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Milking machine installations — Construction and performance

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 5707 was prepared by Technical Committee ISO/TC 23, *Tractors and machinery for agriculture and forestry*.

This third edition cancels and replaces the second edition (ISO 5707:1996) as well as ISO 5707:1996/Cor.1:1997, which have been technically revised.

Introduction

This International Standard has been developed in response to worldwide demand for minimum specifications for milking machine installations. The basic requirements for the construction and performance of milking machines for animals are determined by the physiology of the animal and the need for a standard of high hygiene and milk quality.

Milking machine installations — Construction and performance

1 Scope

This International Standard specifies the minimum performance and information requirements and certain dimensional requirements for satisfactory functioning of milking machines for milking and cleaning. It also specifies minimum requirements for materials, design, manufacture and installation.

This International Standard is applicable to milking machines for milking cows, water buffaloes, sheep and goats where animals are milked with pulsation created by vacuum, and where milk is, at least partly, transported with the help of airflow. Some clauses are not applicable to all types of milking machines. The qualitative requirements also apply to installations for milking other mammals used for milk production.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 3918:2007, *Milking machine installations — Vocabulary*

ISO 4288, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Rules and procedures for the assessment of surface texture*

ISO 6690:2007, *Milking machine installations — Mechanical tests*

ISO 12100-1, *Safety of machinery — Basic concepts, general principles for design — Part 1: Basic terminology, methodology*

ISO 12100-2, *Safety of machinery — Basic concepts, general principles for design — Part 2: Technical principles*

ISO 14159, *Safety of machinery — Hygiene requirements for the design of machinery*

IEC 60335-2-70, *Household and similar electrical appliances — Safety — Part 2-70: Particular requirements for milking machines*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 3918 apply.

4 General

4.1 Tests for compliance

The methods for performance testing referred to in this document are specified in ISO 6690.

These testing methods may not be sufficient to test the performance of an installation incorporating special design features. In order to avoid limitation of development, other systems than those described in this International Standard can be used if the same result can be achieved. Such systems and other special performance characteristics that are not covered by the requirements in this International Standard should also be described and specified in the user's manual.

4.2 Access for measurements

4.2.1 General

The connection points specified in 4.2.2 and 4.2.3 shall be provided to test the function of the installation. Dismantling parts of the milking machine is acceptable to access these connection points. All connection points and their location shall be described in the user's manual.

4.2.2 Airflow measuring connections

The following connection points shall be provided for an airflow meter:

- A1: to enable measurement of effective reserve, manual reserve and regulator leakage:
  - in bucket or direct-to-can milking machines, between the regulator sensing point and the first vacuum tap;
  - in pipeline milking machines, at or near the receiver(s), upstream of the sanitary trap(s);
  - in recorder milking machines, at every sanitary trap, or near the sanitary trap(s) on the milking vacuum line(s);
- A2: to enable measurement of leakage into the vacuum and milk systems, between the vacuum pump(s) and the sanitary trap(s) or the first vacuum tap.

See connection points A1 and A2 in Figures 1, 2 and 3 of ISO 3918:2007.

NOTE In bucket and direct-to-can milking machines, the connection point A2 is the same as A1.

When closed, e.g. not in use, these connection points shall not form any trap for liquids. The connection point shall have the same internal diameter as the air line or (48,5 ± 2) mm, whichever is smaller.

4.2.3 Vacuum measuring connections

The following connection points shall be provided for a vacuum meter:

- Vm at or upstream of the measuring point A1;
- Vr near each regulator sensing point;
- Vp near each vacuum pump inlet.

To enable measurement of exhaust backpressure, a suitable connection point Pe shall be provided to measure exhaust backpressure on each exhaust line at the vacuum pump outlet.

See measuring connections Vm, Vr, Vp and Pe in Figures 1, 2 and 3 of ISO 3918:2007.

NOTE In a pipeline milking machine, Vm can be any point in the milking system in, or upstream of, the receiver. In a recorder milking machine, Vm can be in the milking vacuum line or in the nearest convenient recorder jar. In a bucket milking machine, Vm = Vr and can be combined with the nearest convenient vacuum tap.

These connection points should be located at least five pipe diameters from any elbows, air inlet points or other fittings creating air turbulence.

If the regulator sensing point is on a branch, there shall be two measuring points Vr, one to measure the vacuum drop in the air line upstream of this branch and the other one to determine the regulator leakage near the regulator sensing point.

4.2.4 Other necessary measures

Means shall be provided to isolate the vacuum pump from the installation to make it possible to measure the vacuum pump capacity.

To enable measurement of leakage into the vacuum system and of the air used to produce pulsation, it is necessary that the pulsators can be stopped or disconnected in all types of installation.

4.3 Safety and hygiene

Installations shall comply with the relevant safety requirements given in ISO 12100-1 and ISO 12100-2. The electrical components shall comply with the relevant safety requirements given in IEC 60335-2-70.

NOTE The significant hazards which require action to reduce risk are: crushing, shearing and slipping, tripping and falling hazards; electrostatic phenomena and external influences on electrical equipment, noise; unhealthy postures, inadequate local lighting and hazards caused by failure of the energy supply or disorder of the control system.

The hygiene requirements given in ISO 14159 apply.

The equipment has to be effective, easy and safe to use and test.

Since most milking machines depend on a public electricity supply that fails occasionally, alternate means for operating the machine in such emergencies should be installed. It is important to design and install the equipment so that noise levels in the cowshed or parlour and in the vicinity are as low as practicable and comply with requirements in national legislation.

Milking equipment and connection to milk storage facilities on the farm should be designed and maintained to minimize turbulence, frothing, foaming or agitation of the milk, thereby reducing physical damage to the milk fat and the development of free fatty acids.

Further safety and hygiene requirements will be covered by legislation that will be the subject of other International Standards.

4.4 Materials

All components that are subjected to a vacuum shall be designed and constructed to withstand a minimum vacuum of 90 kPa without permanent distortion.

Materials that may involve danger if damaged, such as glass, shall be designed using a safety factor of 5 against external pressure (i.e. 5×90 kPa).

Materials in contact with milk shall meet requirements for food contact surfaces. All materials in contact with milk or cleaning solutions, whether used for rigid components (e.g. buckets, pipelines or recorder jars) or flexible components (e.g. joint rings, teatcup liners), shall be constructed to withstand the maximum temperature used in the plant as specified in the user's manual. In addition, such materials, when used in accordance with the recommendations in the user's manual, shall not impart taint to the milk.

All milk contact surfaces shall be free from engraving or embossing. All metal milk contact surfaces, except for welded seams, shall have a surface roughness, Ra, less than or equal to 2,5 µm when tested in accordance with ISO 4288. Surface roughness, Ra, on welded seams shall not exceed 16 µm.

Copper or copper alloys shall not be used in any part of the installation that may come into contact with milk or cleaning and disinfecting fluids other than water.

Materials that come into contact with cleaning and disinfecting fluids at concentrations of normal use shall be suitable for such contact. Materials that also come into contact with milk shall be resistant to both milk fat and cleaning and disinfecting solutions.

4.5 User's manual

4.5.1 General

The user's manual shall specify a system of measures that ensure that the function, safety and hygiene of the milking machine are maintained during its intended lifetime. This includes instructions for routine servicing and replacement of individual parts. An indication shall be given as to whether particular actions should be performed by the user or if other suitably qualified personnel are needed.

If it is intended that the user shall make adjustments, instructions for such adjustments shall be included. If special tools are required, these shall be supplied with the installation.

The user's manual shall be written in at least one of the country's official languages that is relevant for the user.

Besides the instructions stated in this clause, data given in other clauses in this document shall also be specified in the user's manual.

4.5.2 Installation details

At least the following details shall be provided:

— mounting dimensions, space requirements and critical building dimensions;

— recommended ambient conditions for the different parts of the milking machine;

— minimum electrical power supply and earthing requirements;

— minimum water supply and drainage requirements;

— nominal working pressure and capacity of a compressed air system;

— amount of airflow and vacuum for cleaning;

— the minimum required airflow use of vacuum-driven ancillary equipment.

4.5.3 Instructions for use

At least the following instructions shall be provided:

— start up, operating and shut down procedures;

— the effective reserve, as calculated and as measured;

— recommended cleaning and disinfecting procedures, including temperatures and chemicals, and components requiring manual cleaning;

— the maximum temperature at which the installation can be cleaned and disinfected;

— definition of any manual intervention, such as manual actuation of valves or replacement of single use items such as filters, along with the appropriate time interval;

— procedures necessary to avoid contamination of the milk from cleaning solutions, withheld, abnormal and undesirable milk;

— the maximum number of units or maximum milk flow per slope of the milkline;

— procedures for introducing animals new to the milking installation.

5 Vacuum system

5.1 General

The ultimate goal of vacuum regulation is to maintain vacuum conditions at the teat end within the intended range. In order to meet this requirement the machine shall be capable of adequate vacuum control and the operators shall use the machine with reasonable care and in accordance with the user's manual.

