BS EN 12109:1999

Vacuum drainage systems inside buildings

The European Standard EN 12109:1999 has the status of a British Standard

ICS 91.140.80

National foreword

This British Standard is the English language version of EN 12109:1999.

The UK participation in its preparation was entrusted by Technical Committee B/505, Wastewater engineering, to Subcommittee B/505/21, Roof drainage and sanitary pipework, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the BSI Standards Catalogue under the section entitled “International Standards Correspondence Index”, or by using the “Find” facility of the BSI Standards Electronic Catalogue.

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English version

Vacuum drainage systems inside buildings

Réseau d'évacuation sous vide à l'intérieur des bâtiments

Unterdruckentwässerungssysteme innerhalb von Gebäuden

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CEN

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

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Contents

Foreword

This European Standard has been prepared by Technical Committee CEN/TC 165, Wastewater engineering, the Secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by October 1999, and conflicting national standards shall be withdrawn at the latest by October 1999.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

Introduction

This European Standard is a system standard.

A vacuum drainage system is a designed system. Each system is individually designed and based upon a specification with specific design parameters for the application and the selected equipment.

This European Standard contains additional information of importance to specifiers, designers, constructors and operators.

This European Standard has three normative and three informative annexes.

1 Scope

This European Standard specifies system requirements (performance) and the principal requirements for design and installation, with related verification and test methods, for vacuum drainage systems inside buildings transporting domestic wastewater from dwellings and commercial properties, but excluding stormwater and rainwater.

If requirements for products used within the system are needed, annex D (informative) provides guidance to performance requirements, design, verification and quality assurance.

The gravity system which feeds the wastewater to the vacuum drainage system is not covered by this European Standard.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references, the latest edition of the publication referred to applies.

EN 1085, *Wastewater treatment — Vocabulary*.

prEN 1717, *Protection against pollution of potable water in drinking water installations and general requirements of devices to prevent pollution by backflow*.

prEN 12056-2, *Gravity drainage systems inside buildings — Part 2: Wastewater systems, layout and calculation*.

EN 60204, *Safety of machinery — Electrical equipment of machines*.

IEC 335-2-84, *Safety of household and similar electrical appliances — Part 2-84: Particular requirements for toilets*.

3 Definitions

For the purpose of this European Standard, the definitions according to EN 1085 and the following definitions apply.

3.1
***a*-factor**
variable factor used to calculate probable static loss from theoretical static loss

3.2
discharge unit
unit of measurement for the wastewater outflow of appliances

3.3
interface unit
assembly with an interface valve and a buffer volume receiving wastewater

3.4
interface valve
valve which admits the flow of wastewater only, or wastewater and air, into the vacuum drainage system pipeline

3.5
analysis
breaking a requirement down to its constituent parts for clear evaluation

3.6
service connection
section of vacuum pipeline connecting an individual interface unit to the vacuum main

3.7
automatic interface unit (AIU)
assembly consisting of an interface valve, buffer volume, sensor and controller

3.8
dynamic losses
sum of losses caused by inertia, friction and lifts when the water is in motion

3.9
pipe profile
vertical elevation of the vacuum pipeline

3.10
***K*-factor**
variable reduction factor used in design calculations to take into account the frequencies of use of sanitary appliances in different types of building

3.11
air–water ratio (A/W-ratio)
ratio of the volume of air to the volume of wastewater passed through an interface unit for each cycle of operation

3.12
buffer volume
storage volume of the interface unit which balances the incoming flow of wastewater to the output capacity of the discharge valve

3.13
reforming pocket
low point in the piping profile installed intentionally to produce a controlled slug flow

3.14
slug
isolated quantity of wastewater flowing full bore through the vacuum pipeline

3.15
forwarding pump
pump installed at the vacuum station to deliver the wastewater from the vacuum system

3.16
inspection
visual review of drawings, hardware or installation

3.17
static loss
loss of vacuum due to lifts when the system is at rest

3.18
lift
section of vacuum pipeline with an increase in invert level in the direction of flow

3.19
theoretical static loss
static loss obtained by considering every lift full of water

3.20
vacuum
any pressure below atmospheric

3.21
vacuum container
container connected to the vacuum pump, the vacuum drainage pipelines and a means of discharge

3.22
vacuum drainage
transportation of wastewater by vacuum

3.23
vacuum recovery time
time taken, after the operation of an interface valve, for the vacuum at the valve to be restored to its operational value

3.24
vacuum generator
equipment installed at the vacuum station to generate and maintain the vacuum within the system

3.25
vacuum station
installation comprising vacuum generator(s), a means of discharge and control equipment, and which may also incorporate vacuum vessel/holding tank(s)

3.26
vacuum toilet
toilet incorporating an interface unit and a means of rinsing

3.27
controller
device which, when activated by its level sensor, opens the interface valve and, after the passage of wastewater and normally air, closes the valve

3.28
available vacuum differential
difference between the vacuum level in the vacuum station and the initial vacuum needed to operate an interface unit

3.29
availability
operating time of a vacuum drainage system divided by its operating time plus time out of service

3.30
data submittal
supplying detailed information supporting compliance with the requirements of this standard

3.31
probable static loss
theoretical static loss multiplied by a probability factor

3.32
water valve
controlled valve regulating the entry of flush water of a vacuum toilet

4 System description

A vacuum drainage system is a drainage system under sub-atmospheric pressure where:

- the wastewater is let into the pipework through interface units;
- most of the air necessary for the transportation of the wastewater enters through interface units;
- the interface units are normally operated by the pressure differential to atmosphere.

This European Standard considers the vacuum drainage system in four system elements:

- automatic interface units (AIU);
- vacuum toilets;
- pipework;
- vacuum station.

