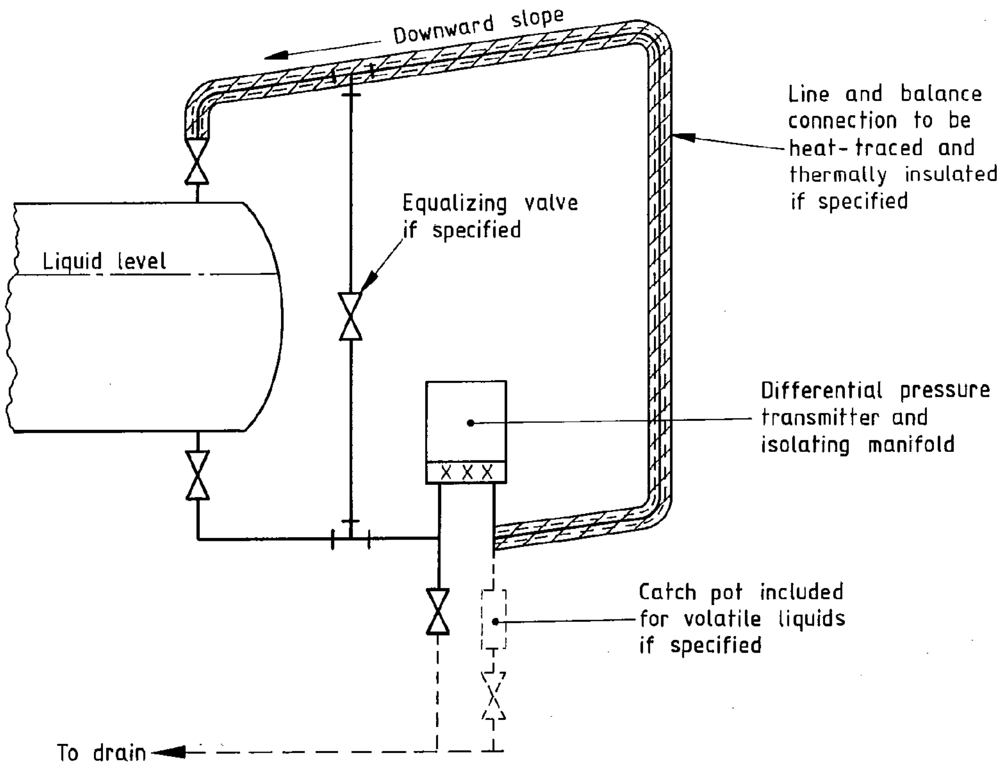


Figure 28. Differential pressure level measurement on a pressurized vessel

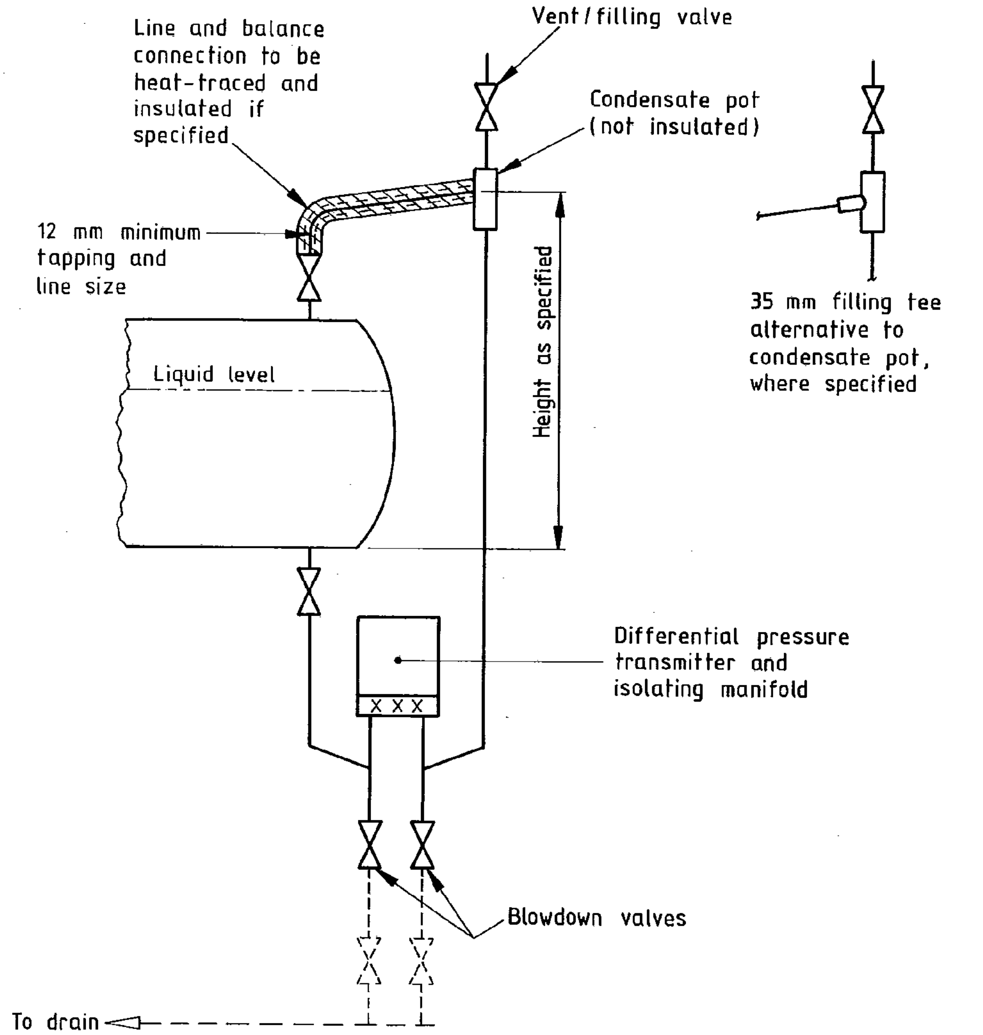


Figure 29. Differential pressure level measurement on a vessel containing a liquid near saturation conditions