5.2 Vacuum regulation

5.2.1 Vacuum deviation

The regulation system shall, together with the vacuum pump capacity, be such that the working vacuum, after a specified start-up period, at measuring point Vm, is maintained within ± 2 kPa of the nominal vacuum when tested in accordance with 5.2.1 of ISO 6690:2007. The minimum start-up time shall be specified in the user's manual.

5.2.2 Regulation sensitivity

The regulator(s) shall control the working vacuum such that, when tested in accordance with 5.2.2 of ISO 6690:2007, the regulation sensitivity does not exceed 1 kPa.

5.2.3 Regulation loss

In order to use the installed vacuum pump capacity efficiently, the regulation loss, when tested in accordance with 5.2.3 of ISO 6690:2007, shall not exceed 35 l/min of free air or 10 % of the manual reserve, whichever is the greater.

NOTE Regulation loss and effective reserve depend on the vacuum pump capacity, the regulation characteristics and the vacuum drop between Vm and the regulator sensing point. See 5.6.2 and Figure 6 of ISO 3918:2007.

5.2.4 Regulation characteristics and effective reserve

The regulation characteristic overshoot shall be less than 2 kPa when the regulation characteristic tests are conducted in accordance with 5.2.4 of ISO 6690:2007.

One of the following requirements shall be fulfilled:

— the regulation characteristic vacuum drop and undershoot shall be less than 2 kPa when the regulation characteristic test is conducted in accordance with 5.2.4 of ISO 6690:2007

or

— at least the minimum effective reserve at standard atmospheric pressure shall be that given in A.1 for cows and buffaloes and in D.1 for sheep and goats.

The calculation of the effective reserve in accordance with A.1 and D.1 is considered to be sufficient for small milking systems and where the operator(s) take reasonable care to avoid air inlet in the cluster during normal milking, whereas the vacuum drop and undershoot tests are more appropriate for large milking systems and where the operators are less careful during attachment. Under such circumstances, there should be sufficient effective reserve to maintain the working vacuum within ± 2 kPa at measuring point Vm during the course of normal milking, including teatcup attachment and removal, liner slip or teatcup/cluster fall, for most of the milking time.

The effective reserve shall be measured in accordance with 5.2.5 of ISO 6690:2007. Standard atmospheric pressures are given in Table A.4.

5.3 Vacuum pumps

5.3.1 General

The vacuum pump shall have adequate airflow capacity to meet the requirements for milking and cleaning, including the air used by all ancillary equipment operating during milking and cleaning, whether continuously or intermittently.

For calculation of airflow capacity of the vacuum pump see the examples in Annex A. The airflow shall be measured in accordance with 5.3.1 of ISO 6690:2007.

If more than one vacuum pump is installed, it shall be possible to isolate the pump(s) not in use.

5.3.2 Influence of altitude

Vacuum pump capacity decreases with altitude. This shall be taken into account when determining vacuum pump capacity. See A.5.

5.3.3 Exhaust

The exhaust shall not obstruct the passage of the exhaust air by sharp bends, T-pieces or unsuitably designed silencers.

Means shall be provided to minimize oil discharge from oil-lubricated vacuum pumps into the environment, for example with an oil separator, collection or recirculation system fitted in the exhaust pipe.

Moisture from the exhaust pipe shall be prevented from entering the vacuum pump, for example by fitting a moisture trap or having an exhaust pipe with a continuous slope away from the vacuum pump.

The exhaust pipe should not discharge into a closed room where foodstuffs are stored or processed, or where persons or animals are present.

5.3.4 Prevention of reverse flow through vacuum pump

Automatic means shall be provided to prevent reverse flow of air from the exhaust, which may contaminate the milk system.

5.3.5 Location

The vacuum pump shall be located so that the air line vacuum drop recommendation in 5.6.2 can be achieved using air lines with reasonable diameter. The vacuum pump shall be installed so that its capacity, vacuum and, where applicable, speed can be easily measured.

NOTE The vacuum pump should be placed in a well-ventilated and non-freezing area isolated from the milking parlour and milk room.

5.3.6 Marking and specifications

The vacuum pump shall be indelibly marked with the following information:

- the name of the manufacturer;
- the type and identification, e.g. model number or code;
- the direction of rotation;
- the recommended operating speed(s), corresponding capacity at 50 kPa, expressed as free air at an atmospheric pressure of 100 kPa, and power consumption in kW;
- when applicable, the maximum permissible exhaust backpressure, measured in accordance with 5.3.3 of ISO 6690:2007.

The user's manual shall also state:

- the oil consumption, if appropriate;
- the recommended lubricant, if used;
- mounting points and dimensions;
- how a capacity-controlled vacuum pump can be run with its maximum and/or constant capacity.

5.4 Vacuum regulator

5.4.1 Regulator leakage

The regulator leakage, when tested in accordance with 5.4 of ISO 6690:2007, shall not exceed 35 l/min of free air or 5 % of the manual reserve, whichever is the greater.

5.4.2 Mounting

The vacuum regulator shall be mounted in a readily accessible location and protected from moisture from the milking machine and installed in a place and manner in which it is protected from excessive dust.

Examples of location of the sensing point are:

a) in pipeline and automatic milking machines, either between the interceptor and the sanitary trap or in the sanitary trap or in the receiver;

b) in recorder milking machines, either between the interceptor and the sanitary trap or in the sanitary trap or in the milking vacuum line;

c) in bucket milking machines, either between the interceptor and the first connection to the air line or on the interceptor.

Vacuum sensors not fulfilling the hygiene requirements shall be located in the vacuum system as near to the sanitary trap as practical.

The regulator should be installed in a place and manner so as to minimize noise for the operator(s).

5.4.3 Marking and specification

The vacuum regulator shall be marked indelibly with the following information:

- the name of the manufacturer;
- the type and identification, e.g. model number or code;
- the designed working vacuum range;
- the airflow capacity range at 50 kPa working vacuum, expressed as free air at an atmospheric pressure of 100 kPa.

The user's manual shall also state the airflow capacity at the upper and lower end of the designed working vacuum range.

5.5 Vacuum gauge

5.5.1 General

Over the vacuum range from 20 kPa to 80 kPa, the vacuum gauge shall indicate intervals of 2 kPa or less. When mounted and calibrated, the error measured in accordance with 5.5 of ISO 6690:2007 shall not exceed 1 kPa at the working vacuum.

NOTE 1 A vacuum gauge of accuracy class 1,6 that is calibrated and adjusted in place will meet this requirement.

NOTE 2 The accuracy class is the maximum permissible error expressed as a percentage of the pressure range for the gauge.

5.5.2 Mounting

A vacuum gauge shall be mounted where it is readable while milking.

NOTE More than one vacuum gauge may be needed.

5.6 Air lines

5.6.1 General

Air lines shall be installed so that they are sloped to a readily accessible drain valve and are self-draining when the vacuum is shut off. Provision shall also be made for cleaning and inspection of these lines.

5.6.2 Internal diameter and airflow

The internal diameter of the air lines shall be of large enough dimensions that the vacuum drop does not seriously affect the functioning of the milking machine. The vacuum drop between Vm and Vr reduces the regulating range of the regulator and may increase the regulation loss. The vacuum drop between Vr and Vm shall therefore not exceed 1 kPa when tested in accordance with 5.6 of ISO 6690:2007.

The vacuum drop between Vm and Vp leads to higher vacuum at Vp, increases power consumption and decreases the vacuum pump capacity. Therefore the vacuum drop between Vm and Vp should preferably not exceed 3 kPa.

Annex B gives guidelines for the required internal diameter of the air lines based on the specified vacuum drop and the effective length of the pipe system at a given average airflow.

5.7 Interceptor

An interceptor shall be fitted near the vacuum pump, between the vacuum pump and the regulator.

There shall not be any intermediate connections into the air line between the interceptor and the vacuum pump, except as required for test purposes or connection of a safety valve.

NOTE The safety valve may be fitted to protect the pump from effects of high vacuum caused by the activation of any vacuum shut-off valve in the interceptor.

Means shall be provided to prevent liquids trapped in the interceptor from entering the vacuum pump. It shall also be provided with automatic drainage facilities and it shall be possible to inspect and clean the inside of the interceptor.

The effective volume of the interceptor shall be given in the user's manual, as measured in accordance with 5.7 of ISO 6690:2007.

The effective volume should be adequate to facilitate washing of the air lines and should be determined by the air line sizes.

5.8 Sanitary trap

A sanitary trap shall be fitted between the milk system and the vacuum system in pipeline and recorder milking machines, between the receiver vessel and the vacuum system, except where the vacuum and pulsation systems form part of the routine circulation cleaning and disinfection system.

The sanitary trap shall have provision for drainage and shall have means to minimize liquid entry into the vacuum system

The effective volume of the sanitary trap shall be stated in the user's manual, measured in accordance with 5.8 of ISO 6690:2007.