The system is based upon the principles of intermittent transport and immediate access to vacuum.

When the interface valve is opened, the difference in pressure between the atmosphere and the main pipeline pushes the volume of water and normally several times that volume of air through the service connection into the main pipeline. This creates a large local pressure differential which accelerates the water in the vicinity. As the pressure is equalized and the air is rushing through the system, it sequentially accelerates several independent masses of water that have accumulated in the low points of the pipework. This movement of water takes place in both directions, but the slope has a directional effect on the water flow.

After a number of repeated accelerations of water slugs, the air has lost most of its kinetic energy and cannot create any more pumping action. For indoor systems, the transportation length is normally within the reach of every interface unit. For longer systems, the interface units have to interact to provide the necessary pumping action.

For a vacuum drainage system, it is necessary to sequentially generate high acceleration and self-cleansing velocities without the use of tremendous amounts of energy.

NOTE A vacuum drainage system is *not* a reversed pressure system where all the water would be accelerated simultaneously.

5 Principal design factors

5.1 General

The general performance of a vacuum drainage system is governed by its principal design factors:

- safety and health;
- availability;
- reliability;
- maintainability;
- noise and odour control;
- energy economy;
- fire resistance.

For assessment of general performance, see clause **12**.

5.2 Health and safety

The principal objectives for health and safety are the following.

- There shall be no danger to public health.
- There shall be no danger to operating personnel.
- There shall be no danger to existing adjacent structures or services.

Potential hazards, identified through experience or analysis, shall be eliminated or controlled in accordance with the following order of precedence:

- design to eliminate hazards;
- use of safety devices;
- use of warning devices;
- use of special procedures.

The following safety requirements apply.

- All electrical equipment design shall be in accordance with EN 60204.
- The installation shall be in accordance with current national regulations and codes.
- All electrical equipment situated in sewage or sewage gases shall be explosion proof.
- All electrically operated vacuum toilets shall conform to IEC 335-2-84.
- Vacuum toilets shall ensure that sub-atmospheric pressures, which could cause harm to the user, cannot be generated in the bowl, if flushed when sealed from above.
- Installation instructions shall include requirements for securing the pipework.
- System operations and maintenance manuals shall include detailed safety instructions. Potential safety hazards caused by component failure(s) or improper use shall be addressed.

The following health requirements apply.

- Where interface units are directly connected to a potable water system, they shall comply with prEN 1717.
- The bowl of the vacuum toilet shall have an impervious and smooth surface and shall be easily cleaned in order to provide long-term hygienic performance.
- Instructions and procedures concerning handling of components contaminated by human waste shall be included in the operations and maintenance manual.

5.3 Availability

Availability for a system, part of a system, or a component is expressed as:

$$availability = \frac{operating\ hours}{operating\ hours + hours\ of\ service} \quad (1)$$

System availability shall be addressed as part of system design.

High availability implies:

- high reliability;
- component failures will be of short duration and have a limited effect;
- redundancy for key components and power supply;
- rapid fault finding, isolation and repair;
- easy maintenance.

The systems shall be designed such that malfunctioning branches or sub-systems can be isolated.

The maximum number of interface units per system and per sub-system can be specified.

Failure of one interface unit should not be allowed to affect the performance of adjacent interface units or toilets. If this cannot be achieved, each interface unit shall have a means of being isolated manually to stop the airflow. This procedure shall be incorporated within the operation and maintenance manuals.

No valve cycle may occupy the line for more than a short period of time, not normally exceeding 10 s, in order not to block other units from operating.

5.4 Reliability

System reliability, expressed as the number of failures in a year, is to a large extent dependent upon the number of valve cycles performed during that period. A system reliability prediction shall be performed as part of system design and shall at least address the following:

- number of AIUs and vacuum toilets to be installed;
- estimated cycles per day per AIU and vacuum toilet in the planned application;
- estimated total number of valve cycles per day for the system;
- reliability data as supplied by the manufacturers of the interface units and the vacuum station equipment.

5.5 Maintainability

System maintainability affects not only maintenance cost but also system availability. At least the following aspects shall be addressed as part of system design:

- access to interface units, isolation valves, cleanouts etc.;
- maintenance schedules for interface units in relation to cycle frequency and endurance;
- estimated repair or replacement times of interface units;
- maintenance schedules for vacuum station equipment;
- estimated repair or replacement times for vacuum station equipment.

5.6 Noise and odour control

5.6.1 ***Noise***

The specifier shall be responsible for specifying the permitted noise levels and test methods. The system shall be designed, constructed and installed in such a way that noise nuisance will not occur.

NOTE Noise is dependent upon the required system vacuum.

5.6.2 *Odour control*

The system shall be designed, constructed and maintained in such a way that odour nuisance will not occur.

5.7 Energy economy

Energy consumption, although normally low, shall be considered during planning and design of the system. It can be reduced by:

- avoiding high lifts;
- avoiding high air–water ratios;
- using a control system which detects air leaks;
- selecting high-efficiency components.

5.8 Fire resistance

The system and all components shall be designed with fire safety as a consideration.

6 Performance

6.1 Wastewater discharge

The system shall be capable of receiving the wastewater from all connected appliances, transporting it to the vacuum station and forwarding it to the receiving sewer system. Its capacity shall be sufficient to serve the system under all conditions, low flow as well as design flow, or as specified by the system specification when tested in accordance with annex B (normative).

6.2 Vacuum at line extremities

The prescribed minimum vacuum level shall be maintained during normal operational conditions at every interface unit except momentarily during vacuum recovery.

NOTE Some systems do not operate for a few minutes whilst emptying the storage container.