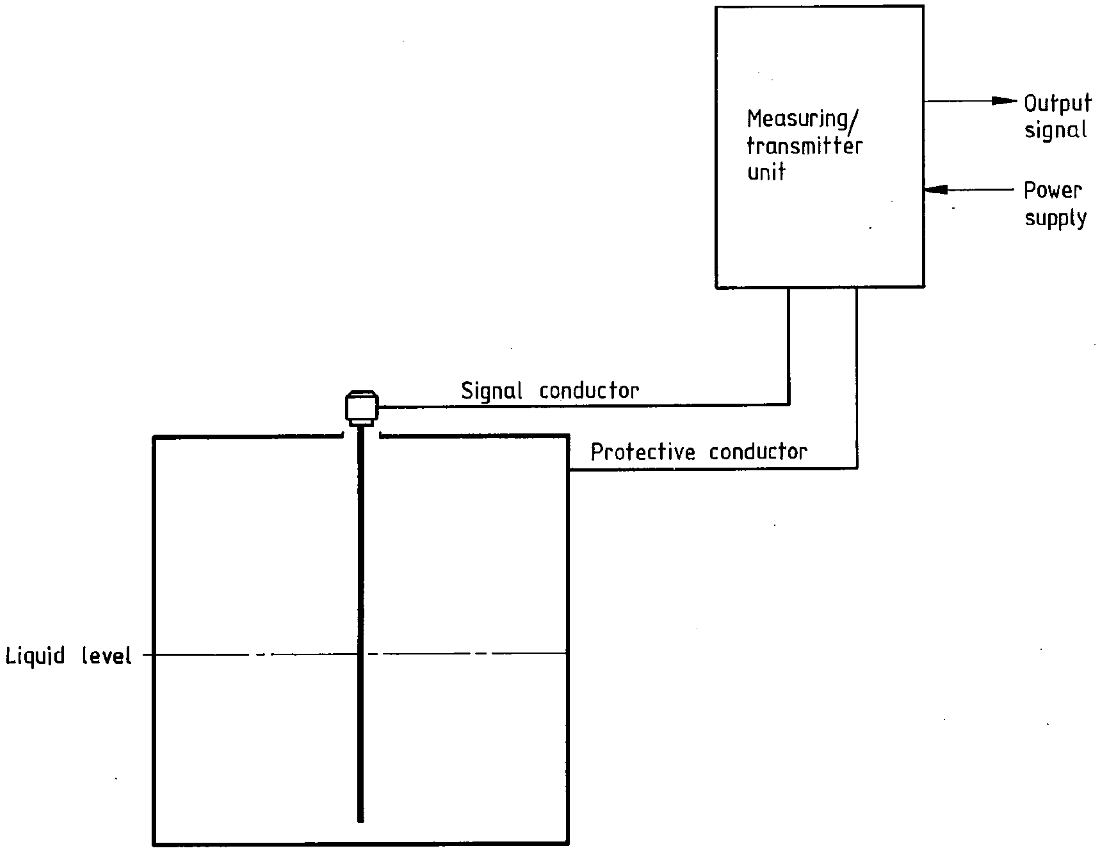


Figure 30. Capacitive level measurement

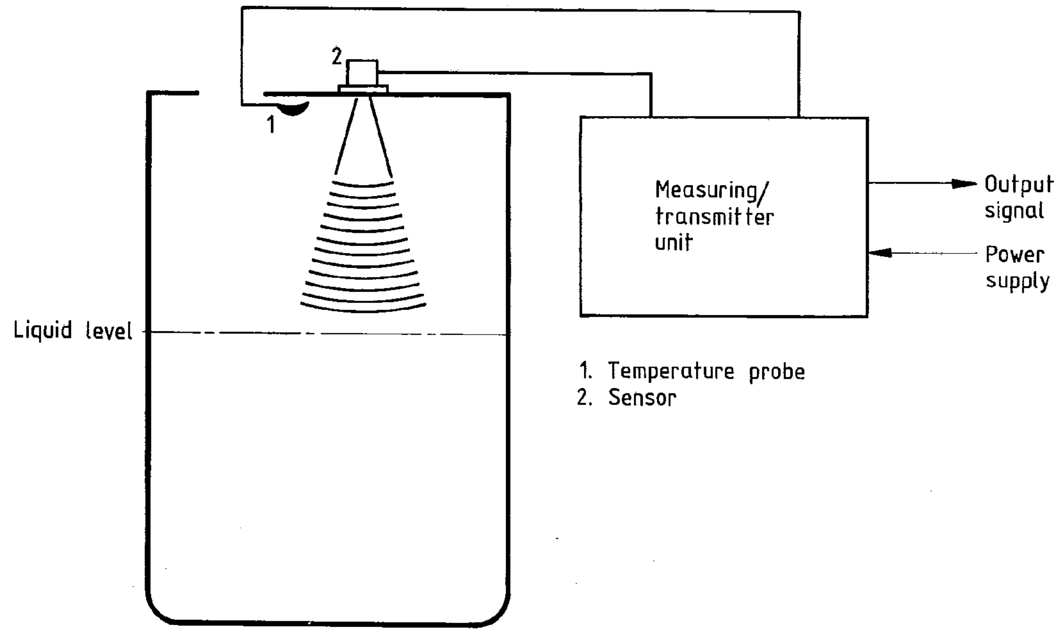


Figure 31. Ultrasonic level measurement

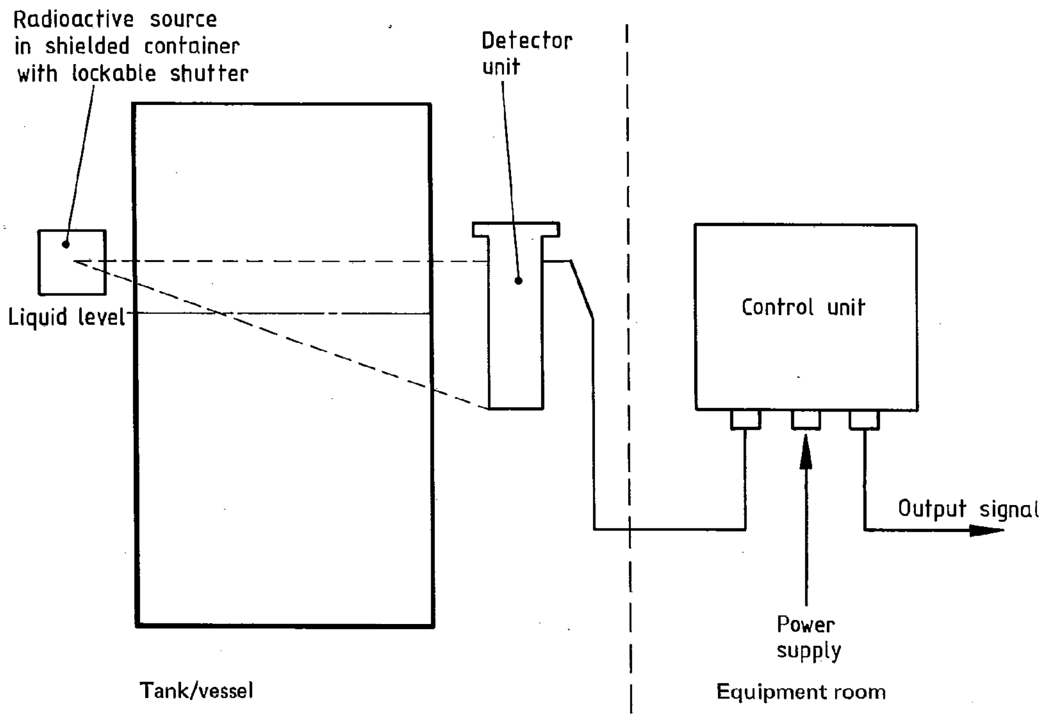


Figure 32. Nucleonic level measurement

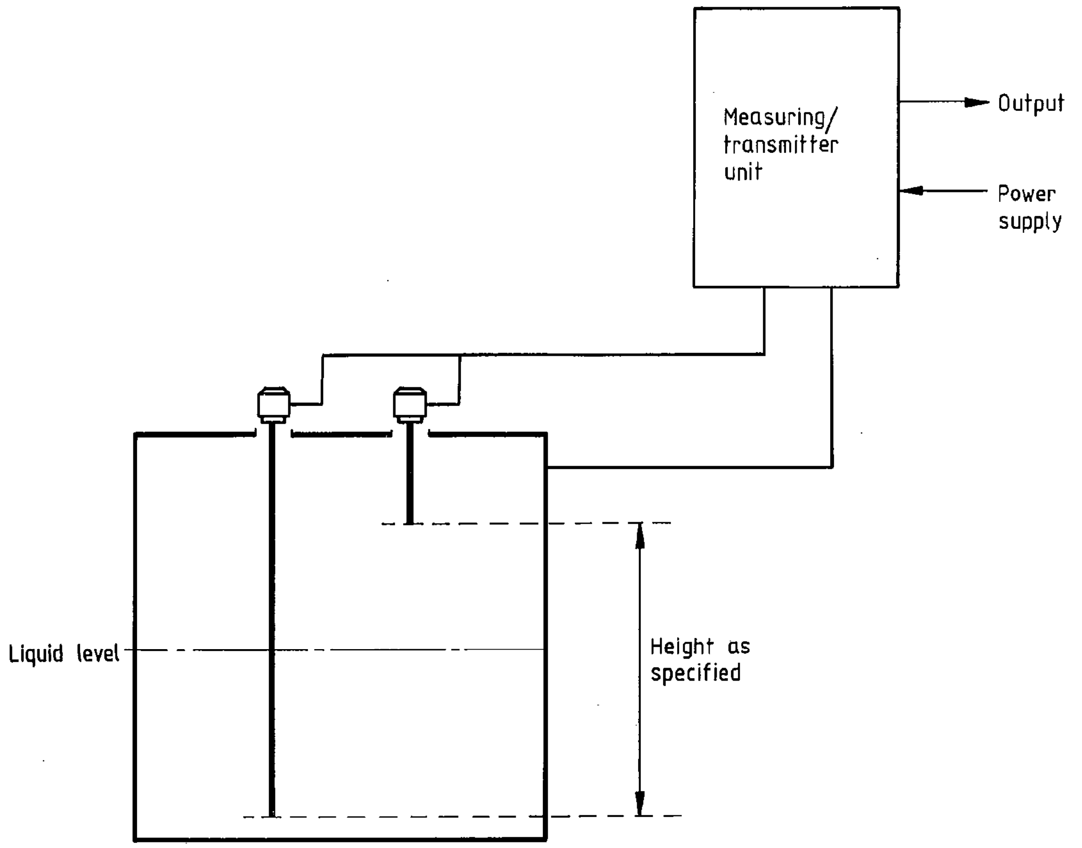


Figure 33. Electrical conductivity level switching

