All the components of the dispensing system should be rated for, as a minimum:

— a maximum allowable working pressure (MAWP) equal to or greater than 138 % of the dispenser nominal working pressure (H35 or H70 as defined in ISO 17268);

— an ambient temperature range of −40 °C to +50 °C; (consideration should be given to the possibility of higher temperatures, with the use of protection from the sun and/or higher rated components where necessary)

— use with hydrogen;

— a specified cycle life beyond which the component should be removed from service.

It is recommended that dispenser components are rated for use at the MAWP listed below in Table 5, and tested as a minimum to the appropriate Integrity Test Pressure (ITP) for their pressure class.

NOTE Further guidance on pressure terminology is included as Annex D.

When components in the dispensing system have a lower maximum allowable working pressure than 138 % of nominal working pressure (NWP), the set point of the PSV should be defined by the lowest maximum allowable working pressure of any component in the relevant pressure system. The fuelling protocol should take this restriction into account to minimise the likelihood of over-pressurisation of the dispenser.

Table 5 — Pressure levels for dispensing system components

Pressure Class	NWP (Nominal Working Pressure) due to a CHSS gas temperature of 15 ºC	MOP (Maximum Operating Pressure) Highest pressure permitted during normal fuelling due to a CHSS gas temperature of 85 ºC	MAWP [1] (Maximum Allowable Working Pressure) Minimum pressure to which component is rated Highest permissible dispenser PSV set-point – see 8.2.3.3	ITP [2, 3] (Integrity Test Pressure) Minimum pressure to which component is tested before use.
	1,00 x NWP	*1,25 x NWP*	*1,375 x NWP*	*1,50 x NWP*
H25	25 MPa	31,25 MPa	34,375 MPa	37,5 MPa
H35 [4]	35 MPa	43,75 MPa	48,125 MPa	52,5 MPa
H50	50 MPa	62,5 MPa	68,75 MPa	75,0 MPa
H70 [4]	70 MPa	87,5 MPa	96,25 MPa	105,0 MPa

NOTE 1 Component rating to be valid at maximum and minimum allowable material temperatures as defined by the manufacturer;

NOTE 2 The proposed test level matches the maximum pressure expected during PSV relieving;

NOTE 3 Other test pressure required according to national regulations;

NOTE 4 Pressures used for hydrogen road vehicle fuelling in this document.

NOTE 5 The ratio between MOP and MAWP is different (greater or lower than 1,1) depending on the processor design of the hydrogen fuelling station and corresponding sub-systems (for example in Japan).

NOTE 6 ITP is either a hydraulic or pneumatic test.

9.10.3.3 Dispenser hydrogen isolation valves

Means to automatically isolate all hydrogen dispensers from the hydrogen supply should be included.

The manufacturer's risk assessment should consider the need for an automatic isolation valve to be provided at each end of the pipe between the dispenser and the hydrogen buffer storage, dependent on the amount of hydrogen that would be released in case of a loss of containment. At least one automatic isolation valve should be located in a place not accessible to public, and protected from vehicle impact.

Where required, the automatic valve at the dispenser should be located such that it is protected from vehicular impact.

The automatic valves should be normally-closed. The automatic shut-off valves should be closed if an emergency shutdown occurs as defined in 8.2.3.2 and when no dispensing is taking place. While the automatic shut-off valves should open to allow dispensing, these valves should not perform process control as described in 8.2.2.4.6.

Means to provide positive isolation of the dispenser automatic shut-off valve and of the dispenser, for example using manual shut-off valves, should be included where appropriate for maintenance.

The leak-tightness of the isolation valves should be periodically checked.

Where required by risk assessment, the isolation valve body should be constructed with material that will continue to function in the case of engulfment in fire.

9.10.3.4 Dispenser cabinet

The construction of the cabinet should be such that it will not become warped, bent, loosened or otherwise damaged in normal operation. The dispenser cabinet should:

— be able to withstand the expected service loads;

— be made from non-combustible and antistatic materials.

A recess or depression in the cabinet that may collect water should contain means to drain the water to an area that will not cause an unsafe condition.

The dispenser cabinet should afford space for making field connections of gas-carrying piping and electrical equipment. Openings should be provided for making connections and for inspection and adjustment of the operating mechanism after installation. Openings should require a key or tool to open.