6.3 Vacuum recovery time

The air transportation capability shall be such that the vacuum recovery time at each interface unit is sufficiently short not to cause overfilling of the AIUs or nuisance because of slow flush response of the toilets.

A maximum allowable delay may be specified.

6.4 Automatic restart

After a power failure, the system shall have the ability to automatically resume its performance within a prescribed time period even if all AIUs are full of wastewater and all vacuum toilets with memory are waiting to flush.

The permissible time to resume complete operation should be specified. This is dependent upon system size and vacuum station capacity. It is the responsibility of the designer to calculate the admissible start-up time unless it is already specified in the system specification.

7 Design

7.1 General

It is the responsibility of the designer to ensure that discharges from the vacuum drainage system will not adversely affect the receiving drainage system.

NOTE National or local regulations may require consideration of other relevant documents.

The designer shall take any known future additions or modifications to the system into consideration to avoid future operating problems. The designer shall keep all his calculations, and experience-based rules or graphs upon which the calculations are based, available for the system owner or his representative.

See **11.3**.

7.2 Static losses

The system shall be designed so that the probable static loss at all times is less than the available vacuum differential, i.e. the difference between the system vacuum and the initial vacuum needed to operate the interface units.

If the theoretical static loss from the vacuum station to any interface unit is larger than the available vacuum differential, but the probable static loss is smaller, extra care should be taken to ensure that the system operates in its entire length at all flow conditions. Special measures may be needed to ensure that the system can always restart automatically and recover vacuum at power-up after a mechanical or electrical breakdown.

The probable static loss (in pascals) is calculated by the following equation (2):

$$\Delta P_{st} = a \times g \times r \times \sum_{i=1}^{n} (h - d)$$

where

? p_{st}	is the static loss, in pascals (Pa);
a	is the variable factor [-];
g	is the acceleration due to gravity, in metres per second squared (m/s^2);
r	is the specific density of the wastewater, in kilograms per cubic metre (kg/m^3);
h	is the height of the lift, in metres (m);
d	is the pipe ID, in metres (m);
n	is the number of lifts [-].

Static losses are not recuperated at transportation downwards.

The theoretical static loss is obtained when $a = 1$, which reflects all lifts being filled to their overflow level. This is a rare event.

The a-factor indicates to what degree the lifts are expected to be filled with water. $a \leq 1$ and decreases with increasing air–water ratio.

The a-factor is normally provided by the system supplier.

7.3 Wastewater flow rate

Unless specified otherwise, the expected wastewater flow rate shall be calculated using the probability calculation methods for gravity drainage systems. See annex C (normative) and prEN 12056-2.

Discharge units (DU) for the vacuum toilets, vacuum urinals or other water-saving devices to be installed shall be stated by the manufacturer.

7.4 Dynamic losses

The system shall be designed so that the dynamic losses of the line, at the design flow rate, calculated from the vacuum station to the end of the line, are less than the available vacuum differential.

The sum of the friction losses and the lift and acceleration losses is the total dynamic loss.

Friction losses are normally calculated from friction losses for full bore flow corrected by a two-phase flow factor. This factor increases with increasing air–water ratio.

Losses due to lifts and accelerations decrease with increasing air–water ratio.

7.5 Vacuum recovery

The design of the system shall take the transient nature of the flow into account. Therefore, pipe diameters and piping profiles based on calculations of static and dynamic losses may have to be corrected in order to achieve shorter recovery times. This final correction is based on experience.

NOTE The expected vacuum recovery time should be considerably shorter than the calculated detention time of the liquid in the buffer volume during design flow conditions. A commonly used value for vacuum recovery time is one third of the detention time at peak flow.

7.6 System controls

The system controls shall be designed, as a minimum, to maintain the system vacuum within the prescribed range and protect the equipment from flooding or running dry.

The process shall restart automatically after a power failure (see **6.4**).

7.7 System status monitoring

The status monitoring system shall, as a minimum, be designed to detect and indicate abnormal liquid and vacuum levels, abnormal vacuum generator running time and major equipment failures.

8 Installation

Detailed information, e.g. drawings, parts list and installation instructions, shall be provided. These instructions shall be written in the language of the country where the system will be installed.

The installation shall comply with the drawings provided.

If deviations from the drawings are necessary because of unforeseen circumstances, the installer shall inform the designer.

Any deviation from the designed pipe profile shall not create backflow, if the pipe section is not a lift section.

Bracing shall be firmly secured to the pipes and also firmly anchored to the building structure to prevent vibration and rattling noise. All pipes shall, as a minimum, be fixed securely as follows:

- at all points where the pipeline changes direction;
- at reforming pockets, pipe branches and service connections;
- at intervals which ensure suitable support, taking into account the structural characteristics of the pipe and the inherent periodical dynamic stresses occurring in a vacuum system.

Service access shall be provided to isolation valves, cleaning eyes, check valves and interface units.

The system shall be tested for tightness in accordance with test procedures in annex B (normative).

9 Commissioning

9.1 General

Commissioning shall form part of the approval process of the system. All the requirements of clauses **5** to **8** shall be addressed as specified in clause **11** and in annex A (normative).

Prior to final approval, those responsible for commissioning shall satisfy themselves that adequate written instructions on the operation and maintenance of the entire system have been delivered to the operator.

The system owner shall be provided with as-constructed drawings of the system.

9.2 Commissioning tests

Commissioning tests shall be undertaken on the system, or part system, after it has been started and adjusted.

The commissioning tests shall verify system performance.

Test procedures are contained in annex B (normative).

10 Maintenance

Detailed operation and maintenance manuals (OMM) shall be supplied with each system. The OMM shall be written in the language of the country where the maintenance will be performed.