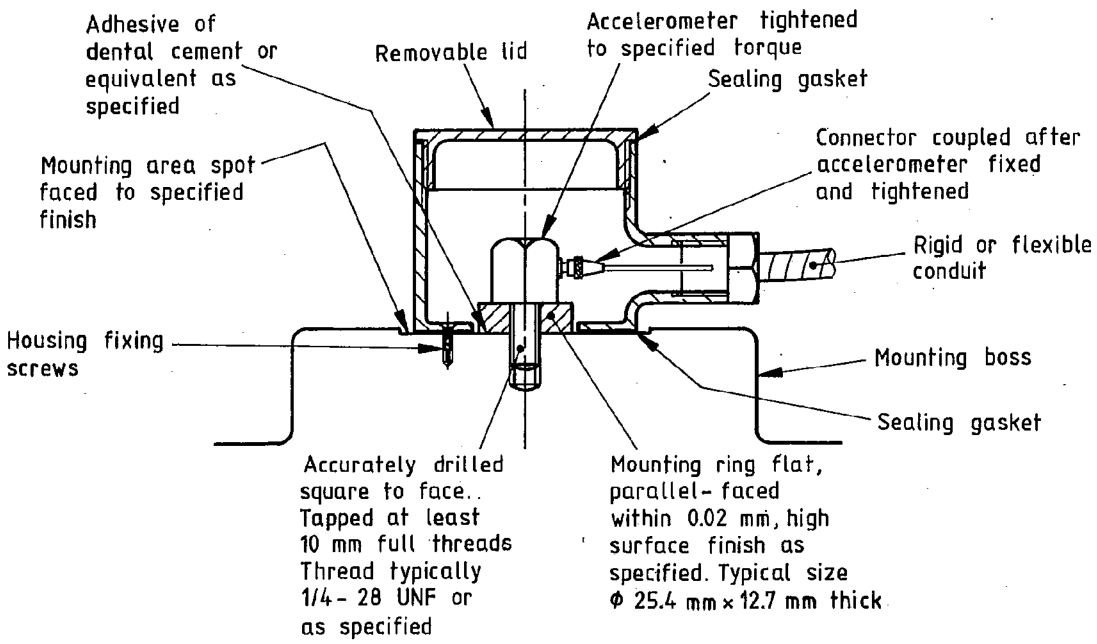


Figure 34. Accelerometer mounting

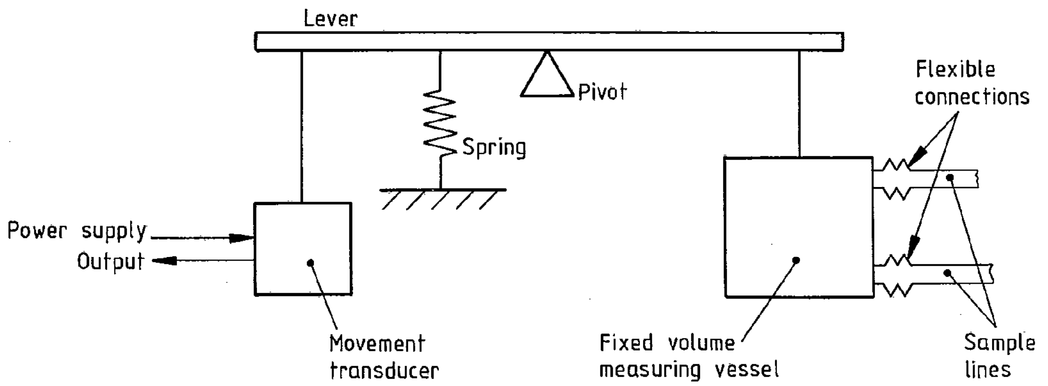


Figure 35. Weighing type density measurement

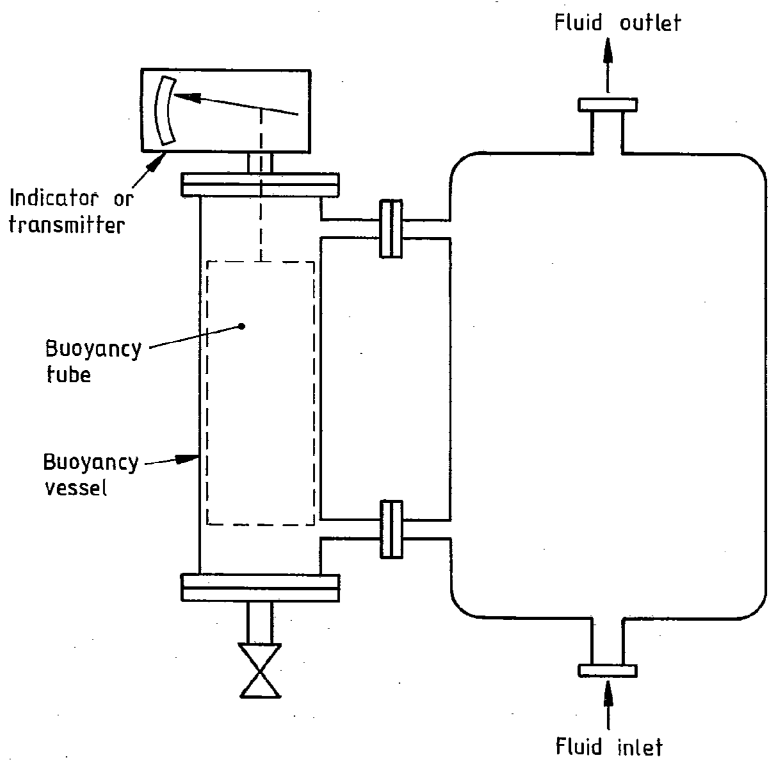


Figure 36. Buoyancy density measurement

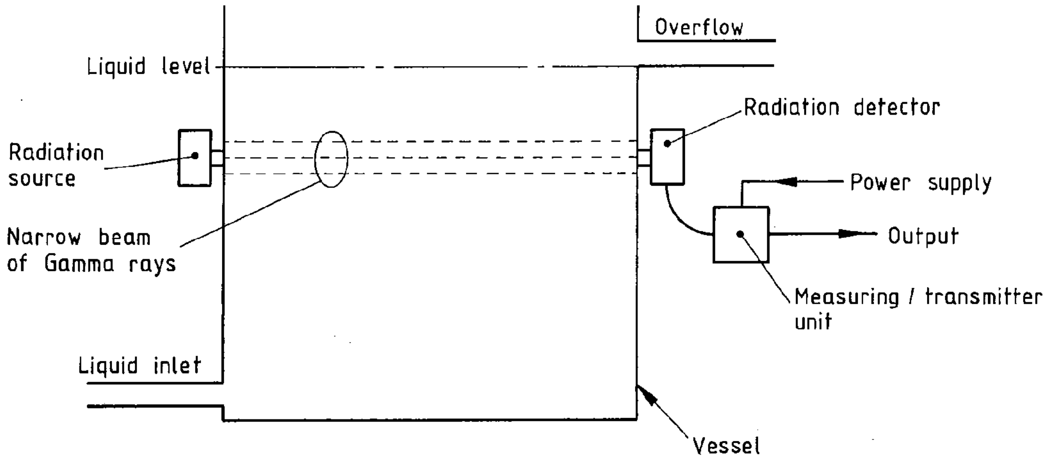


Figure 37. Gamma radiation density measurement

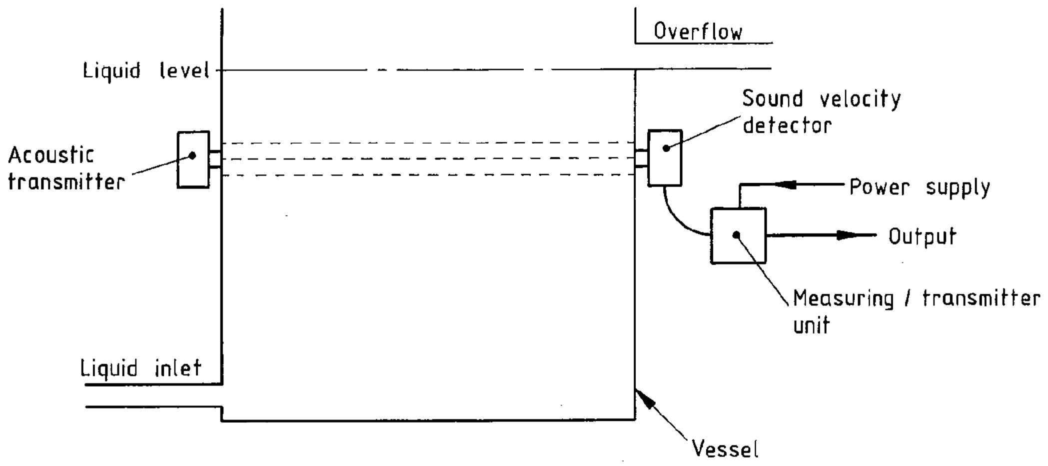