The equipment and parts within the dispenser cabinet should comply with the recommendations of 10.2.2. The interior of the dispenser cabinet should be naturally- or force- ventilated to prevent flammable mixtures in case of a reasonably foreseeable leak. This may be achieved by openings at different elevations so as to ensure sufficient ventilation. Ventilation outlets should be located in a way as to avoid exposure of the user. Pressurized gases emerging from pressure relief devices should be ventilated and dissipated in a safe manner to a safe location outside the dispenser cabinet, avoiding any flammable gas atmosphere within the dispenser cabinet.

9.10.3.5 Dispenser piping and fittings

The dispenser piping and fittings should comply with the recommendations of 9.2.

9.10.4 Dispenser fuelling assembly

9.10.4.1 General

A dispenser fuelling assembly should consist of a breakaway device, a hose(s), a nozzle and connectors between these components.

Suitability of the fuelling assembly components for the specified service conditions and cycle life should be demonstrated by type testing. Type testing to enable a rated pressure to an MAWP of 1,375 % NWP could for example include:

— a hydrostatic pressure test to 375 % NWP;

— 100 000 pressure cycles to 125 % NWP;

— 10 pressure cycles to 150 % NWP.

Where a MAWP of a lower ratio of 137,5 % NWP is used, the test pressures above may be lower.

The maximum and minimum operational temperatures of the fuelling assembly components should be used during type testing, i.e. see 9.10.3.2.

Each fuelling assembly component should have been hydraulically tested by the manufacturer to a minimum 150 % of the nominal working pressure, see 9.10.3.2, and had a certificate issued to that effect.

NOTE National requirements can require a higher test pressure for assemblies/components as well as the involvement of third party inspection.

9.10.4.2 Composition and integration

The hose breakaway device should be positioned such that when the fuelling hose is pulled along its axis, it will release without damage to the dispenser cabinet. If the fuelling assembly includes a venting hose, the latter should also be fitted with a breakaway device.

The fuelling assembly should be strong enough to withstand the loads (tensile and torsion) exerted by the user without damage.

9.10.4.3 Prevention of damage to fuelling assembly in service

Between fuelling, the hose assembly and nozzle should be stored in such a way that they are protected from damage by vehicles.

The hose assembly should be prevented from contacting the ground unless appropriate measures are taken to protect the hose from any damage resulting from contact with the ground.

The hose assembly should be prevented from being bent to the point of damaging the hose in the conditions of use that are likely to occur.

9.10.4.4 Electrical continuity

Electrical continuity should be ensured throughout the fuelling assembly. The outer surface cover should be non-conductive. The total electrical resistance between the (vehicle) end of the fuelling nozzle to the station electrical ground should be a maximum of 1 000 Ω.

The resistance should be measured equal to the manufacturer's specified maximum allowable working pressure.

9.10.4.5 Marking

The fuelling assembly components should be individually marked with:

— the manufacturer's name or trademark;

— the model designation;

In addition, the fuelling assembly components should be marked with either the date of manufacture or testing, or a serial or batch number, to enable traceability of the component to a test report or certification.

Where appropriate, reference should be made to the design standard with the appropriate pressure class, H25, H35, H35HF or H70 identified.

Where this isn't applicable, the component should be marked with:

— the maximum allowable working pressure;

— permissible operating temperature range; and

— suitability for use with hydrogen.

Breakaway couplings should be marked with the direction of gas flow.

The markings should be designed to be permanent throughout the expected lifetime of the component.

9.10.4.6 Assembly and installation

The components of the fuelling assembly should be assembled and installed according to the manufacturer's instructions.

9.10.4.7 Maintenance and inspection

The fuelling assembly should be visually inspected regularly to check that the assembly is free from damage.

The fuelling hose should be visually inspected regularly to check that the hose is free from damage, cuts, cracks, bulges or blisters, and kinks.

The fuelling assembly should be periodically tested for leaks with a compatible leak detection fluid. Any leakage should be reason for rejection.

The use of protective covers and/or automatic leak tests should be used to define the frequency of visual inspection.

Fuelling hose assemblies that fail visual inspection or leakage test should be withdrawn from service.

9.11 Hose assembly

9.11.1 Rated operating conditions

The hose should be rated for the conditions specified in 9.10.3.2.

9.11.2 Hose assembly design

The hose should be designed for hydrogen service and the environmental conditions at site of use.