The OMM shall state the necessary preventive maintenance as well as necessary tools and spare parts.

The OMM shall contain safety instructions for the installed equipment.

11 Verification

11.1 General

Compliance with the requirements shall be addressed during all phases of the project, i.e. planning, design, construction and installation. Methods of verification of compliance are summarized in annex A (normative).

Test analyses, results and other documents necessary to verify compliance with the requirements shall be recorded in a verification report.

The verification report shall as a minimum include the following:

- identification of requirement;
- verification method;
- statement of compliance or non-compliance;
- identification of the responsible authority within the manufacturer or system supplier.

If the verification method is by tests, the test report shall as a minimum include the following:

- identification of the test;
- dates of the testing;
- test procedures used;
- test results;
- statement of pass or failure;
- identification of the responsible testing authority;
- calibration records.

The system owner, or his representative, shall be allowed to witness the verification testing.

Test procedures are found in annex B (normative).

11.2 Performance requirements

Verification of system performance (see clause **6**) shall be accomplished by tests and is generally part of commissioning of the system.

Except where phased completion takes place, system performance shall be verified after completion of the entire system and when the system parameters are adjusted. See annex B (normative) for test procedures.

11.3 Design requirements

Compliance with the design requirements (see clause **7**) is normally verified by analysis and data submittal (drawings etc.) at regular project design reviews.

NOTE The design review can take place in stages, but should be finalized before purchase of equipment and commencement of construction.

Requirements which cannot be fully verified until after start-up become part of commissioning of the system as summarized in the requirements verification matrix [see annex A (normative)].

The specifier may in addition require verification of certain aspects by tests.

11.4 Installation requirements

Compliance with installation requirements (see clause **8**) is partly verified by tests and inspection as work proceeds. The final verification is part of commissioning of the system.

The inspections shall verify compliance with drawings and that all specified installation requirements have been met. In particular:

- safety regulations;
- electrical regulations.

Tightness tests shall be performed according to test procedures in annex B (normative).

12 Assessment of general performance

The general performance of the system, i.e. the performance governed by the principal design factors (see clause **5**), is assessed during a longer period of operation. A practical assessment period is, unless otherwise agreed, from approved commissioning tests to the end of the agreed warranty period.

In order to make assessment possible, records of performance, failures (causes, modes and effects), corrective actions, maintenance time and cost, spares, energy consumption etc. should be kept by the system operator.

The system supplier shall recommend record keeping procedures and routines.

13 Quality control

Quality control of the system is covered by commissioning (see clause **9**) and assessment of general performance (see clause **12**).

Annex A (normative)
Methods of verification of compliance with the requirements of this standard

Table A.1 — Requirements verification matrix

Requirements	Verification method				Verification of compliance
	Tests	Judgement		Inspection	
Paragraph		Analysis	Data submittal		Paragraph
5.2	—	—	×	×	**9**, **11.3** and **12**
5.3	—	×	×	—	**9**, **11.3** and **12**
5.4	—	×	×	—	**9**, **11.3** and **12**
5.5	—	×	×	—	**9**, **11.3** and **12**
5.6	—	×	—	×	**9**, **11.3** and **12**
5.7	—	×	×	—	**9**, **11.3** and **12**
6.1	×	—	—	—	**9**, **11.2** and **B.2**
6.2	×	—	—	—	**9**, **11.2** and **B.2**
6.3	×	—	—	—	**9**, **11.2** and **B.2**
6.4	×	—	—	—	**9**, **11.2** and **B.2**
7.1	—	×	×	—	**9** and **11.3**
7.2	—	×	—	—	**9** and **11.3**
7.3	—	×	—	—	**9** and **11.3**
7.4	—	×	—	—	**9** and **11.3**
7.5	—	×	—	—	**9** and **11.3**
7.6	×	—	×	×	**9**, **11.3** and **B.2**
7.7	×	—	×	×	**9**, **11.3** and **B.2**
8	×	—	—	×	**9**, **11.4** and **B.1**
× required — not required					

Annex B (normative)
Test procedures

B.1 Tightness tests

B.1.1 *Method*

a) Close all open connections with suitable plugs.

NOTE If only one section of pipework is to be tested, it should be isolated from the rest of the system.

b) Evacuate the system, or the part of the system under test, to normal operating vacuum $^{+10}_{0}$ %.

c) Record the ambient pressure, temperature and pipeline vacuum.

d) The temperature shall be measured at three or more representative locations along the pipeline and the mean value calculated.

e) At the end of the test period, again record the ambient temperature, pressure and pipeline vacuum. If there is a temperature change, calculate the correction of the vacuum in accordance with the ideal gas equation.

B.1.2 *Pass/fail criteria*

B.1.2.1 *Tests performed as work proceeds — Pipeline only*

The vacuum shall not decrease by more than 10 % of the value recorded in **B.1.1**c in (30 ± 2) min.

B.1.2.2 *Final tightness test on complete system*

One of the following two criteria shall be met.

1) For a complete system *excluding* interface valves, the vacuum shall not decrease by more than 20 % of the value recorded in **B.1.1**c in:

   (180 ± 2) min for systems with vacuum vessel(s); or

   (60 ± 2) min for systems without vacuum vessel(s).

2) For a complete system *including* interface valves, the vacuum shall not decrease by more than 20 % of the value recorded in **B.1.1**c in:

   (120 ± 2) min for systems with vacuum vessels; or

   (40 ± 2) min for systems without vacuum vessels.

NOTE If the system is built in stages, the vacuum station is only tested after completion of the first stage.

B.2 System performance tests

B.2.1 *Wastewater discharge tests*

Performance requirement: **6.1**.