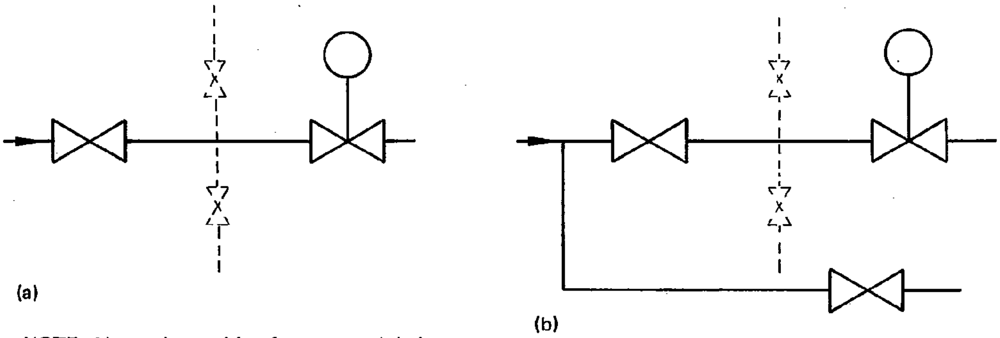
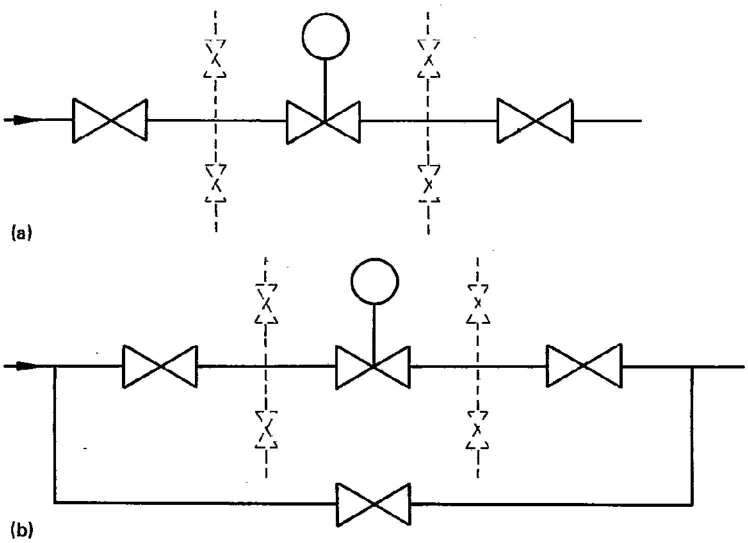


Figure 38. Ultrasonic density measurement



NOTE. Alternative position for vents and drain.
Dotted lines are optional.

Figure 39. Preferred arrangement for a control valve with downstream side connected to atmosphere



NOTE. Dotted lines are optional.