Hydrogen leakage by permeability should not exceed 10 cm^3/h per metre of hose at 20 °C.

Construction and materials should be such as to prevent the trapping of hydrogen within or between the materials at a pressure that could damage the hose when the internal pressure is relieved.

Metal mesh reinforcement should not be susceptible to corrosion from penetration of humidity, if such penetration is reasonably foreseeable during expected lifetime.

The fuelling hose assembly should be strong enough to withstand without damage the expected loads (tensile and torsion) exerted by the user.

The length of the fuelling hoses should be long enough to fill vehicles, but should not be longer than necessary to fill vehicles at the intended location.

9.11.3 Hose assembly type testing and production testing

For rated pressures of up to 45 MPa, the fuelling hose assembly should be type tested and production tested according to ISO 14113.

9.11.4 Venting hose assembly

The venting hose, if present, is subject to the same recommendations as the fuelling hose, as defined in 9.10.4.2 to 9.10.4.7.

9.12 Fuelling connector (nozzle) general design and assembly

9.12.1 General design and assembly

The fuelling nozzle should comply with ISO 17268 or SAE J2600 and be rated for the appropriate pressure class. The use of adapters should be prohibited.

The fuelling nozzle should be securely supported and protected from the accumulation of foreign matter (e.g. snow, ice or sand) that could impede operation.

The fuelling nozzle should prevent the entry of air into the vehicle fuel system and fuelling station equipment.

9.12.2 Depressurization of nozzles

A mechanism should be provided to depressurize nozzles as required in ISO 17268.

The gas should be vented in a safe manner to a safe location.

9.13 Hose breakaway device general design and assembly

9.13.1 Rated operating conditions

The hose breakaway device should be rated for the conditions specified in 9.10.4.1.

The hose breakaway device should disconnect when subjected to a maximum force of 1000 N but not less than 220 N independent of the operating pressure within the device when installed as specified by the manufacturer. This condition should be met at all operating fuelling pressures.

The hose breakaway on the fuelling line should incorporate double shut-off features that isolate both sides of the connection when uncoupled.

A method requiring the use of tools should be provided to reconnect the hose breakaway device if it is not a “one-time-use device”. In the event of a reconnection, the fuelling hose assembly should be pressurized and leak tested under operating conditions before recommencing operation.

9.13.2 Breakaway durability

The hose breakaway device should withstand 100 000 cycles of hydrogen gas pressure pulses without separation or leakage. The breakaway device should be inspected and tested according to the supplier’s maintenance scheme.

9.14 Gaseous hydrogen vent systems

9.14.1 General

The venting of hydrogen is typical in a hydrogen fuelling station, and measures should be taken to ensure that hazards arising from venting are minimised, see 5.4.5.

Hydrogen venting systems should be designed and sized according to the following considerations.

9.14.2 Piping design

Design pressure should be such that the pipe system will not rupture in the event of detonation of a flammable hydrogen air mixture in the system. The vent system should be designed for the thrust of the discharging jet.

The recommendations of 9.1.2 should be applied. Vent piping of cryogenic hydrogen should not be insulated to allow the maximum heat transfer from atmosphere in order to reduce the probability of cold hydrogen vent gas vapor clouds. Thermal contraction should be accounted for.

9.14.3 Flame arrestors

Flame arrestors are not needed for vent systems that follow the recommendations of this document.

NOTE Flame arrestors are typically used on combustion systems such as a pre-mixed air fuel supply to a hand torch for example. Flame arrestors can apply a backpressure to increase velocity at the “fire check”.

Back pressure devices used on hydrogen vent systems with gas recovery or atmosphere exclusion systems should be engineered for the specific hydrogen vent recommendations.

9.14.4 Vent outlet

Outlet may be vertical upwards, horizontal, or any direction in between. Caps should not be used.

Drains and water accumulation points should be protected from freezing to avoid blockage or breaking of vent stack. Consideration should be given in the fuelling station risk assessment to the prevention of accumulation of water, including that from condensation, in the vent stack outlet (or other requirements for protection against freezing.)

Where the risk assessment deems appropriate, vent systems, particularly those with a vertical outlet should be equipped with a water drain valve at the bottom of the vent stack.