The test shall simulate a design flow and a low-flow situation at ambient temperature and pressure.

Capacity at extreme ambient and wastewater temperatures can be verified by analysis and extrapolation, if requested.

The system shall be in normal operation mode.

Before starting the test, the connected appliances shall be operated individually and found working correctly.

B.2.1.1 *Method*

a) Determine the number of sanitary appliances on:

   1) each main pipeline;

   2) the whole system.

b) Select the pipeline with the highest expected flow rate. For that main pipeline, calculate the number of appliances for simultaneous discharges as per Table B.1.

c) Calculate the number of appliances for simultaneous discharges for the entire system, also as per Table B.1.

d) On the selected line, locate the appliances farthest from the vacuum station.

e) Select the additional appliances needed for the simultaneous discharge test towards the extremities on the other lines.

f) Fill the selected appliances to their overflow level. Use baths or washing machines, if such appliances are installed, instead of washbasins. Use dishwashers instead of kitchen sinks. Washing machines and dishwashers should be run using a full-load programme.

g) Perform the test by simultaneously discharging the selected appliances in such a way that the wastewater cycles the AIU at least three times. Vacuum toilets are flushed once.

h) Following g), discharge each connected appliance individually to verify proper performance.

i) Following h), select the AIU closest to the extremity of the line with the largest probable static loss. Discharge (3 ± 1) l/min into that AIU for at least 180 min.

k) Following i), operate the appliances connected to adjacent AIUs and, where fitted, vacuum toilets.

B.2.1.2 *Pass/fail criteria*

All appliances, whether discharged singly or in groups, shall drain completely without back-up into any appliance. Vacuum toilets shall flush normally within the expected or prescribed vacuum recovery time. There shall be no discernible difference in operation of the appliances between simultaneous and individual operation.

Table B.1 — Simultaneous discharge performance test

Type of use	Number of appliances of *each type* on the same line	Number and type of appliances to be discharged simultaneously		
		Vacuum toilets	Bathroom appliances	Kitchen appliances
Domestic	1 to 9	1	1	1
	10 to 24	1	1	2
	25 to 35	1	2	3
	36 to 50	2	2	3
Commercial or public	1 to 9	1	1	—
	10 to 18	1	2	—
	19 to 26	2	2	—
	27 to 50	2	3	—
Congested	1 to 4	1	1	—
	5 to 10	1	2	—
	10 to 13	2	2	—
	14 to 26	2	3	—
	27 to 39	3	4	—
	40 to 50	3	5	—

B.2.2 ***Line vacuum monitoring***

Performance requirement: **6.2** and **6.3**.

The vacuum shall be monitored during the water discharge tests given in **B.2.1**.

B.2.2.1 *Method*

Install one vacuum gauge with recorder at the interface unit closest to the end of the line with the highest probable static loss, and a second gauge with recorder at the end of the line with the highest expected flow rate. In some circumstances this could be the same line and only one recorder would be required.

B.2.2.2 *Pass/fail criteria*

The vacuum shall be above the initial vacuum needed to operate the interface units except momentarily during vacuum recovery after a valve cycle on the line. The vacuum recovery time, at design flow, shall be shorter than the detention time of the wastewater in the buffer. Vacuum toilets shall flush within the same recovery time or within a prescribed time period.

B.2.3 ***Automatic restart***

Performance requirement: **6.4**.

This test shall be carried out after the wastewater discharge tests have been completed. The system shall be in normal operating mode. The previously installed test vacuum gauges with recorders shall be operating.

B.2.3.1 *Method*

a) Shut down the vacuum station.

b) Fill all AIUs with water. Press the flush buttons of all vacuum toilets with memory.

c) Start up the system.

Monitor the vacuum and record the time elapsed until the last interface unit has automatically cycled.

B.2.3.2 *Pass/fail criterion*

Intended system performance shall be resumed within the admissible time period.

B.2.4 ***Operation of vacuum station***

B.2.4.1 *Performance of vacuum generators and forwarding pumps*

Observe the system during all the above tests. Verify that the equipment capacity is sufficient to serve the system, by monitoring cycling and running times and start and stop levels for wastewater and system vacuum.

All values shall be normal and within the requirements of the specification.

During the discharge test given in **B.2.1**, stand-by equipment, if installed, shall not be caused to operate.

B.2.4.2 *Vacuum station control and monitoring system*

The vacuum station control and monitoring details are specified for each system and vary with the type of equipment installed. The appropriate procedures have to be worked out for each system individually.

Performance in normal operation mode is verified by monitoring the controls during the tests given in **B.2.4.1**.

Verify the system's ability to detect and indicate specific failures, by simulating the failure of the equipment in sequence, according to the logic of the control system, and observe and record the response in terms of equipment shutdown and alarms.

Annex C (normative)
Calculation of probable wastewater flow rate

C.1 Probability calculation

Unless otherwise specified, the expected flow rate in a vacuum drainage system shall be calculated as for gravity systems using a probability calculation.

$$Q_{\mathrm{WW}} = K \times \sqrt{\sum \mathrm{DU}} \qquad \text{(C.1)}$$

Q_{ww}	is the wastewater flow rate;
K	is the reduction factor;
DU	is the discharge unit.

The calculated wastewater flow rate (Q_{ww}) for a particular vacuum line is the greater of:

a) the calculated wastewater flow rate Q_{ww}, in litres per second (l/s); or

b) the flow rate of the appliance with the largest discharge unit (DU), in litres per second (l/s) connected to the vacuum line.