Figure 40. Preferred arrangement for a control valve when both sides could become pressurized

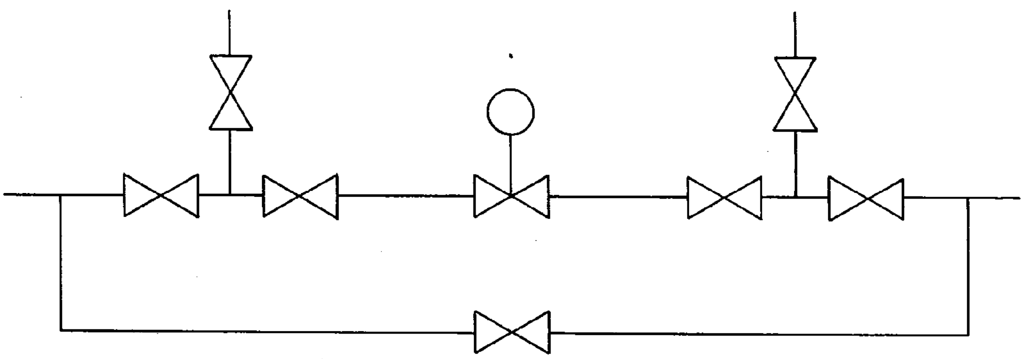


Figure 41. Preferred arrangement for a control valve for highly toxic or extremely high pressure applications