For horizontal outlets (T-vent or single outlet vent), the cut plane should not face downward if the exit velocity is sufficiently high for the direction of the release to be determined by the orientation of the cut plane.

The outlet piping may be slightly inclined downwards to avoid entry of water if measures are taken to avoid that the plume or jet will be pointing downwards (e.g. through low velocity release, or by use of a cut plane facing upwards for exit velocities that are sufficiently high for the direction of release to be determined by the orientation of the cut plane.

9.14.5 Maximum flow rate calculation

The maximum flow rate should be calculated as the sum of all the flows in normal or foreseeable operating conditions that are expected to be simultaneous, and the highest flow generated by upset conditions.

Normal and foreseeable operating conditions to be considered are, for example, the venting of compressor flow. For liquid hydrogen supply systems, normal and foreseeable operating conditions include:

— cool down of lines, pumps and connected equipment;

— liquid flash and gas displacement during filling of the tank;

— normal boil-off rate from ambient heat leak.

Upset and accidental conditions maximum flow rate should include the largest of the following independent upset conditions such as

— emergency discharge of gaseous hydrogen buffer storage;

— external fire;

— malfunction of dispensing control valve causing pressure relief valve(s) to open.

For liquid hydrogen supply systems: Upset and accidental conditions maximum flow rate should include

— excessive rate of cool-down;

— loss of vacuum;

— malfunction of control valves in the pressure control circuits or fuelling line causing excess vapour generation in the tank;

— venting of pumped liquid flow.

9.14.6 Piping diameter and exit velocity

The vent piping diameter should not be smaller than the diameter of any pressure-relief valve outlet, and large enough to prevent the pressure relief valve functioning properly. Limitation of noise level may also need to be considered.

NOTE 1 For vertical venting, the higher the discharge velocity the smaller the separation distance recommendations around the vent [1)].

NOTE 2 For T-venting, the smaller the discharge velocity the smaller the separation distance recommendations in the axis of discharge [2)].

9.14.7 Maximum pressure drop

The maximum pressure drop resulting from the sum of design flows of all vent devices discharging into a common vent system at the same time should not exceed 10 % of the lowest set pressure of these relief valves, in order to prevent counter-pressure in the vent line from preventing the opening of the relief valve.

9.15 Pneumatics

Instrument air from an air compressor or cylinder supply system should be supplied through control valves. A buffer volume should maintain the air pressure to allow a safe shutdown of the fuelling station should the supply lapse. Pneumatic equipment and systems should satisfy the requirements of ISO 4414.

Pneumatic systems should be designed so that no hazard may result from pressure losses, pressure drops.

All elements of the pneumatic system, especially pipes and hoses, should be protected against harmful external effects where this is required by the fuelling station risk assessment.

9.16 Hydrogen purifier

Hydrogen purification should be provided as necessary to meet the recommendations of 8.3 and 8.4 under all operating conditions where vehicle fuelling is possible. The hydrogen purifier should be designed taking into account possible contamination from the hydrogen supply system or process equipment, such as oil in vapour or liquid form.

If adverse effects on the performance and/or corrosion are to be expected because of the quantity of moisture, the hydrogen gas should be dried such as to avoid water condensation at the highest pressure and in all operating conditions.

1) The higher the velocity, the higher the vertically directed momentum and, thus, the lower the chance for the cross wind to bend the resulting flammable plume towards the ground. High momentum nature of the vertical release will ensure that the bulk of released gas is directed away from people and equipment.

2) The lower the velocity, the lower the horizontally directed momentum and, thus, the lower the horizontally projected footprint of the formed flammable plume. Buoyancy dominated nature of the horizontal release will ensure that the orientation of flammable plume will become vertical within a short proximity to the vent stack thus directing the bulk of released gas away from people and equipment. Cross wind in this case will help dispersion.

10 Electrical safety

10.1 General

10.1.1 Overview of electrical hazards

Clause 10 addresses electrical safety for hydrogen fuelling stations. There are many aspects to electrical safety in general and additional, specific aspects related to hydrogen and hydrogen fuelling. Some of the hazards common in electrical systems are:

— electric shock;

— electrical burns;

— arc flash / arc blast;

— fire;

— Electromagnetic interference (EMC).

Fuelling systems include many features and hazards common with many types of complex machinery including hazards due to:

— failure of control systems;

— operator error;

— etc.