It shall be possible for the operator to detect the presence of milk and/or cleaning solutions in the sanitary trap when the machine is running, for example by use of transparent sections.

NOTE It is an advantage to the operator if the trap is situated adjacent to the receiver and within sight during milking.

Where there is no provision for circulation cleaning of the sanitary trap(s), the receiver(s) and the receiver air line, this line shall be designed to drain towards the sanitary trap(s).

5.9 Leakage into the vacuum system

When determined in accordance with 5.9 of ISO 6690:2007, leakage into the vacuum system shall not exceed 5 % of the vacuum pump capacity at the working vacuum and for capacity-controlled vacuum pumps at the pump's maximum capacity.

5.10 Vacuum taps for bucket milking units

The vacuum drop across the tap shall not exceed 5 kPa with an airflow of 150 l/min of free air through the tap, measured in accordance with 5.10 of ISO 6690:2007.

The taps shall have stops at the fully open and fully closed positions. The taps shall be fixed to the air pipeline to prevent displacement in relation to the pipeline orifices. Gaskets shall not obstruct the tap aperture. The taps shall be connected to the upper part of the pipe.

For taps connected by means of a special adapter, the adapter shall be considered as part of the tap.

6 Pulsation system

6.1 Design data

The following data shall be included in the user's manual:

- the pulsation rate and pulsator ratio at a nominal vacuum and specified temperature;
- the temperature range over which the pulsation rate will stay within ± 5 % of the nominal pulsation rate;
- the temperature range over which the pulsators can be operated;
- the variation of pulsation rate within this range;
- typical pulsation chamber vacuum records for a defined milking unit;
- total air use with a defined milking unit connected under specified operating conditions;
- minimum airflow at the stall tap measured in accordance with 6.1 of ISO 6690:2007;
- where applicable, deliberate variations in pulsation rate and pulsator ratio, e.g. in conjunction with stimulation and changes in milk flow.

6.2 Pulsator air line

The vacuum drop between the working vacuum at the measuring point Vm and the maximum pulsation chamber vacuum shall be no more than 2 kPa when pulsation is tested in accordance with 6.2 of ISO 6690:2007.

6.3 Pulsation rate, pulsator ratio and pulsation chamber vacuum phases

The pulsation rate, pulsator ratio and phases shall be measured in accordance with 6.2 of ISO 6690:2007.

The pulsation rate shall not deviate more than ± 5 % from the intended values given in the user's manual.

NOTE Pulsation rate is typically between 50 cycles/min and 65 cycles/min for cows and water buffaloes, 60 cycles/min and 120 cycles/min for goats and 90 cycles/min and 180 cycles/min for sheep.

The pulsator ratio shall not differ more than ± 5 units of percentage from the values given in the user's manual. The pulsator ratios of all pulsators in an installation shall not vary from each other by more than 5 units of percentage.

Limping shall not be more than 5 units of percentage, except where the milking unit is designed to provide different ratios between the fore- and hindquarters.

In case of alternate pulsation in combination with a claw, a ratio of, or near, 50 % should be avoided due to pumping between teatcups.

For cows and water buffaloes phase b shall be not less than 30 % of a pulsation cycle and phase d shall be not less than 150 ms.

Vacuum drop during phase b shall not be more than 4 kPa below maximum pulsation chamber vacuum and the vacuum during phase d shall not be more than 4 kPa.

7 Milk system

7.1 General

It shall be possible to inspect the inside of the milk system for cleanliness.

The flow of any air that is deliberately admitted into the milk system shall be stated in the instructions for installation.

7.2 Design of milklines

The internal diameter and slope of the milkline shall be such that the vacuum drop between the receiver and any point in the milkline does not exceed 2 kPa with all units operating at the designed milk flow and airflow.

The internal diameter and slope of the milkline can be determined in accordance with Annex C for cows and water buffaloes and D.3 for sheep and goats

If the milkline is installed to form a loop, then each end of the loop shall have a separate full-bore connection to the receiver. If several loops are used, two ends may be grouped together directly in front of the receiver to form a single line. This line shall have an adequate cross-sectional area for the combined designed milk flow and airflow that can be determined in accordance with Annex C for cows and water buffaloes or D.2 for sheep and goats.

Milklines shall have a continuous fall towards the receiver for drainage, measured in accordance with 7.1 of ISO 6690:2007. Equipment that can cause an obstruction or a reduction in vacuum, milk flow or drainage, such as enlargements, restrictions or filters, shall not be used.

Branches in the milkline shall be swept in the direction of milk flow. The minimum centre-line radius for bends shall be 1,5 times the diameter.

The milkline should be installed to minimize the milk lift and preferably no more than 2 m above the animal standing level.

7.3 Air leakage

The air leakage into the milk system, when tested in accordance with 7.2 of ISO 6690:2007, in a pipeline, recorder or automatic milking installation, shall not exceed 10 l/min, plus 2 l/min for each milking unit.

7.4 Drainage

Provisions shall be made for complete drainage of all parts of the milk system.

7.5 Milk inlets

Milk inlet valves and milk inlets shall be fitted to the upper half of a pipeline.

7.6 Diversion of milk

There shall be provisions to ensure that withheld, abnormal or undesirable milk cannot be mixed with normal milk.

7.7 Receiver

The receiver shall have sufficient volume to accommodate slugs of liquid which may be formed during milking and cleaning. The effective volume, measured in accordance with 7.3 of ISO 6690:2007, shall be stated in the instructions for installation.

The receiver inlet(s) should be shaped to limit formation of foam during milking.

7.8 Releaser

7.8.1 General

A releaser, when fitted in the installation, shall be adequate to deal with the maximum flow at which milk and cleaning and disinfecting fluids flow through the system.

The releaser milk pump's discharge flow at 50 kPa working vacuum and typical discharge pressures shall be stated in the instructions for installation.

There shall be no air leaks in the releaser or between the receiver and the releaser when checked in accordance with 7.4 of ISO 6690:2007. Flow of milk from the releaser to the receiver shall be prevented. It can be checked according to 7.4.5 of ISO 6690:2007.

7.8.2 Control of releaser milk pumps

The operation of a milk pump shall be controlled by the quantity of milk in the receiver so that flooding of the receiver or mixing of air and milk is avoided.

7.9 Delivery line

Means shall be provided at every low point to permit drainage of the delivery line, filters and any in-line cooling equipment.

If compressed air is used to purge milk from the delivery line, this air shall be free from contaminants.

The method of injection of compressed air should avoid unnecessary formation of free fatty acids.

Where in-line cooling equipment is fitted, means which are preferably automatic shall be provided to stop the flow of coolant during the washing cycle.

If a restriction needs to be fitted in the delivery line to reduce milk flow suitable for an in-line cooler or where an in-line cooler restricts flow below that needed for cleaning and disinfection, means shall be provided to open or bypass the restriction during the washing cycle.

8 Milking unit

8.1 General

Milk contact surfaces within each component of the milking unit shall be accessible for convenient visual inspection.

8.2 Teatcup

The shell and liner shall be marked to identify manufacturer and type. The liner and shell combination shall be provided with a means of indicating if the liner is twisted or a means of preventing the liner from twisting in the shell. The internal dimensions of the shell shall not restrict the operation of the liner.

The user's manual shall include:

— air use caused by the teatcup or cluster fall-off measured in accordance with 8.2 of ISO 6690:2007;

— sufficient data to be able to choose the liner for a herd.

NOTE Such data may include teat sizes, liner type or dimensions (see Figure 5 of ISO 3918:2007).

8.3 Teatcup attachment

Means shall be provided to limit the airflow through the cluster or teatcup until attachment.

8.4 Teatcup removal

Means shall be provided of shutting off the vacuum to the liner before teatcup removal. If vacuum is reduced only as a result of the air vent(s), the leakage of the shut-off shall be less than 2 l/min for a claw and less than a quarter of the air vent admission for individual teatcups. The leakage shall be measured in accordance with 8.3 of ISO 6690:2007 and the admission of air in accordance with 8.4.6 of ISO 6690:2007.

Teatcup removal shall be initiated:

— if milk flow is not present after a specified time;

— when the milk flow has ceased or has gone below a specified flow;

— when a specified total machine-on time has elapsed;

— by human intervention.

This initiation together with the limits shall be described in the user's manual.

8.5 Vacuum shut-off

It shall be possible to shut off vacuum to the liner when not milking.

8.6 Air vent and leakage

To allow effective milk transport from the claw and to limit excessive agitation of the milk, the total air admission per cluster shall be at least 4 l/min and shall not exceed 12 l/min for cows and water buffaloes or 8 l/min for sheep and goats at the nominal working vacuum. The air vent(s) shall be made of a rigid material.

For clusters where there is a risk of slugs in the short milk tube at designed milk flow, means shall be applied to avoid them, for example an air vent for each teatcup.