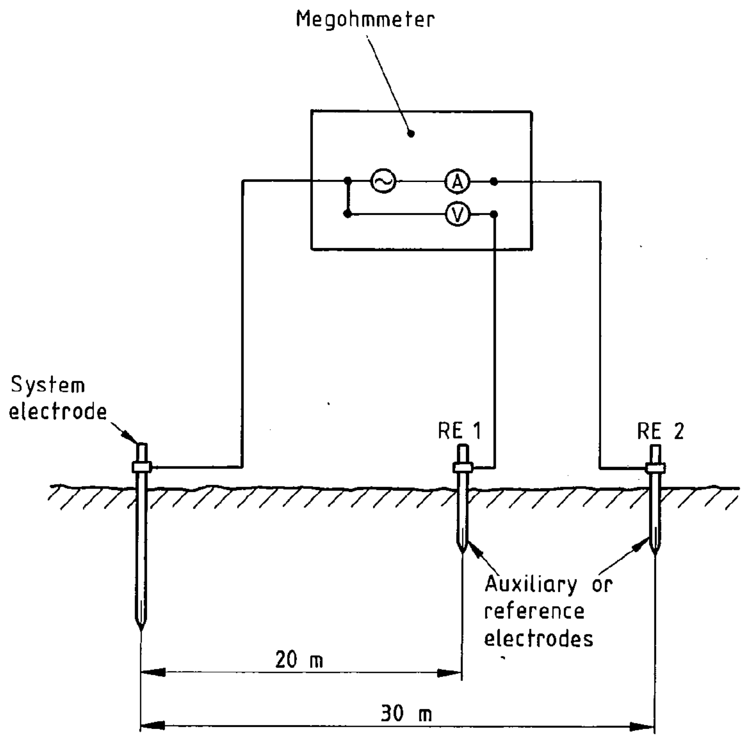


Figure 42. Earth resistance measurements

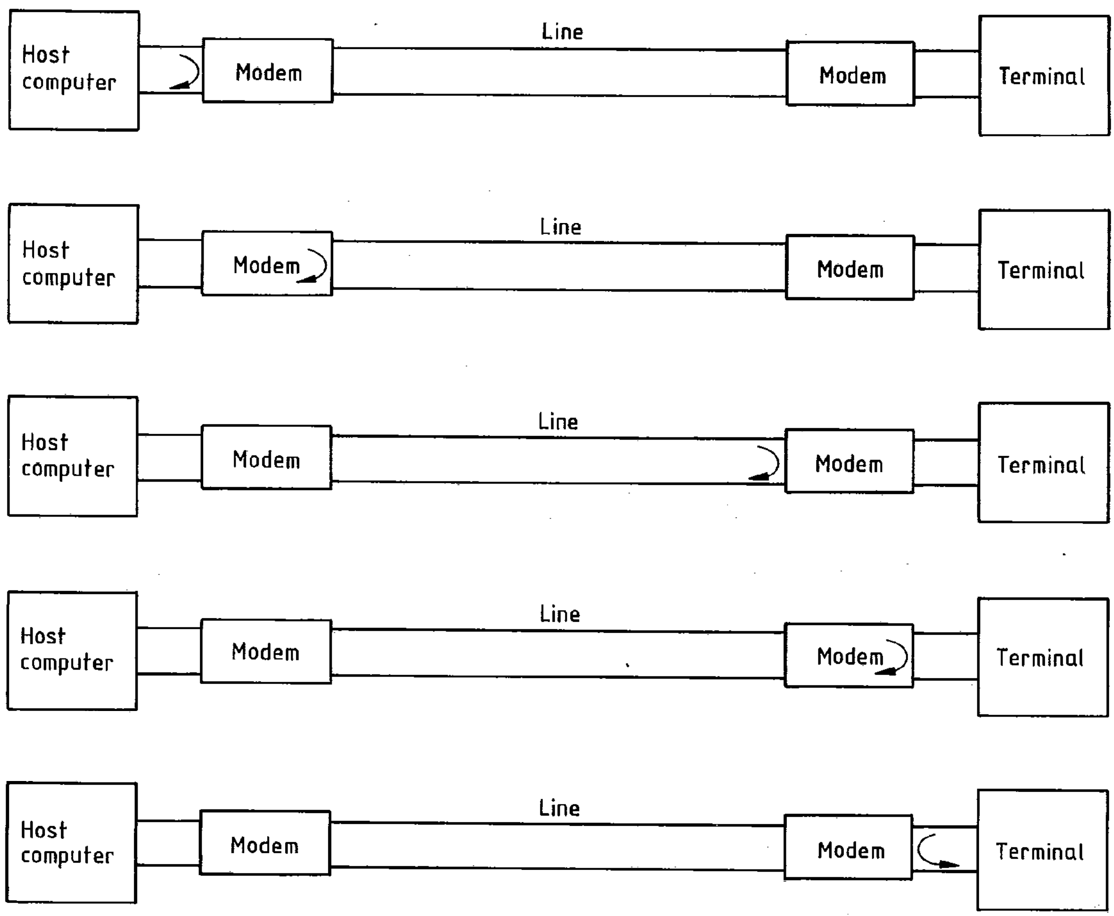


Figure 43. Fault diagnosis on modem link

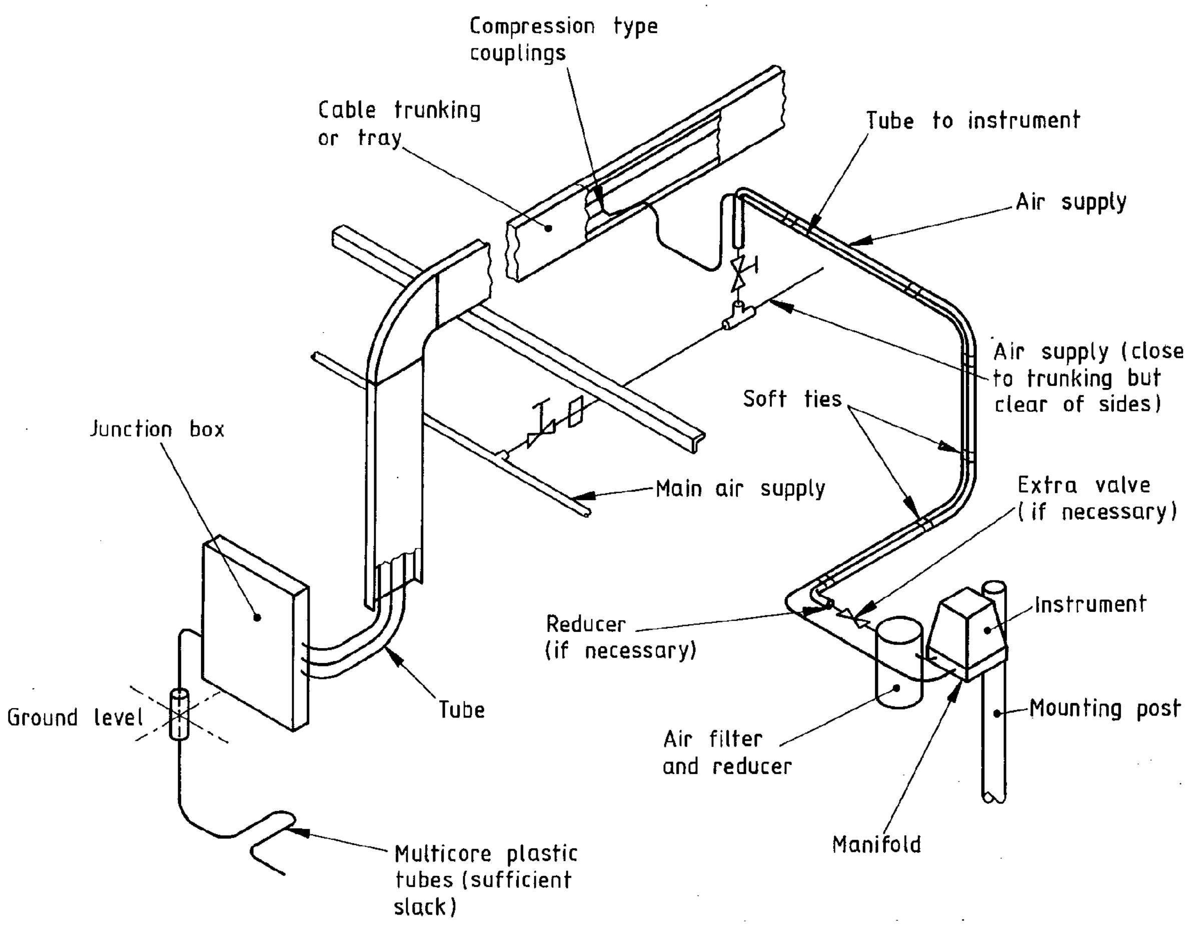
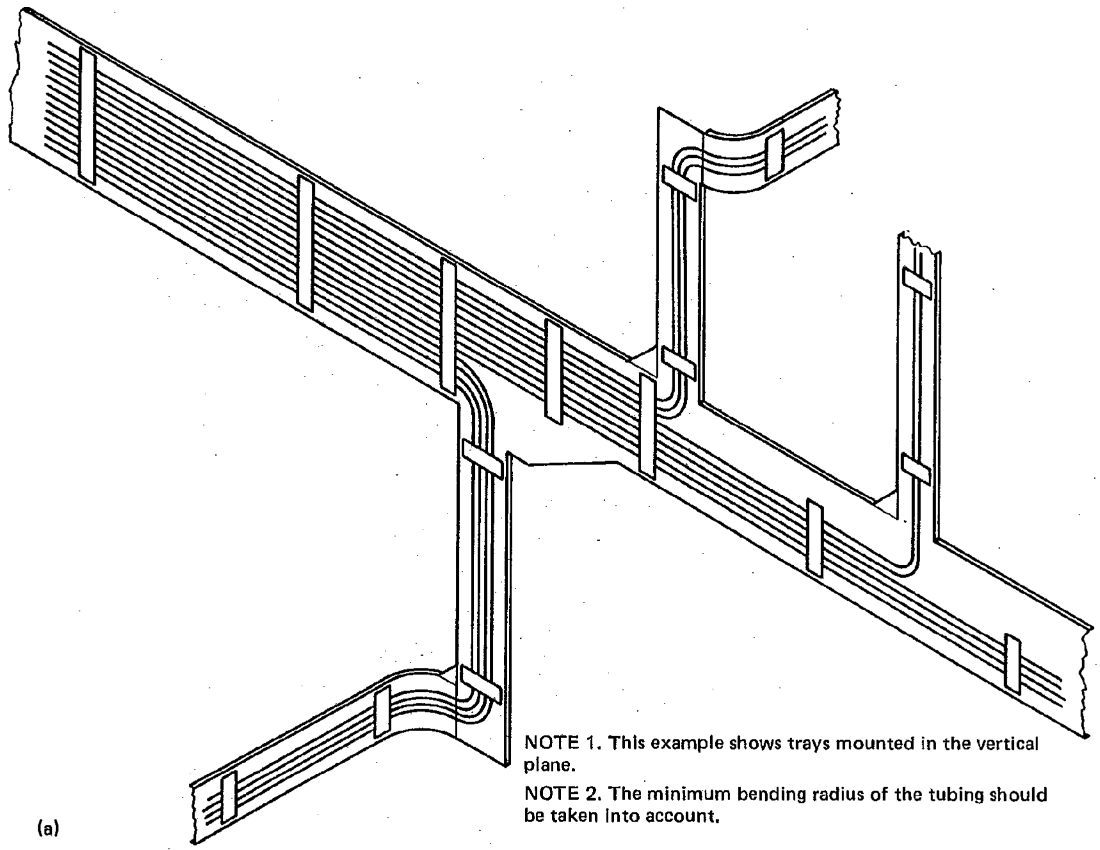


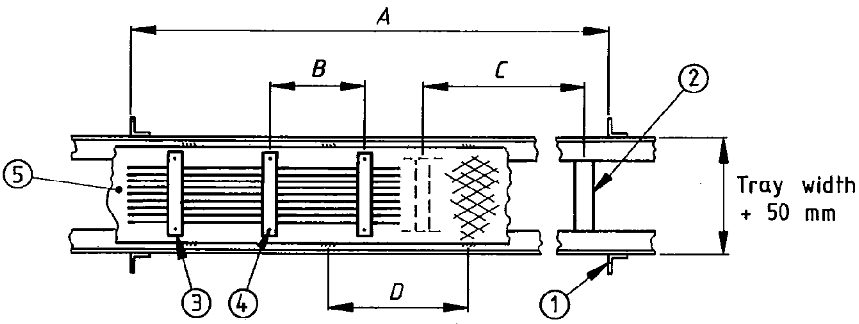
Figure 44. Field termination of pneumatic multitubes

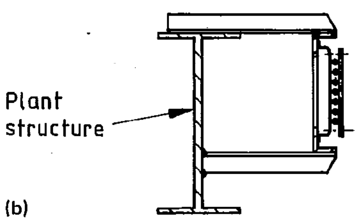


(a)

NOTE 1. This example shows trays mounted in the vertical plane.

NOTE 2. The minimum bending radius of the tubing should be taken into account.