Hydrogen fuelling systems in particular add this hazard:

— ignition of flammable atmospheres

The electrical system of the hydrogen fuelling station should be designed, installed, maintained, and serviced to eliminate these hazards where possible and minimize any that remain.

The electrical system of the hydrogen fuelling station should also be designed, installed, maintained, and serviced to eliminate any other electrical hazards identified in the risk assessment (see 5.1) where possible and minimize any that remain.

At a minimum the electrical system of the hydrogen fuelling station should comply with this clause, which is organized as follows:

— general electrical

    — components

    — equipment assemblies

    — site (interconnections to and/or between equipment assemblies)

    — lightning

— hazardous areas (potentially explosive atmospheres)

    — electrical equipment

    — other equipment

— Electromagnetic compatibility (EMC).

10.1.2 Components

Individual electrical components / devices or equipment assemblies that have any of the characteristics or are used in any of the ways listed below should comply with the requirements of the product safety standard(s) corresponding to that component device or assembly:

— connected to the electrical mains;

— contain, use, or are connected to hazardous voltage;

— perform a safety function.

Hazardous voltages are typically defined as greater than 50 VAC and 120 VDC in clean, dry conditions. However, much lower voltages can be hazardous in other conditions. The conditions of use should be considered when determining the hazardous voltage levels. See the SELV and PELV clauses of IEC 60364-4-41, and IEC 60204-1, for more information.

If there is no product safety standard(s) corresponding to a type of equipment, the equipment should conform to IEC 60204-1.

Valves, sensors, and other individual components or devices that are connected to the equipment assemblies should also conform to IEC 60204-1.

10.1.3 Site interconnections to and/or between equipment assemblies

Connections between the electrical equipment of the hydrogen fuelling stations and the electrical mains, or connections between electrical equipment assemblies of the hydrogen fuelling stations should also be designed, erected, installed, connected, tested, and verified in accordance with IEC 60364, Low-voltage electrical installations.

There are many clauses and sub-clauses to IEC 60364; the electrical equipment connections should comply with all clauses of IEC 60364 that apply.

NOTE 2 In many cases the requirements of IEC 60204-1 also apply to connections between electrical equipment assemblies of the hydrogen fuelling stations.

10.1.4 Electrical grounding

Hydrogen tanks, associated piping and systems should be earthed to prevent potential electrical shock.

NOTE IEC 60204-1 provides requirements for both protective and operational bonding.

The earthing system resistance should be less than 30 Ω.

Flanges should be electrically bonded. Electrical continuity across joints with an isolating seal (e.g. a polymer) should be ensured with electrical straps or similar. For example the 2 halves of flanged joints should be bonded together.

Enclosures where hydrogen is stored or used should be grounded.

Effectiveness of grounding connection should be verified at a frequency according to local regulation.

10.1.5 Lightning protection

Lightning protection should be provided in accordance with the IEC 62305 series of standards, i.e. IEC 62305-1, and the other parts of IEC 62305 appropriate for the type of equipment.

All hydrogen delivery vehicles should be electrically connected to the same earth ground as the fixed storage hardware prior to flexible hose connection.

10.2 Hazardous areas (potentially explosive atmospheres)

10.2.1 General

Hazardous areas, as classified according to IEC 60079-10-1, in which fixed electrical equipment should be appropriately classified, should be defined.

Hazardous areas are applicable from points of potential releases of hydrogen and/or other flammable fluids, or from the exhaust of natural or active ventilation of enclosures around equipment containing flammable fluids. Locations below the exhaust of ventilation of enclosures around hydrogen systems may be excluded.

A shelter or a canopy with a flat roof surface and with the sides sufficiently open to allow free passage of air through all parts should be considered well ventilated and should be treated as an outdoor area (i.e. “medium” degree and “good” availability). If the canopy is within the height of the classified area, the classified area should extend to the border of the canopy.

Where enclosures are placed around hydrogen equipment to contain and / or control hazardous areas, these should be in accordance with 5.6.3.

Area classification around venting system outlets should be defined on the basis of the specified maximum flow rate, considering also potential upset or accidental flow as defined in 9.14.5.