For quarter milking, clusters with deliberate cyclic air admission or other specific design, the above quantitative requirements do not apply. In such cases, the total air admission per cluster or teat cup shall be stated in the user's manual.

Air vents necessary for proper operation of milk meters, automatic teatcup valves or other devices may add air admission. The air use and location of such air vents shall be stated in the user's manual.

Leakage into each cluster assembly with the liners and air vent(s) plugged and the vacuum shut-off valve opened shall not exceed 2 l/min. The air admission and air leakage shall be measured and calculated in accordance with 8.4 of ISO 6690:2007.

All air vents should be positioned to avoid unnecessary turbulence in the milk to limit free fatty acid development.

8.7 Vacuum in the milking unit

The user's manual for the milking unit shall state, for specified milk flows (where at least one shall be chosen from Table 1):

a) the desired average liner vacuum and/or the desired average liner vacuum during phase b and phase d of the pulsation chamber vacuum record;

b) the corresponding nominal vacuum in the milkline; this nominal vacuum shall be based on the average vacuum drop measured in accordance with 8.6 of ISO 6690:2007.

NOTE Both research and field experience indicate that a mean liner vacuum within the range 32 kPa to 42 kPa during the peak flow period of milking for cows ensures that most cows will be milked quickly, gently and completely. Similarly, a mean liner working vacuum, within the range 28 kPa to 38 kPa during the peak flow period of milking for sheep and goats will ensure that most animals will be milked quickly, gently and completely.

For devices not originally fitted to a milking unit between the cluster and the milkline or milking vacuum line, the effect on the milking vacuum conditions shall be stated in the user's manual, measured in accordance with 8.7 of ISO 6690:2007.

Table 1 — Representative peak milk flows for commercially milked species

Species commercially milked		Reference liquid flow for testing kg/min
Cows	Low producing	3
	High producing	5
Water buffaloes	Low producing	1,5
	High producing	2,5
Sheep	Low producing	0,8
	High producing	1,5
Goats	Low producing	1,0
	High producing	2,0

8.8 Milk recording equipment

8.8.1 General

Milk recording equipment shall comply with the requirements given in 8.9.

NOTE For official yield recording, the requirements to be met are stated by the International Committee for Animal Recording (ICAR).

8.8.2 Recorder jars

Recorder jars shall comply with the following requirements:

a) the effective volume shall be stated in the user's manual, measured in accordance with 8.5 of ISO 6690:2007;

b) the internal diameter of the outlet shall be not less than 18 mm for cows and water buffaloes, and for sheep and goats not less than the internal diameter of the long milk tube.

Connections for milk and vacuum tubes should be placed to minimize the risk of carry-over of milk or froth into the vacuum system.

Recorder jars should be designed or fitted with a means of ensuring even distribution of cleaning and disinfecting fluids over the internal surface during washing without adversely affecting the vacuum in the recorder jar during milking.

8.9 Attachments to the milking unit

Devices, including additional necessary connecting tubes, fitted between the cluster or teatcup and the milkline or milking vacuum line, shall not cause any additional vacuum drop greater than 5 kPa at a milk flow of 5 kg/min for cows or 2 kg/min for water buffaloes, sheep and goats, compared with the same milking unit without those devices when measured in accordance with 8.7 of ISO 6690:2007.

8.10 Long milk tubes

Means shall be provided to minimize the risk of flattening of the long milk tube due to direct pull or constant drag on the milk inlet.

Where milk is lifted by means of airflow, the maximum internal diameter of the long milk tube shall be 16 mm for cows and 14,5 mm for sheep and goats, in order to limit harmful agitation of the milk.

NOTE Where long milk tubes are attached to single teatcups it is advisable to use tubes with a smaller diameter.

The length and the internal diameter of the long milk tube shall be specified in the user's manual and, for reference purposes, with the airflow at the end of the long milk tube measured in accordance with 8.8 of ISO 6690:2007.

To avoid unnecessary vacuum drop, the long milk tube shall be as short as practicable.

8.11 Bucket milking units

The effective working volume of buckets and transport cans shall be stated in the user's manual, measured in accordance with 8.5 of ISO 6690:2007.

To allow the bucket to be moved from one vacuum tap to another without losing the vacuum in the bucket, a non-return valve shall be fitted between the air line and the bucket. The vacuum reduction of that non-return valve shall be specified in the user's manual, when tested in accordance with 8.8 of ISO 6690:2007.

The length and internal diameter of the vacuum tube shall be specified in the user's manual.

The capacity at the end of the long milk tube shall be at least 65 l/min of free air, when tested in accordance with 8.8 of ISO 6690:2007.

Where the installation's working vacuum is leading to too high a liner vacuum on the bucket unit, it is recommended to use a non-return valve that reduces the liner vacuum to an appropriate level. Where a bucket milking unit is used to milk abnormal, undesirable or withheld milk, it is recommended to connect the bucket to the vacuum system to avoid contamination.

9 Cleaning

The cleaning system shall be designed and installed so that cleaning and disinfecting solutions cannot enter the milk. Methods of verifying that the cleaning system is operating properly, and any components that shall be manually disassembled or hand cleaned, shall be specified in the user's manual.

NOTE 1 The success of a circulation cleaning system depends on:

- design and installation ensuring adequate circulation volume, velocity and contact time of cleaning solutions;
- temperature and concentration appropriate to the type of cleaning and sanitizing solutions used.

A velocity range of 7 m/s to 10 m/s is preferred for the cleaning of pipelines containing liquid-slugs.

NOTE 2 It is expected that any cleaning procedure will:

- leave milk contact surfaces visibly free from milk residues and other deposits;
- leave surfaces free from undesirable residues of cleaning and disinfecting chemicals;
- reduce the count of viable bacteria to an acceptable level on milk contact surfaces.

Annex A
(normative)

Vacuum pump capacity — Effective reserve plus allowances for cows and water buffaloes

A.1 Effective reserve

The effective reserve to fulfil the demand of a minimum effective reserve in 5.2.4 is given in Tables A.1 and A.2.

For installations with milking units without automatic shut-off valves, the minimum effective reserve in Table A.1 shall be increased by 80 l/min for bucket milking machines and by 200 l/min for the other types of milking machines.

Table A.1 — Minimum effective reserve where milking units with automatic shut-off valves are used

Values in litres per minute of free air

Number of units	Minimum effective reserve [a]	
n	Bucket or direct-to-can milking machines	Other milking machines
$2 \leqslant n \leqslant 10$	$80 + 25\,n$	$200 + 30\,n$
> 10	$330 + 10(n - 10)$	$500 + 10(n - 10)$

[a] Add the airflow required for ancillary equipment in accordance with 5.3.

Table A.2 gives the calculated effective reserve derived from formulae in Table A.1 for different numbers of milking units between 2 and 20. For more than 20 milking units, the formulae in Table A.1 can be used.

Table A.2 — Minimum effective reserve

Values in litres per minute of free air

Number of milking units	Minimum effective reserve [a]			
	Bucket or direct to can milking machines		Other milking machines	
	With automatic shut-off valve	Without automatic shut-off valve	With automatic shut-off valve	Without automatic shut-off valve
2	130	210	260	460
3	155	235	290	490
4	180	260	320	520
5	205	285	350	550
6	230	310	380	580
7	255	335	410	610
8	280	360	440	640
9	305	385	470	670
10	330	410	500	700
11	340	420	510	710
12	350	430	520	720
13	360	440	530	730
14	370	450	540	740
15			550	750
16			560	760
17			570	770
18			580	780
19			590	790
20			600	800

[a] Add the airflow required for ancillary equipment in accordance with A.3.

A.2 Airflow use and vacuum for cleaning

Milklines and milk transfer lines are usually cleaned by a cleaning solution transported and agitated by the vacuum difference to achieve effective cleaning. Slug speeds of 7 m/s to 10 m/s optimize this cleaning action.

To achieve these slug speeds it might be necessary to use a higher pump capacity than that necessary for milking. Other washing systems may not need increased pump capacity.

Where washing systems rely on high pump capacity to achieve the air speed necessary to produce slugs for washing, this capacity, q_{clean}, can be calculated from:

$$q_{\text{clean}} = \frac{\pi \times d^2}{4} \times v \times \frac{p_{\text{a}} - p_{\text{w}}}{p_{\text{a}}} \times \frac{6}{100} \qquad \text{(A.1)}$$

where:

q_{clean} is the pump capacity, in litres per minute (l/min);

d is the internal diameter of the milkline, in millimetres (mm);

v is the air slug speed in the milkline, in metres per second (m/s);

p_a is the actual atmospheric pressure during the test, in kilopascals (kPa);

p_w is the vacuum when washing the plant, in kilopascals (kPa).

Table A.3 gives the air capacity for some milkline dimensions and working vacuums at an atmospheric pressure of 100 kPa. It also gives the airflow at the vacuum in the line to be used for calculations for plants at high altitudes.