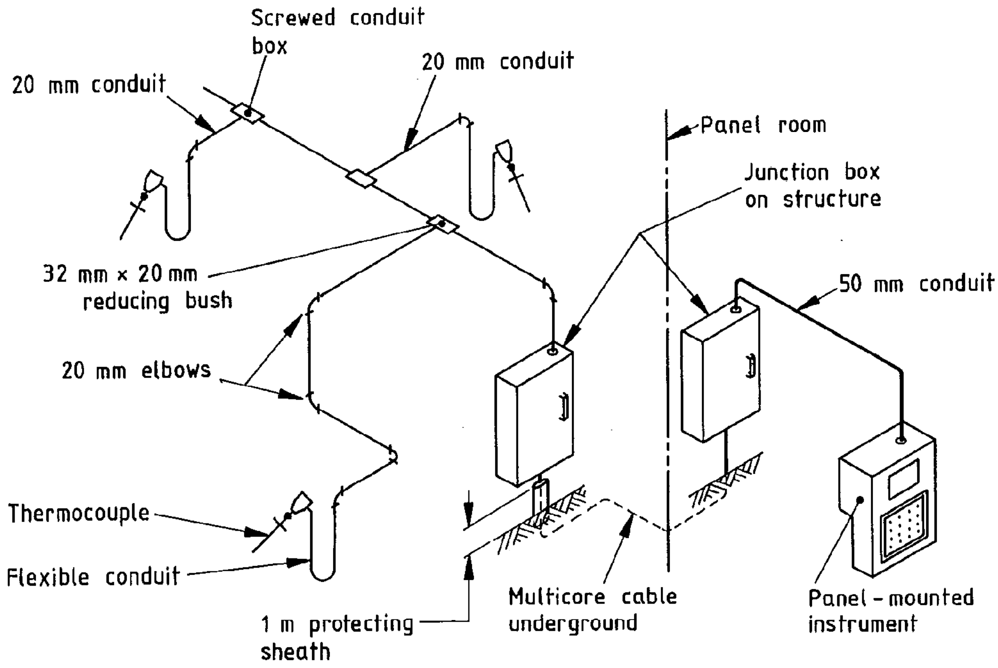
A. Angles supported on structure at 3 m to 4 m centres.
B. Tubing clipped at 0.5 m centres.
C. Strips between toes of angles at 1 m centres.
D. Tray tack-welded to supporting angles at 0.5 m centres.

(b)

Key

1. Steel angle 40 mm X 40 mm X 6 mm.
2. Steel strip 40 mm X 6 mm.
3. Steel strip 25 mm X 6 mm.
4. Brass screws 5 mm dia.
5. Galvanized, perforated steel tray (width to suit).

Figure 45. Details of copper tubing trays (examples of construction)



NOTE. All elbows and conduit boxes should be of the inspection-type.