Hydrogen fuelling stations can include several hazardous areas, e.g. areas with potentially flammable or explosive atmospheres. The energy required to ignite a mixture of hydrogen and air is extremely small; see IEC 60079-20-1. Almost all electrical equipment can be an ignition source for a hydrogen / air mixture if proper protection is not implemented. In addition to the electrical circuits other aspects of the electrical installation or equipment can be ignition sources for hydrogen / air mixtures, for example:

— Rotating blades in fans;

— Hot surfaces;

— Electrostatic discharge from conductive parts or equipment to other conductive parts or earth.

Additional guidance on reducing the potential for the formation of explosive atmospheres included in 5.4.1 and 5.5.1.

10.2.2 Protection requirements for electrical equipment within hazardous (classified) areas

All electrical equipment in hazardous (classified) areas should be protected in accordance with the IEC 60079 series of standards, i.e. IEC 60079-0 and the appropriate other clause of IEC 60079 for the type of protection used. For example an intrinsically safe electrical system should comply with IEC 60079-0 and IEC 60079-11, and IEC 60079-25.

All electrical equipment in hazardous (classified) areas should be installed in accordance with IEC 60079-14.

Where new or existing electrical equipment is within the hazardous area surrounding hydrogen equipment, this should be rated for gas group IIC, or IIB+H2 hazardous areas. This is particularly relevant to integrated fuelling stations, where existing fuel dispensing equipment may not be rated for hydrogen. Further information is available in IEC 60079-14.

All electrical equipment installed in hazardous (classified) areas should be inspected and maintained in accordance with IEC 60079-17.

All electrical equipment installed in hazardous (classified) areas should be serviced, repaired, overhauled, and reclaimed in accordance with IEC 60079-19.

Mechanical parts of electrical equipment installed in hazardous (classified) areas should be protected in accordance with the ISO/IEC 80079 series of standards, i.e. ISO/IEC 80079-36, and the appropriate other clause of ISO/IEC 80079 for the type of protection used. For example a fan protected by construction should comply with ISO/IEC 80079-36 and ISO/IEC 80079-37.2.

10.2.3 Other equipment in hazardous (classified) areas

Mechanical equipment and mechanical parts of electrical equipment installed in hazardous (classified) areas should be protected in accordance with the ISO/IEC 80079- series of standards, i.e. ISO/IEC 80079-36, and the appropriate other clause of ISO/IEC 80079 for the type of protection used. For example a fan protected by construction should comply with ISO/IEC 80079-36 and ISO/IEC 80079-37.2.

10.2.4 Areas adjacent to hazardous areas

Flammable gases should be prevented from entering adjacent areas or compartments unless the equipment within the adjacent area or compartment is suitable for the resulting area classification.

Methods to prevent flammable gases from entering an adjacent area or compartment include but are not limited to:

— maintaining the adjacent area or compartment at a relative pressure higher than the area or compartment containing the flammable gas;

— sealing between areas / compartments;

— separation between the exhaust of one compartment and the intake of another compartment (allowance for ambient air dilution) (see 5.8.2.3).

NOTE One approach is to use negative pressure when ventilating an area containing a flammable gas.

When multiple purged hydrogen equipment enclosures are located in one area, the exhaust of ventilation from one hazardous area should not be introduced into adjacent enclosure compartments.

10.2.5 Protection from ignition due to accumulation of static charge

All exposed and extraneous conductive parts should be connected to the bonded grounding system in accordance with IEC 60079-14.

Development of electrical charges should be prevented by means ensuring both electrical continuity (throughout equipment and piping) and grounding.

To prevent the accumulation of static electricity in conductive equipment, the total resistance of the ground path to earth should be sufficient to dissipate charges that are otherwise likely to be present. The bonding system resistance should be less than or equal to 1 MΩ.

All sources that are able to cause static charges should be addressed, and measures should be taken to remove them completely or reduce the probability of their occurrence. At the design stage, the fuelling station should be examined to identify possible electrostatic hazards and the requirements of earthing should be determined.

WARNING — Electrostatic charges can occur when mechanical separation of similar or different substances takes place and also when a gas, containing droplets or dust particles, flow past the surface of a solid, e.g. valve openings, hose or pipe connections. If the accumulation of electric charges is released suddenly, the resulting electric spark can be sufficiently strong to ignite hydrogen.

Equipment and electrical sources that may unintentionally be in contact should have a common grounding.

Earthing devices should:

— either be clearly visible or be essential to the correct functioning of the fuelling station, so that any shortcomings are quickly detected;