Table A.3 — Airflow for cleaning at a speed of 8 m/s and under atmospheric pressure of 100 kPa

Value in litres per minute

Internal milkline diameter mm	**Airflow admission to produce slug flow for cleaning at a vacuum of**			**Airflow in milkline** l/min of expanded air
	40 kPa	**45 kPa**	**50 kPa**	
34	261	240	218	436
36	293	269	244	488
38	326	299	272	544
40	362	332	301	603
44	438	401	365	729
48	521	477	434	868
50	565	518	471	942
60	814	746	678	1 356
63	985	903	821	1 641
73	1 205	1 104	1 004	2 008
98	2 171	1 990	1 809	3 619

NOTE To calculate the airflow for cleaning at higher altitudes, i.e. where atmospheric pressure is less than 100 kPa, use the last column in Table A.3 and multiply the value by $(p_a - p_w)/p_a$.

In installations with excessive lengths of wash line or excessive lift from the wash sink to the wash line, or when the nominal vacuum is low such as in milking installations for sheep and goats, it may be beneficial to increase vacuum during washing, lift the wash sink or provide a positive pressure pump.

A.3 Ancillary equipment

Ancillary equipment can be divided into three groups:

a) equipment running continuously during milking;

b) equipment that uses a quantity of air for a short time during milking;

c) equipment only operating before or after the milking session.

For equipment of the type defined in a) the minimum airflow use shall be added when calculating the pump capacity and effective reserve.

For equipment of the type defined in b) the ancillary equipment simultaneously uses the same vacuum supply as that for milk extraction. In many cases, it is not necessary to take their air use into account, as ancillary equipment used during milking consumes only small quantities of air over a short time. Such equipment includes cluster removers and gate cylinders. However, this equipment may use a high instantaneous airflow that shall be considered when sizing the air lines.

For equipment of the type defined in c) there is no need to take its capacity into account when calculating the vacuum pump capacity for milking.

A.4 Calculations of vacuum pump capacity based on effective reserve requirements

A.4.1 The vacuum pump(s) shall have adequate capacity to meet the performance requirements for milking and cleaning. This includes air used by all ancillary equipment operating during milking and cleaning, whether continuously or intermittently.

A.4.2 Calculate the airflow use for all equipment continuously running or using airflow during milking and during cleaning such as pulsators, air inlets and vacuum-operated milk pumps. The milking units and the pulsators shall be regarded as continuously running.

Check the airflow for equipment that uses air for a short time.

A.4.3 Add the effective reserve from A.1 and the airflow use during milking from A.4.2.

A.4.4 Add the airflow use for cleaning from A.2 and the airflow use during milking from A.4.2.

A.4.5 Take the higher of the values calculated in A.4.3 and A.4.4.

A.4.6 Add 10 l/min, plus 2 l/min for each milking unit, for leakage into the milk system determined in accordance with 7.3 and add airflow admitted deliberately into the milk system in accordance with 7.1.

A.4.7 Add leakages in the air lines, which have been determined in accordance with 5.9 of ISO 6690:2007.

A.4.8 Add the regulation loss, in accordance with information in the user's manual or that determined in accordance with 5.2.3.

A.4.9 Calculate the pressure drop in the main air line, in accordance with Annex B, and add it to the desired working vacuum of the plant. The derived values for airflow and vacuum are the bases for choosing the vacuum pump.

A.4.10 For a vacuum other than 50 kPa or at altitudes greater than 300 m the factor H, specified in Table A.4, should be used as a multiplier to correct the derived airflow.

A.5 Prediction of vacuum pump capacity at altitude

To be able to choose a suitable pump size, the calculated airflow use shall be corrected to nominal values for pump data.

To select the correct size of a positive displacement pump, the corrected airflow from A.4.10 shall be multiplied by H to allow comparisons with pump capacities rated at 100 kPa ambient atmospheric pressure. The correction factor, H, shall be calculated as follows:

$$H = \frac{p_{max} - \dfrac{p_N \times p_s}{p_{an}}}{p_{max} - p} \qquad (A.2)$$

where:

p_{max} is the vacuum at the totally closed pump inlet during the test, in kilopascals (kPa);

p_N is the nominal vacuum at the pump inlet, in kilopascals (kPa);

p_s is the standard atmospheric pressure at the altitude of the plant, in kilopascals (kPa);

p_{an} is the nominal atmospheric pressure, in kilopascals (kPa);

p is the vacuum at the pump inlet (actual or calculated), in kilopascals (kPa).

NOTE This formula for determining H is principally the same as the formulae for determining K_1 and K_2 in 5.3.2.1 and 5.3.2.2 of ISO 6690:2007.

Consideration should also be given to the fact that the maximum power of most electric motors will decrease at high altitude because of the decrease in the cooling capacity of the air. This means that a motor will be hotter and thus allow a lower maximum load. This information can be obtained from the manufacturer of the motor.

Table A.4 — Standard atmospheric pressures, p_s, and correction factor, H, at various altitudes

Altitude m	Standard atmospheric pressure, p_s kPa	Correction factor, H, at a pump vacuum, p, of 40 kPa	 45 kPa	 50 kPa
< 300	100	0,80	0,89	1,00
from 300 to 700	95	0,84	0,94	1,07
from 700 to 1 200	90	0,88	1,00	1,16
from 1 200 to 1 700	85	0,93	1,08	1,28
from 1 700 to 2 200	80	1,00	1,19	1,45

NOTE 1 These values are based on a volumetric efficiency, η_V, equal to 0,9, calculated from:

$$\eta_v = \frac{p_{max}}{p_a}$$

where p_{max} is the vacuum, in kilopascals (kPa), at the inlet of the pump when completely closed, measured at atmospheric pressure, p_a.

NOTE 2 p_{max} or the value of volumetric efficiency can be obtained from the manufacturer.

A.6 Example of prediction of a vacuum pump capacity

A.6.1 Data

a) a herringbone milking parlour with 12 milking units direct to line, automatic cluster removers and automatic shut-off valves at claw situated 1 300 m above sea level;

b) one milker;

c) working vacuum: 44 kPa;

d) milkline diameter: 48,5 mm;

e) airflow use for each pulsator: 25 l/min;

f) airflow inlet in the clusters: 10 l/min;

g) maximum airflow for each automatic cluster remover: 50 l/min.

A.6.2 Calculations

In accordance with A.1, the effective reserve capacity for milking will be:

$$500 + [(12 - 10) \times 10] = 520 \text{ l/min}$$

In accordance with Clause 9 and Equation (A.1), the airflow use for cleaning at 44 kPa should be 498 l/min for a milkline with a diameter of 48,5 mm.

As the altitude for the plant is 1 300 m, the airflow use for cleaning could be adjusted to the lower atmospheric pressure.

The atmospheric pressure at 1 300 m is 85 kPa (see Table A.4). The last column in Table A.3 shall be used, which gives by interpolation 886 l/min. To obtain the capacity necessary at cleaning, multiply this value by $(p_a - p_w)/p_s$:

$$q_{clean} = 886 \times (85 - 44)/85 \text{ l/min} = 427 \text{ l/min}$$

If many recorders or automatic cluster removers are operated simultaneously, the total airflow use from them might exceed the effective reserve or airflow use for cleaning. In such a case, that airflow use has to be the base for sizing.

With one milker it is likely that not more than two automatic cluster removers are operated simultaneously, which gives a maximum airflow use of 2 × 50 l/min = 100 l/min, which is less than the necessary effective reserve and need therefore not be taken into account.

Airflow use for the milking units (air inlets and pulsators) will be 12 × (10 + 25) l/min = 420 l/min. The milking units will consume about the same amount of airflow during milking and cleaning.

Total airflow use during milking will be 520 l/min + 420 l/min = 940 l/min (A.4.3).

Total airflow use during cleaning will be 427 l/min + 420 l/min = 847 l/min (A.4.4).

In this example the capacity for milking is the larger and therefore the base for the pump dimensioning (A.4.5).

Leakage into the milk system: 10 l/min + (2 × 12) l/min = 34 l/min (A.4.6).

Total: 940 l/min + 34 l/min = 974 l/min.

Regulation loss is 10 % of the manual reserve. The effective reserve was 520 l/min and is smaller than the manual reserve. Consequently:

— manual reserve = 520 l/min × 100/(100 − 10) = 578 l/min;

— regulation loss = 578 l/min × 10/100 = 58 l/min;

— total: 974 l/min + 58 l/min = 1 032 l/min.

Leakages into the air lines are equal to 5 % of the pump capacity (A.4.7), that is

— vacuum system leakage: 1 032 l/min × 5/(100 − 5) = 54 l/min;

— total: 1 032 l/min + 54 l/min = 1 086 l/min.

With an assumed vacuum drop of 3 kPa between vacuum pump and measuring point Vm, the vacuum at the pump will be:

44 kPa + 3 kPa = 47 kPa

Correction for higher altitude in accordance with Table A.4 for the altitude of 1 300 m and a vacuum of 47 kPa will give a factor H = 1,16 which gives, for an atmospheric pressure of 100 kPa and a vacuum of 50 kPa, a nominal pump capacity of:

1 086 l/min × 1,16 = 1 260 l/min

The minimum nominal capacity of the vacuum pump must therefore be 1 260 l/min.