C.2 Discharge from domestic sanitary appliances

In a gravity system, the discharge time is influenced by the design of the appliance, the outlet of the appliance, its mode of use and the pipework configuration. In a vacuum drainage system, however, the AIUs have buffer volumes which, in principle, balance out these differences. Therefore, the vacuum drainage system only considers two types of appliance:

— type I with a DU = 0,3 l/s;

— type II with a DU = 0,5 l/s.

Type II are appliances with a large discharge rate or volume, such as baths, dishwashers, washing machines and floor drains. All other sanitary appliances are type I.

For vacuum pipe flow calculations, the AIUs are considered transparent, i.e. the flow rate in is equal to the flow rate out.

C.3 Selection of the reduction factor (*K*)

The *K*-factor is a variable which takes account of the various types of building and therefore the different frequency of use.

The designer shall be responsible for choosing the appropriate *K*-factor.

K-factors can be selected from Table C.1.

Table C.1 — *K*-factors

Buildings	*K*
Dwellings, guesthouses, offices (intermittent use)	0,5
Hospitals, schools, restaurants, hotels (frequent use)	0,7
Showers open to the public (congested use)	1,0

Table C.2 — Example using DUs

Hotel with 100 bathrooms, divided equally on five vacuum lines. Each bathroom containing the following sanitary appliances connected to one AIU:	DU	Q_{WW} l/s
2 washbasins	0,6 (2 × 0,3)	–
1 bath	0,5	–
1 shower without plug	0,3	–
1 bidet	0,3	–
Total per AIU	1,7	$0{,}9 (0{,}7 \times \sqrt{1{,}7})$
Total per vacuum line	34 (20 × 1,7)	$4{,}2 (0{,}7 \times \sqrt{34})$
Total	170 (34 × 5)	$9{,}1 (0{,}7 \times \sqrt{170})$

In addition to discharges mentioned above, the system shall receive the discharges from the vacuum toilets.

C.4 Vacuum toilets

The DUs for the vacuum toilets and the vacuum urinals, as well as the air consumption per flush, shall be stated by the manufacturer.

The hydraulic loading from vacuum toilets and vacuum urinals is normally small. The air loading, however, is relatively large. The effect on pipe sizing is therefore normally based on airflow and vacuum recovery according to proprietary graphs or tables.

NOTE The following values are typical for vacuum toilets:

- wastewater volume: 1,5 to 3 litres/flush;
- air–water ratio at normal temperature and pressure conditions: 20 to 30;
- public vacuum toilets: 15 flushes/toilet/hour;
- public vacuum urinals: 60 flushes/urinal/hour;
- hotel room toilets: 1,5 flushes/toilet/hour.

Annex D (informative)
Vacuum drainage systems products — Requirements and verification

If requirements for products used within the system are needed, this informative annex provides guidance to performance requirements, design, verification and quality assurance.

D.1 Performance requirements

D.1.1 ***Automatic interface units (AIU)***

D.1.1.1 *General*

The AIUs shall receive, temporarily hold and automatically discharge the wastewater from the connected appliances.

Noise from the AIUs shall be within specified limits.

D.1.1.2 *Reliability*

The complete AIU shall have a laboratory-tested reliability of 250 000 mean cycles between failures (MCBF) when maintained according to the manufacturer's scheduled maintenance programme.

NOTE In most applications, 250 000 MCBF corresponds to a mean time between failures (MTBF) in excess of 10 years.

The manufacturer shall provide evidence that the complete interface unit will function effectively in the intended working environment.

D.1.1.3 *Endurance*

The key components of the AIU, i.e. the level sensor, the controller and the interface valve, shall have a proven ability to undertake a minimum of 300 000 cycles under normal operating load, without failure.

D.1.2 ***Vacuum toilets***

D.1.2.1 *General*

The vacuum toilet shall receive and temporarily hold human waste along with various sanitary items. The toilet shall evacuate the contents and rinse the bowl. Flushing performance requirements can be specified.

The toilet shall use the amount of water specified by the specifier and stated by the manufacturer.

If the toilet is flushed when totally sealed from above, the vacuum in the bowl shall, for safety reasons, not exceed 5 kPa for more than 1 s at a system vacuum of 50 kPa.

The flushing noise shall be within specified limits.

D.1.2.2 *Reliability*

The vacuum toilet shall have a laboratory-tested reliability of 250 000 mean cycles between failures (MCBF) when maintained according to the manufacturer's scheduled maintenance programme.

NOTE For heavily used public toilets, an MCBF of 250 000 cycles might correspond to an MTBF in the range of 5 years. In most other applications, 250 000 MCBF corresponds to an MTBF in excess of 10 years.

The manufacturer shall provide evidence that the complete vacuum toilet will function effectively in the intended working environment.

D.1.2.3 *Endurance*

The water valve, the discharge valve and the flush control unit shall each have a proven ability to undertake 300 000 cycles under normal operating load, without failure.

D.1.3 ***The pipework***

The pipework shall transport the air and wastewater, including solids, from the interface units to the vacuum station.

The pipework shall be airtight and watertight when tested.

D.1.4 ***The vacuum station***

The vacuum station shall perform three functions:

— generate vacuum with sufficient capacity to serve the system;

— receive and forward the wastewater with sufficient capacity to serve the system;

— control and monitor the system.

The vacuum station is designed for each application and is based upon the design requirements of **D.2.4**.

Vacuum station performance in accordance with the specification is verified by the commissioning tests. See **9.2** and annex B (normative).

D.2 Design requirements

D.2.1 ***Automatic interface units (AIUs)***

The AIU shall be designed to operate without blocking. When the interface valve is open, the flow path should not be significantly obstructed by the valve plunger or closing membrane.

The AIU shall be designed to prevent, through screening or other means, the passage of objects which because of their size or shape are not suitable for transportation through the vacuum piping.