Figure 46. Layout of thermocouple extension cable in conduit

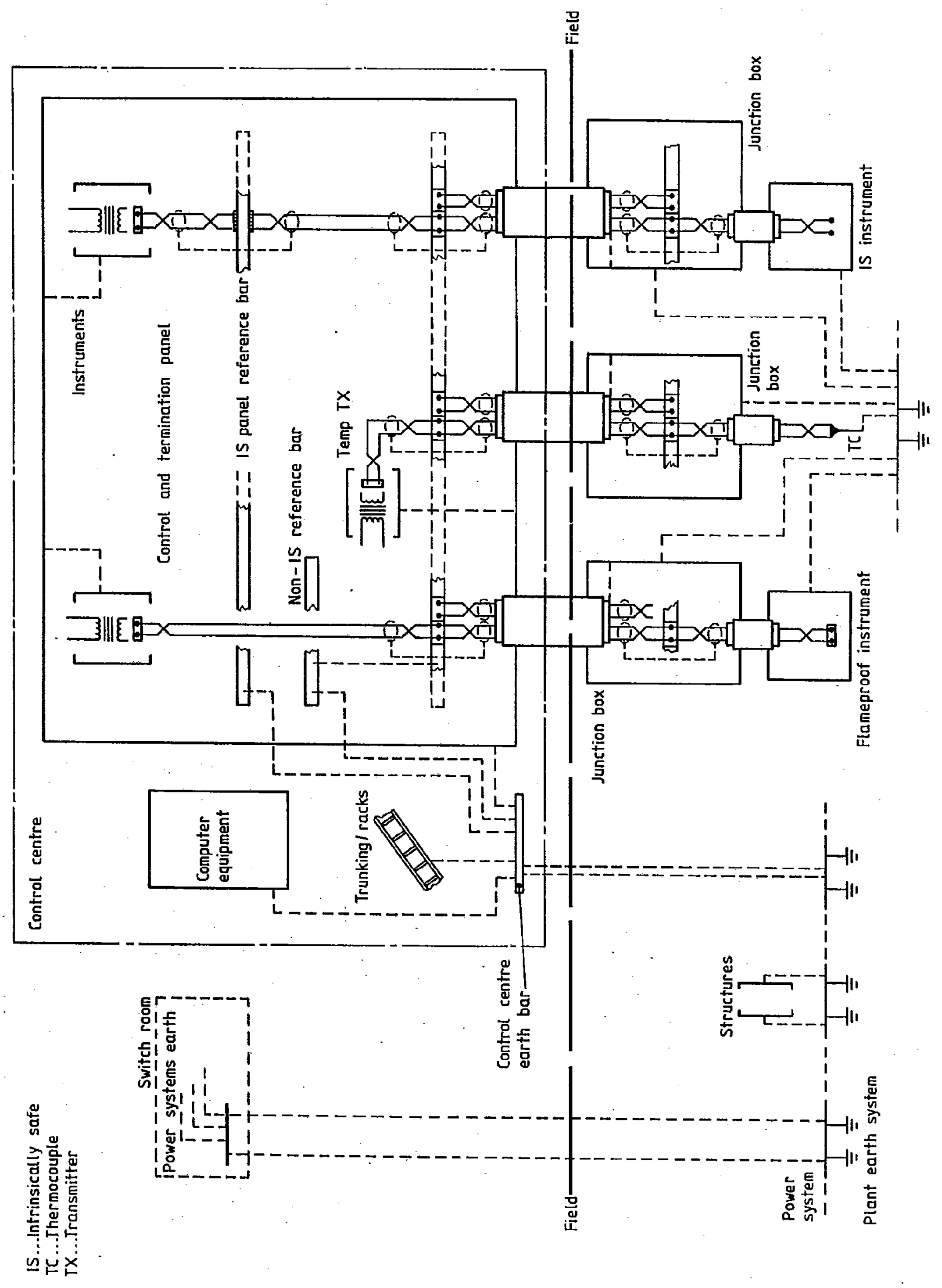


Figure 47. Control centre earthing system

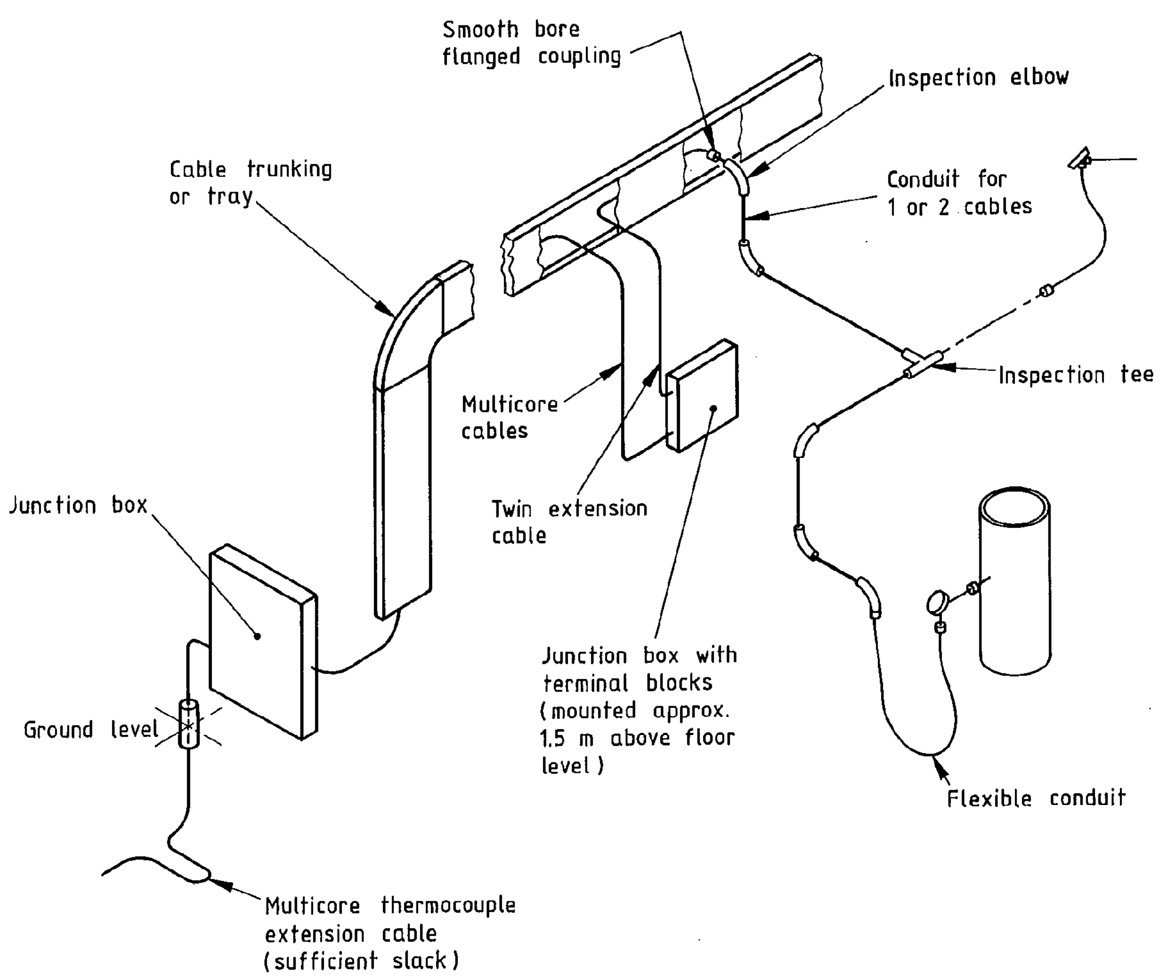


Figure 48. Field termination of multicore thermocouple extension cable

Publications referred to

BS 229 Flameproof enclosure of electrical apparatus
BS 731 Flexible steel conduit for cable protection and flexible steel tubing to enclose flexible drives
BS 759 Specification for valves, gauges and other safety fittings for application to boilers and to piping installations for and in connection with boilers
Part 1 Specification for valves, mountings and fittings
BS 889 Flameproof electric lighting fittings
BS 1042 Methods of measurement of fluid flow in closed conduits
BS 1259 Intrinsically safe electrical apparatus and circuits for use in explosive atmospheres
BS 1471 Wrought aluminium and aluminium alloys for general engineering purposes — drawn tube
BS 1780 Specification for Bourdon tube pressure and vacuum gauges
BS 1843 Colour code for twin compensating cables for thermocouples
BS 1904 Specification for industrial platinum resistance thermometer sensors
BS 2765 Dimensions of temperature detecting elements and corresponding pockets
BS 2871 Copper and copper alloys. Tubes
Part 2 Tubes for general purposes
BS 3351 Piping systems for petroleum refineries and petrochemical plants
BS 3510 A basic symbol to denote the actual or potential presence of ionizing radiation
BS 3601 Steel pipes and tubes for pressure purposes; carbon steel with specified room temperature properties
BS 3605 Seamless and welded austenitic stainless steel pipes and tubes for pressure purposes
BS 3680 Methods of measurement of liquid flow in open channels
Part 4A Thin-plate weirs
Part 4B Long-base weirs
Part 4C Flumes
Part 4D Compound gauging structures
Part 4E Free overfall weirs of finite crest width (rectangular broad-crested weirs)
Part 4F Round-nose horizontal crest weirs
Part 4G Flat-V weirs
BS 4137 Guide to the selection of electrical equipment for use in Division 2 areas
BS 4683 Electrical apparatus for explosive atmospheres
Part 1 Classification of maximum surface temperature
Part 2 The construction and testing of flameproof enclosures of electrical apparatus
Part 3 Type of protection N
Part 4 Type of protection 'e'
BS 4727 Glossary of electrotechnical, power, telecommunication, electronics, lighting and colour terms
BS 4794 Specification for control switches (switching devices, including contactor relays, for control and auxiliary circuits, for voltages up to and including 1000 V a.c. and 1200 V d.c.)
Section 2.20 Position switches with positive opening operation
BS 4803 Radiation safety of laser products and systems
BS 4937 International thermocouple reference tables
BS 5306 Code of practice for fire extinguishing installations and equipment on premises
BS 5308 Instrumentation cables
Part 1 Specification for polyethylene insulated cables
Part 2 Specification for PVC insulated cables
BS 5345 Code of practice for the selection, installation and maintenance of electrical apparatus for use in potentially explosive atmospheres (other than mining applications or explosive processing and manufacture)
Part 1 Basic requirements for all parts of the code
Part 2 Classification of hazardous areas
Part 3 Installation and maintenance requirements for electrical apparatus with type of protection 'd'. Flameproof enclosure
Part 4 Installation and maintenance requirements for electrical apparatus type of protection 'i'. Intrinsically safe electrical apparatus and systems
Part 5 Installation and maintenance requirements for electrical apparatus protected by pressurization 'p' and by continuous dilution, and for pressurized rooms
Part 6 Installation and maintenance requirements for electrical apparatus with type of protection 'e'. Increased safety
Part 7 Installation and maintenance requirements for electrical apparatus with type of protection N
Part 8 Installation and maintenance requirements for electrical apparatus with type of protection 's'. Special protection
Part 9* Installation and maintenance requirements for electrical apparatus with type of protection 'o' and 's'. Oil immersed and sand filled
Part 10* Equipment for use with combustible gases
Part 11* Specific industry applications
Part 12* The use of gas detectors
BS 5378 Safety signs and colours
Part 1 Specification for colour and design
BS 5500 Specification for unfired fusion welded pressure vessels

* In preparation.

BS 5501	Electrical apparatus for potentially explosive atmospheres
	Part 1 General requirements
	Part 2 Oil immersion 'o'
	Part 3 Pressurized apparatus 'p'
	Part 4 Powder filling 'q'
	Part 5 Flameproof enclosure 'd'
	Part 6 Increased safety 'e'
	Part 7 Intrinsic safety 'i'
	Part 9 Intrinsically safe electrical systems 'i'
BS 5958	Code of practice for the control of undesirable static electricity
BS 6351	Electric surface heating
BS 6423	Code of practice for maintenance of electrical switchgear and controlgear for voltages up to and including 650 V
BS 6759	Safety valves
CP 1013	Earthing

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British Gas plc
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Department of Energy (Gas and Oil Measurement Branch)
Department of Trade and Industry (National Weights and Measures Laboratory)
Energy Industries Council
Engineering Equipment and Materials Users' Association
GAMBICA (BEAMA Ltd.)
Institution of Gas Engineers
STC Water Regulations and Fittings Scheme

The following bodies were also represented in the drafting of the standard, through subcommittees and panels:

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Electricity Supply Industry in England and Wales
Health and Safety Executive
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Institution of Electrical Engineers
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