Annex B
(informative)

Determination of the minimum internal diameter of air lines

B.1 Vacuum drop due to airflow in straight smooth pipelines

The pressure drop, up to about 3 kPa, in a smooth vacuum air line, usually in plastics or stainless steel, can be calculated from:

$$\Delta p = 27{,}8 \times l \times \frac{q^{1{,}75}}{d^{4{,}75}} \quad \text{(B.1)}$$

where:

Δp is the pressure drop in the pipe, in kilopascals (kPa);

l is the length of the pipe, in metres (m);

q is the flow in the pipe, in litres per minute (l/min) of free air;

d is the internal diameter of the pipe, in millimetres (mm).

Since the flow in the pipe and the maximum allowed pressure drop are usually known, this equation can be written as:

$$d = \sqrt[4{,}75]{\frac{27{,}8 \times l \times q^{1{,}75}}{\Delta p}} \quad \text{(B.2)}$$

Table B.1 gives the pipeline diameters for a straight single smooth pipeline in accordance with Equation (B.2) at 100 kPa atmospheric pressure and 50 kPa vacuum. This equation is generally used for sizing the main air line.

Table B.2 gives the pipeline diameters for straight looped smooth pipelines, at 50 kPa vacuum and 100 kPa atmospheric pressure, provided that both ends are connected to a pipe with at least twice its cross-sectional area. The table is based on Equation (B.2), applied to the case of two pipes of equal length with the same flow, and considering that the total length is the sum of the lengths of each pipe (branch); calculations were made, for example, with $l/2$ and $q/2$. This table should be used for the sizing of the pulsator air line.

Table B.1 — Recommended minimum pipeline diameters for a design limit of 1 kPa vacuum drop due to airflow in straight single smooth pipelines

Values in millimetres

Airflow	Minimum internal diameter for a pipe length of									
l/min	5 m	10 m	15 m	20 m	25 m	30 m	40 m	50 m	60 m	70 m
100	15	18	19	21	22	22	24	25	26	27
200	20	23	25	27	28	29	31	32	34	35
300	23	27	29	31	32	34	36	37	39	40
400	26	30	32	34	36	37	40	42	43	45
500	28	32	35	37	39	41	43	45	47	49
600	30	34	38	40	42	43	46	48	50	52
700	32	36	40	42	44	46	49	51	53	55
800	33	38	42	44	46	48	51	54	56	58
900	35	40	44	46	48	50	54	56	58	60
1 000	36	42	45	48	50	52	56	58	61	63
1 200	38	44	48	51	54	56	60	62	65	67
1 400	41	47	51	54	57	59	63	66	69	71
1 600	43	49	54	57	60	62	66	69	72	74
1 800	45	52	56	60	63	65	69	72	75	78
2 000	46	54	58	62	65	68	72	75	78	81
2 500	50	58	63	67	71	73	78	82	85	88
3 000	54	62	68	72	76	79	83	87	91	94
3 500	57	66	72	76	80	83	88	93	96	99
4 000	60	69	75	80	84	87	93	97	101	104
4 500	63	72	79	84	88	91	97	102	106	109
5 000	65	75	82	87	91	95	101	106	110	113
5 500	67	78	85	90	94	98	104	109	114	117
6000	70	80	88	93	98	101	108	113	117	121
6 500	72	83	90	96	100	104	111	116	121	125
7 000	74	85	93	99	103	107	114	119	124	128

Equivalent lengths for inlets and outlets to tanks, elbows and T-pieces should be added to the length. See Table B.5.

NOTE As pressure drop and pipe length are proportional, diameters for pressure drops of 2 kPa and 3 kPa can be calculated using the values given in this table corresponding to one-half of the pipe length (for 2 kPa) and one-third of the pipe length (for 3 kPa).

Table B.2 — Recommended minimum pipeline diameters for a design limit of 1 kPa vacuum drop due to airflow in straight looped smooth pipelines

Values in millimetres

Airflow	Minimum internal diameter for a pipe length of											
l/min	**40 m**	**60 m**	**80 m**	**100 m**	**120 m**	**140 m**	**160 m**	**180 m**	**200 m**	**220 m**	**240 m**	**280 m**
100	16	17	18	19	20	21	21	22	22	23	23	24
150	19	20	21	22	23	24	25	25	26	27	27	28
200	21	22	24	25	26	27	28	28	29	29	30	31
250	22	24	26	27	28	29	30	31	31	32	33	34
300	24	26	28	29	30	31	32	33	34	34	35	36
350	25	28	29	31	32	33	34	35	36	36	37	38
400	27	29	31	32	34	35	36	36	37	38	39	40
450	28	30	32	34	35	36	37	38	39	40	40	42
500	29	3-l	33	35	36	38	39	40	41	41	42	43
550	30	33	35	36	38	39	40	41	42	43	44	45
600	31	34	36	37	39	40	41	42	43	44	45	47
650	32	35	37	39	40	41	43	44	45	46	46	48
700	33	36	38	40	41	43	44	45	46	47	48	49
800	34	37	40	42	43	45	46	47	48	49	50	52
900	36	39	41	43	45	47	48	49	50	51	52	54
1 000	37	41	43	45	47	49	50	51	52	53	54	56
1 200	40	43	46	48	50	52	53	55	56	57	58	60
1 400	42	46	49	51	53	55	56	58	59	60	62	64
1 600	44	48	51	54	56	58	59	61	62	63	65	67
1 800	46	50	54	56	58	60	62	64	65	66	67	70
2 000	48	52	56	58	61	63	64	66	68	69	70	72
Equivalent lengths for inlets and outlets to tanks, elbows and T-pieces should be added to the length. See Table B.5.												

B.2 Vacuum drop due to airflow in straight galvanized pipelines

The pressure drop, up to about 3 kPa, in galvanized vacuum air lines, can be calculated from:

$$\Delta p = 18{,}74 \times l \times \frac{q^{2}}{d^{5}} \quad \text{(B.3)}$$

where:

Δp is the pressure drop in the pipe, in kilopascals (kPa);

l is the length of the pipe, in metres (m);

q is the flow in the pipe, in litres per minute of free air (l/min);

d is the internal diameter of the pipe, in millimetres (mm).

Since the airflow and the maximum allowed pressure drop are usually known, this equation can be written as:

$$d = \sqrt[5]{\frac{18{,}74 \times l \times q^2}{\Delta p}} \quad \text{(B.4)}$$

Table B.3 gives pipeline diameters for a straight single galvanized pipeline in accordance with Equation (B.4) at 100 kPa atmospheric pressure and 50 kPa vacuum. This table is generally used for sizing the main air line and main pulsator air line.

Table B.4 gives the pipeline diameters for straight looped galvanized pipelines, at 50 kPa vacuum and 100 kPa atmospheric pressure, provided that both ends are connected to a pipe with at least twice its cross-sectional area. The table is based on Equation (B.4), applied to the case of two pipes of equal length with the same flow, considering that the total length is the sum of the lengths of each pipe (branch); calculations were made, for example, with $l/2$ and $q/2$. This table should be used for the sizing of the pulsator air line.

The pipeline diameter derived from Equation (B.4) or Tables B.3 and B.4 should be increased by about 5 % to allow for deposits that might settle.

Table B.3 — Recommended minimum air line diameters for a design limit of 1 kPa vacuum drop due to airflow in straight single galvanized pipelines

Values in millimetres

Airflow	Minimum internal diameter for a pipe length of									
l/min	5 m	10 m	15 m	20 m	25 m	30 m	40 m	50 m	60 m	70 m
100	16	18	19	21	22	22	24	25	26	27
200	21	24	26	27	28	30	31	33	34	35
300	24	28	30	32	33	35	37	38	40	41
400	27	31	34	36	38	39	41	43	45	46
500	30	34	37	39	41	43	45	47	49	50
600	32	37	40	42	44	46	49	51	53	54
700	34	39	42	45	47	49	52	54	56	58
800	36	41	45	47	50	51	54	57	59	61
900	38	43	47	50	52	54	57	60	62	64
1 000	39	45	49	52	54	56	60	62	65	67
1 200	42	49	53	56	58	60	64	67	69	72
1 400	45	52	56	59	62	64	68	71	74	76
1 600	47	54	59	63	65	68	72	75	78	80
1 800	50	57	62	66	69	71	75	79	82	84
2 000	52	60	65	68	72	74	79	82	85	88
2 500	57	65	71	75	78	81	86	90	93	96
3 000	61	70	76	80	84	87	92	97	100	103
3 500	65	75	81	86	89	93	98	103	107	110
4 000	68	79	85	90	94	98	104	108	112	116
4 500	72	82	89	95	99	103	109	114	118	122
5 000	75	86	93	99	103	107	113	119	123	127
5 500	78	89	97	103	107	111	118	123	128	132
6 000	80	92	100	106	111	115	122	128	132	136
6 500	83	95	104	110	115	119	126	132	137	141
7 000	86	98	107	113	118	122	130	136	141	145

Equivalent lengths for inlets and outlets to tanks, elbows and T-pieces should be added to the length. See Table B.5.