The AIU shall be designed to prevent backflow of wastewater at all system vacuum levels or back surges. This can be accomplished by the unit itself or by a separate check valve.

The design shall prevent odour nuisance by venting the interface units in accordance with local regulations. Air admittance valves may be used, but care shall be taken to prevent double cycling of the interface valve.

AIUs allowing only wastewater and no air into the vacuum line shall only be utilized where the lift in the service connection is lower than the available vacuum in the connecting main. Preferably the main should be below the interface unit.

D.2.2 ***Vacuum toilets***

The required vacuum release (**D.1.2.1**) shall be permanent and tamper resistant.

Objects not suitable for transportation through the vacuum piping because of their size or shape should be retained in the toilet. Therefore, the outlet of the bowl should be smaller than the discharge valve and smaller than the service connection.

The toilet should not operate if the initial vacuum is below a predetermined value. This value varies with the type of arrangement and type of discharge valve, and should be established for each system.

D.2.3 ***Pipework***

The pipework shall be designed to operate without blocking.

- Tees and short-radius 90° fittings should not be used. Combinations of Y-branches and bends (maximum 45°) should be utilized instead.
- Long-radius bends should always be used.
- There should be no directional or dimensional change through an isolation valve in its open position.

The smallest pipe shall have a bore exceeding the outlet of the interface unit. There shall be no decrease in nominal bore in the direction of flow.

The pipework shall be designed to withstand the expected forces, pressures and temperatures.

NOTE The minimum pressure rating for plastic pipes is typically 0,6 MPa, but other ratings could be employed. However, if the pipe has an initial ovality, or progressive deformation, or if the long-term loss of strength due to high ambient or wastewater temperatures is likely to occur, higher ratings should be employed.

Where several appliances are connected to one AIU, the pipework shall be arranged in such a way that the user of any appliance will notice a flooding of the lowest appliance in case of a malfunction.

The design shall include means of isolating lengths of vacuum drainage pipes or sub-systems to permit repair or trouble-shooting.

D.2.4 ***Vacuum station***

D.2.4.1 *Redundancy*

D.2.4.1.1 *Stand-by power*

The vacuum station shall have stand-by power capability.

NOTE A socket into which a mobile power generator could be connected could be sufficient for systems where dual power supply or stand-by generators are uneconomic.

D.2.4.1.2 *Stand-by equipment*

Except for small systems with vacuum toilets only, the design shall provide for the possibility of removing one vacuum generator and, if employed, one forwarding pump for maintenance or repair, without the loss of system capacity.

Smaller systems with vacuum toilets only, installed in buildings such us dwellings or guesthouses, are not required to maintain system capacity while the vacuum generator or the forwarding pump, or a combination thereof, is being removed for maintenance or repair, if stand-by equipment is kept available and can be installed within 60 min. A more stringent degree of redundancy may however be specified.

D.2.4.2 *Vacuum generators*

The vacuum generator(s) shall have sufficient capacity to generate the required vacuum and air flow, and to forward the wastewater if the functions are combined.

The vacuum generator(s) shall be suited for the pumping medium. The manufacturer shall provide data to substantiate compliance with this requirement.

The vacuum generator(s) shall be designed to perform the expected maximum number of starts per hour, as well as continuous operation, without overheating or other operational problems.

D.2.4.3 *Vacuum vessels*

The vacuum vessel shall be designed and tested in accordance with EN 286-1.

The vacuum vessel shall be resistant to corrosion, either by virtue of the material from which it is constructed, or by suitable protection.

The vacuum vessel shall be designed to separate the incoming air/wastewater mixture and to temporarily hold the wastewater.

NOTE Vacuum vessels are only used in designs where the air and the water are forwarded by separate equipment.

D.2.4.4 *Forwarding pumps*

The forwarding pumps, where employed, shall have sufficient capacity to serve the system, both in regard to flow, suction and pressure. The pumps shall forward the wastewater without reduction of vacuum drainage capacity.

The forwarding pumps shall be designed for the expected maximum number of starts per hour, as well as for continuous operation.

D.3 Verification of compliance with requirements

D.3.1 *Performance requirements*

D.3.1.1 *Interface units — Type testing*

Verification of compliance with the AIU and vacuum toilet performance requirements (see **D.1**) is performed at the supplier's facility according to product specifications or product standards.

Type testing shall have demonstrated conformity to all requirements specified in the product standard or specification.

Endurance testing, which is part of type testing, of components specified in **D.1.1.3** and **D.1.2.3** shall prove the ability to undertake a minimum of 300 000 cycles and still function effectively. The test can be performed with clean water under normal operating vacuum.

Reliability testing of the interface units, which is also part of type testing, shall demonstrate the required MCBF of 250 000 cycles when the units are maintained according to the manufacturer's scheduled maintenance programme. These tests can be performed with clean water under normal operating vacuum.

Both the endurance and the reliability tests should be performed on a number of production units of each kind, for statistical evaluation. The number of units to be tested, as well as the allowable variance, should be stated in the type test procedures.

Verification of performance requirements which can only be verified after installation is carried out as part of the commissioning tests.

D.3.1.2 *Vacuum station*

Functional testing and inspection of the system control and monitoring system are performed at the supplier's facility before shipment.

The functional tests shall demonstrate conformity to the specified control logic.

Verification of the entire vacuum station performance is part of the commissioning tests (**9.2**). See also **7.6**, **7.7**, **D.1.4**, and annex B (normative).

D.3.2 ***Verification of design requirements***

Verification of design requirements (see **D.2**) can be accomplished by analysis, data submittal (drawings etc.), examination or inspection.

The specifier may require additional verification by testing.