NOTE As pressure drop and pipe length are proportional, diameters for pressure drops of 2 kPa and 3 kPa can be calculated using the values given in this table corresponding to one-half of the pipe length (for 2 kPa) and one-third of the pipe length (for 3 kPa).

Table B.4 — Recommended minimum air line diameters for a design limit of 1 kPa vacuum drop due to airflow in straight looped galvanised pipelines

Values in millimetres

Airflow	Minimum internal diameter for a pipe length of										
l/min	40 m	60 m	80 m	100 m	120 m	140 m	160 m	180 m	200 m	220 m	240 m	280 m
100	16	17	18	19	20	21	21	22	22	23	23	24
150	19	20	21	22	23	24	25	25	26	27	27	28
200	21	22	24	25	26	27	28	28	29	29	30	31
250	23	24	26	27	28	29	30	30	31	32	33	34
300	24	26	28	29	30	31	32	33	34	34	35	36
350	26	28	30	31	32	33	34	35	36	36	37	38
400	27	30	31	33	34	35	36	37	38	38	39	40
450	29	31	33	34	36	37	38	39	39	40	41	42
500	30	32	34	36	37	38	39	40	41	42	43	44
550	31	34	36	37	39	40	41	42	43	44	44	46
600	32	35	37	38	40	41	42	43	44	45	46	47
650	33	36	38	40	41	42	44	45	46	47	47	49
700	34	37	39	41	42	44	45	46	47	48	49	50
800	36	39	41	43	45	46	47	49	50	51	51	53
900	38	41	43	45	47	48	50	51	52	53	54	56
1 000	39	43	45	47	49	50	52	53	54	55	56	58
1 200	42	46	49	51	53	54	56	57	58	59	60	62
1 400	45	49	52	54	56	58	59	61	62	63	64	66
1 600	47	51	54	57	59	61	63	64	65	67	68	70
1 800	50	54	57	60	60	64	66	67	69	70	71	73
2 000	52	56	60	62	62	67	68	70	72	73	74	77
Equivalent lengths for inlets and outlets to tanks, elbows and T-pieces should be added to the length. See Table B.5.												

B.3 Frictional equivalents of bends and fittings

Frictional losses in bends and fittings such as elbows, T-fittings, inlets and outlets to tanks can be regarded as being the same as in a piece of straight pipe. These equivalent lengths of pipe should be added to the total pipe length when calculating the pressure drop in an air line. Table B.5 gives equivalent lengths for various fittings.

Table B.5 — Equivalent length of pipe for various fittings

Values in metres

Type of fitting	Number of pipe diameters	Approximate equivalent length of pipe for a nominal internal pipe diameter of				
		38 mm	50 mm	63 mm	75 mm	100 mm
Elbows						
45° sharp	8 to 10	0,3	0,5	0,6	0,8	0,9
90° short radius (R/D = 0,75) [a]	35 to 40	1,4	1,8	2,4	3,0	3,6
90° medium radius (R/D = 1,8) [a]	15 to 20	0,7	0,9	1,1	1,2	1,8
T-pieces						
Through flow	15 to 20	0,7	0,9	1,1	1,2	1,8
Side flow	40 to 45	1,6	2,1	2,4	2,7	4,2
Swept side flow	20 to 25	0,9	1,1	1,2	1,5	2,2
Tanks and traps						
Sudden contraction	20 to 25	0,9	1,1	1,2	1,5	2,2
Sudden expansion	40 to 45	1,6	2,1	2,4	2,7	4,2
Sanitary trap, distribution tank, receiver [b]	60 to 70	2,5	3,2	3,5	4,2	6,4

[a] R/D is the internal outer radius of the elbow divided by the internal diameter of the pipe.

[b] One expansion point and one contraction point.

B.4 Examples

B.4.1 Main air line

Determine the dimensions of the vacuum air line between receiver and vacuum pump for the plant described in A.6.

The nominal airflow for the pump should be at least 1 260 l/min. The nearest available pump size has a nominal capacity of 1 400 l/min.

The vacuum air line will be in plastics. Table B.1 for smooth pipelines should therefore be used. A design limit for the pressure drop is 2 kPa.

The air line length from pump to receiver is 15 m, consisting of 5 elbows (90° medium radius), one T-piece and a distribution tank.

Table B.1 gives, for a pipeline length of 7,5 m (15 m/2, due to the 2 kPa drop), a diameter of about 45 mm. The nearest pipe diameter is 50 mm.

The elbows, T-piece and tank will restrict the airflow in a similar manner as a piece of straight pipeline (Table B.5, 50 mm tube diameter) having a length of (5 × 0,9) + (1 × 0,9) + (1 × 3,2) = 8,6 m.

The total length of the pipeline for evaluation of the diameter will be: 15 m + 8,6 m = 23,6 m.

Refer back to Table B.1 for a length of 23,6 m/2, that is 11,8 m. The table gives a diameter of about 48 mm.

B.4.2 Pulsator air line

NOTE These calculations are only a crude approximation of the actual situation arising in pulsator air lines. See 6.2.

Determine the dimensions of the looped galvanized pipeline for the plant described in A.6.

Number of pulsators: 12.

Airflow use for each pulsator: 25 l/min.

Length of the pulsator air line: 40 m.

Total airflow use for individual pulsators is: 12 × 25 l/min = 300 l/min.

Where pulsation is so controlled that groups of teatcups pulsate together, the airflow during phase a should be considered as the airflow use for the pulsators.

Cluster removers are connected to the same air line.

Two cluster removers consume: 100 l/min.

Total airflow use in the pulsator air line: 300 l/min + 100 l/min = 400 l/min.

Table B.4 gives a pipe diameter of 27 mm.

Four elbows give a pipe length of about: 4 × 0,7 m, or 3 m.

The new pipe length (43 m) is not significantly more than the 40 m used previously, so the diameter for the 40 m length in Table B.4 is used (see Table B.4).

After increasing the diameter by 5 % to allow for deposits that might restrict the pipe, the pulsator air line diameter should be at least 29 mm but it is usually an advantage to have oversized pulsator air lines. It will lead to a more constant pulsation vacuum.

Annex C
(informative)

Determination of the minimum internal diameter of milklines for cows and water buffaloes

C.1 General

The installer and client should agree on the designed flow conditions based on expected peak milk flow for the herd and the expected rate of unit attachment (see C.2) and on the criteria for airflow and milk flow given in C.3. The design conditions should be summarised and specified as part of the purchase contract. Example calculations are given in C.4.

Milkline vacuum almost always remains stable within ± 2 kPa of the receiver vacuum under stratified flow conditions. Therefore, the performance limit of 2 kPa given in 7.2 essentially means that stratified flow should be the normal flow condition in the milkline for at least 99 % of the milking time.

Factors influencing the effective milk-carrying capacity of a milkline include the following.

a) **Diameter**

Increasing the internal diameter, d, has the greatest single effect. The potential milk-carrying capacity of a milkline is proportional to about d^5.

b) **Slope**

A milkline should have a slope causing milk to flow by gravity under stratified conditions towards the receiver. By increasing the average slope, the influence of gravity increases and reduces the risk of slug flow by reducing the average fill depth for any given milk flow. Smaller variations in the milkline slope do not usually reduce the carrying capacity as long as the average slope is measured over a length not more than 5 m and that that there is continuous slope towards the receiver.

A method of measuring the average slope is given in 7.1 of ISO 6690:2007.

c) **Air admission**

Constant (steady) air admission through air vents and constant leaks has a relatively minor influence on slug formation, over the range of 4 l/min to 12 l/min per unit, compared with the effects of intermittent (transient) airflows. Transient air admission induces slugging at much lower air- and liquid flows compared to the effects of steady air admission.

d) **Looped versus dead-ended milklines**

The benefits of looping the milkline result from the reduction in airflow per slope because the air can flow to the receiver through both arms of the loop in accordance with the easiest flow path.

e) **Length**

When stratified flow is the normal flow condition, milkline length is not limiting and it is not an important design factor for specifying milkline diameter.

f) **Milk inlet**

The guidelines in this annex are based on experimental studies using perpendicular inlets connected at intervals varying from 500 mm to 2 000 mm and fitted to the upper half of the milkline. Spacing of milk inlets appeared to have only a minor influence on the effective milk-carrying capacity over this range. Effective capacity of a milkline might be increased marginally by use of oblique, or tangential oblique, milk inlets mounted so that milk and air enter the line in the direction of flow towards the receiver.

g) **Other components**

Components such as milk meters (especially the fill-and-dump types) may influence instantaneous milk flow into a milkline. The design and action of milk inlet valves may have a marked influence on the instantaneous flow of transient air admitted when a milking unit is moved from one stall to another. The length and bore of long milk tubes, the bore of short milk tubes and the claw design will all affect the amount of transient air admitted when teatcups are attached or detached or when teatcups slip or fall.