D.4 Quality assurance

The manufacturer(s) of components of the vacuum drainage system, and the system supplier, should establish, document and maintain an effective quality management system structured in accordance with EN ISO 9001 for design and development and with EN ISO 9002 for production and installation, so as to achieve compliance with product standards and/or relevant system specifications.

Annex E (informative)
Applications of vacuum drainage systems

E.1 General

Compared to a gravity system, a vacuum drainage system has some significantly different characteristics.

- It is a water-saving technique, especially if vacuum toilets are employed.
- It is a flexible technique.
- It allows the use of small diameter lightweight pipes.
- It allows lateral transportation without the loss of height.

The possibility of lifts and lateral transportation gives freedom to plan the usage of the building space. Appliances producing wastewater can be placed anywhere and are not tied to the vicinity of a gravity drain.

Particular consideration should be given to the use of vacuum drainage in the following circumstances:

- water shortage or other reasons for reducing water consumption;
- limited sewerage capacity;
- where separation of black and grey water is desired, e.g. where a high organic content would improve sewage treatment or where grey water is reused;
- in hospitals, hotels, office buildings or other areas where high levels of sanitation and flush efficiency are required;
- when flexibility in pipe routing is required to drain appliances, or where frequent pipe layout changes are expected;
- building refurbishment;
- where drainage by gravity becomes impractical;
- in complex building structures;
- where voice communication through the drainage system is to be prevented, e.g. prisons.

E.2 System layout

A typical single system is depicted in Figure E.1.

For a larger building, it is customary to divide the system into smaller sub-systems, possibly with a crossover, if not cost-prohibitive, so that each sub-system can operate as a stand-by for the other (Figure E.2).

The pipes can be run in lightweight suspended ceilings rather than being cast integrally with the concrete floor slab or floor structure.

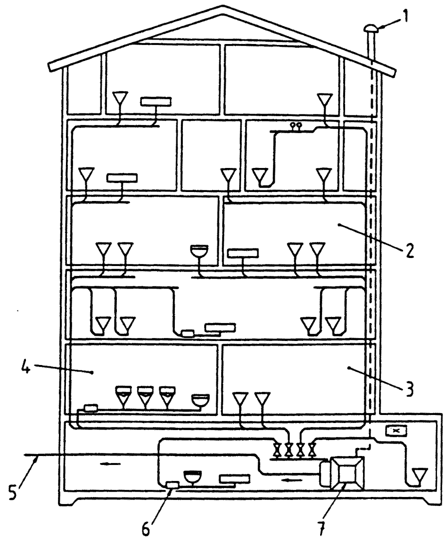
The pipes are installed in a generally horizontal profile to a suitably located vertical pipe.

Once the vertical pipe (stack) is installed, all horizontal pipes may be contained within each level of the building. This makes installation one level at a time possible.

Air entering interface units is released from the vacuum drainage system at a suitable point downstream of the vacuum generator.

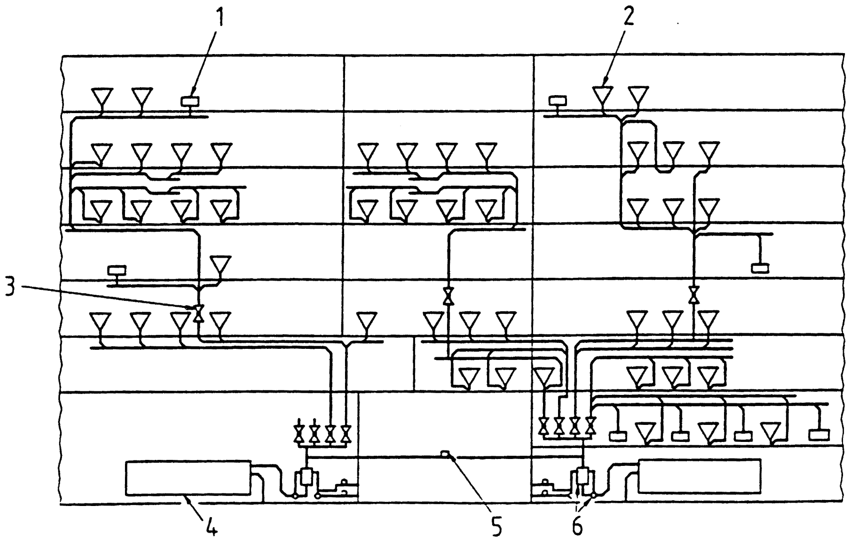
Lifts on the main line are normally vertical. Higher lifts should be divided into several steps.

Vertical lift piping connecting to horizontal piping normally enters from the top.



1 Vent to atmosphere
2 Vacuum toilet
3 Urinal
4 To sewer via manhole
5 Interface unit
6 Vacuum station

Figure E.1 — Building with single system



1 Wastewater collection chamber
2 Vacuum toilet
3 Isolation valve
4 Sewage treatment plant/sewage holding tank
5 Crossover valve
6 Combined vacuum generator and forwarding pumps

Figure E.2 — Dual system with crossover

E.3 Support

The piping network should be both supported and braced. Support is necessary, as in any drainage piping system, to maintain the piping profile required for proper function. Bracing is necessary to resist thrusting and reaction forces occurring when slugs move within the piping.

Thrusting and reaction forces occur wherever there is a change in direction within any plane of reference. Similarly, these forces can be expected to occur wherever piping intersects.

Vacuum drainage piping should be supported using bi-directional braces. When plastic piping is used, the support spacing should be 2 m maximum. For metal piping, support spacing may be increased to 3 m to 4 m.

Expansion and contraction of pipework should be taken into consideration.

Annex F (informative)
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