Such model-specific factors are not dealt with in this annex. Nevertheless, they should be considered when designing a milkline system to meet the 2 kPa performance limit, especially when the predicted maximum milk flow (see C.2) is near the upper limit for any chosen set of designed milk flow and airflow (see C.3 and C.4).

C.2 Predicted maximum milk flow in milklines

Maximum milk flow can be predicted from typical flow curves for individual animals together with the expected average flows of attachment of milking units. Table C.1 shows examples of the predicted maximum milk flow for a group of cows with an average peak milk flow of 2,5 kg/min, 3 kg/min, 4 kg/min and 5 kg/min per cow and units attached at different intervals. The model for 2,5 kg/min and for 3 kg/min is based on Brazilian crossbreeds of Holstein-Friesian Ger or Zebu while the model for 4 kg/min is based on flow measurements of cows in high-producing Holstein-Friesian herds in France and the USA.

The 4 kg/min model assumes a delay of 30 s from teatcup attachment to the start of the period of peak flow, a peak flow period of 4 kg/min during 120 s and a mean milking time of 5,5 min per cow which corresponds to an average flow of 2,6 kg/min.

The model for the higher mean peak flow is based on the 20 % of cows which were the fastest to be milked in the French and United States herds. Their mean peak milking flow was 5 kg/min per cow. The upper limit of the 95 % confidence interval for this fast-milking group of cows was 5,5 kg/min in the US herds. Although mean peak flow tends to increase slightly with higher herd production, the correlation is weak. The French studies indicate a much stronger association between higher production and increasing duration of the peak flow period.

The model for the lower flow is calculated in a similar way, based on a study of Brazilian herds, and can also be used for sizing milklines for water buffaloes.

As a general guideline, a mean peak flow of 4 kg/min per cow will be sufficient for most herds. In very high-producing herds, or for unusually fast-milking herds, the calculations should be based on a mean peak flow of 5 kg/min per cow. The mean peak flow of cows in any herd can be estimated, if desired, in one or more of the following ways.

a) Average peak milk flow, $\overline{q_{max}}$, in kilograms per minute, is closely correlated (coefficient of correlation, r = 0,81) with the average milk flow, $\overline{q}$, (yield in kilograms per cow divided by her milking time in minutes) of a representative group of cows in accordance with the regression:

$$\overline{q_{max}} = 0,2 + 1,5 \times \overline{q} \qquad \text{(C.1)}$$

b) Average peak milk flow, $\overline{q_{max}}$, in kilograms per minute, is highly correlated (r = 0,92) with the average yield, $\overline{Q_2}$, in kilograms, obtained from a representative group of cows in the first two minutes of milking in accordance with the regression:

$$\overline{q_{max}} = 0{,}5 \times (1 + \overline{Q_2}) \quad \text{(C.2)}$$

c) Average peak milk flow, in kilograms per minute, is numerically equal to the mean quantity of milk, in kilograms, obtained from a representative group of cows in their second minute of milking (r = 0,89).

Table C.1 — Maximum predicted milk flow in milklines

Values in kilograms per minute

Attachment intervals	Milk flow [a]	Maximum milk flow [b] per slope for a number of units per slope of																			
s	kg/min	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
5	2,5	5	10	15	20	24,5	29	33,5	37,5	41											
	3	6	12,5	19	25	31	37	43	48	54											
	4	8	16	24	32	40	48	56	64	72	80	88	96	102	108	114	120	126	132	136	140
	5	10	20	30	40	50	60	70	80	90	100	110	120	126	132	138	144	150	156	160	164
10	2,5	5	10	15	20	24,5	29	33,5	37,5	41											
	3	6	12	18,5	24	30	35	40	45	49											
	4	8	16	24	32	40	48	54	60	66	70	74	78	81	83	85	86,5	86,5			
	5	10	20	30	40	50	60	66	72	78	82	86	90	93	95	97	98,5	98,5			
20	2,5	5	9,5	13	16	19	22	25	26	28											
	3	6	12	17,5	23	27	31	34	36	37											
	4	8	16	24	30	35	39	42	44	44											
	5	10	20	30	35	41	45	48	50	50											
30	2,5	5	9	12	15	17	19	20	21	21											
	3	6	12	16,5	20	23	25	26	26,5	26,5											
	4	8	16	23	28	30	31	31													
	5	10	20	28	33	35	35														
50	2,5	5	8	11	12	13	13														
	3	6	11	14	15	16	16														
	4	8	15	18	19	19															
	5	10	18	21	22	22															
70	2,5	5	7	8	9	9															
	3	6	10	12	12																
	4	8	13	13,5	13,5																
	5	10	15	15,5	15,5																
90	2,5	4	6,5	7,5	7,5																
	3	6	8,5	9	9																
	4	8	11	11																	
	5	10	13	13																	

a Average peak flows per cow.

b Underlined figures indicate maximum flow (more units will not increase the flow).

C.3 Recommended minimum diameters for milklines

The calculations in this section take account of pipeline slope and configuration (looped or dead-ended). The designed airflow conditions are based on steady air admission of 4 l/min up to 12 l/min through air vents and constant leaks, plus the intermittent airflows associated with teatcup attachment, liner slips and teatcup removal. Milk flow in the milkline is due to gravity and the friction between air and milk.

A design guideline of 100 l/min for intermittent airflow into a dead-ended line, or 50 l/min per slope for a looped milkline, is a reasonable allowance for liner slip and cup changing for operators who take care to limit the amount of air admitted during teatcup attachment or removal.

The recommended minimum diameter of the milkline can be derived from Table C.2 together with Table C.1, depending on the expected average peak milking flows of a particular herd and the expected time to attach units.

The values listed in Tables C.2 and C.3 are based on experimental data for pipelines of 48,5 mm, 73 mm and 98 mm internal diameter, and slopes of 0,5 %, 1 % and 2 %. These data were used to derive the following equation for predicting the maximum milk flow to ensure that stratified flow is the normal flow condition during milking (R^2 = 0,97).

$$q_{\mathrm{m}} = 8{,}9 \times 10^{-6} \times \frac{s \times d^5}{q_{\mathrm{at}}} \tag{C.3}$$

where

q_{m} is the milk flow per slope, in litres per minute (l/min);

s is the slope, in percent (%);

d is the internal diameter of pipeline, in millimetres (mm);

q_{at} is the total airflow per slope (steady plus transient air admission), in litres per minute (l/min).

The experimental data were based on a ratio of 10 l/min steady airflow per 4,5 kg/min milk flow per unit, i.e. a ratio of 2,2:1. Changes in the steady air:milk flow ratio between 1,5:1 and 3:1 affected the prediction of the flow transition points by less than 5 %. To simplify the calculations, therefore, a constant ratio 2,2:1 was used to derive the figures in Table C.3 in accordance with Equation (C.4) while, for the lower flows of 2,5 kg/min and 3 kg/min, a ratio of 3,3:1 has been used to derive the figures in Table C.2 in accordance with Equation (C.5).

$$q_{at} = 2{,}2 \times q_{\mathrm{m}} + q_{\mathrm{t}} \tag{C.4}$$

$$q_{at} = 3{,}3 \times q_{\mathrm{m}} + q_{\mathrm{t}} \tag{C.5}$$

where q_{t} is the transient air admission, in litres per minute.

By substitution in Equation (C.3):

$$q_{\mathrm{m}} \times (2{,}2 \times q_{\mathrm{m}} + q_{\mathrm{t}}) - 8{,}9 \times 10^{-6} \times s \times d^5 = 0 \tag{C.6}$$

$$q_{\mathrm{m}} \times (3{,}3 \times q_{\mathrm{m}} + q_{\mathrm{t}}) - 8{,}9 \times 10^{-6} \times s \times d^5 = 0 \tag{C.7}$$

q_{m} is then derived by solving Equations (C.6) and (C.7).

Table C.2 — Maximum milk flow and transient airflow per slope to ensure that stratified flow is the normal flow condition during milking of cows with low peak milk flow ~2,8 kg/min (air to milk ratio 3,3:1)

Values in kilograms per minute

Nominal internal diameter of milkline	Maximum milk flow per slope for a transient airflow per slope of															
	25 l/min				50 l/min				100 l/min				200 l/min			
	Slope, %				**Slope**, %				**Slope**, %				**Slope**, %			
mm	**0,5**	**1**	**1,5**	**2**	**0,5**	**1**	**1,5**	**2**	**0,5**	**1**	**1,5**	**2**	**0,5**	**1**	**1,5**	**2**
38	7	11	15	17	5	9	12	14	3	6	8	10	2	3	5	6
48,5	16	23	29	34	12	20	26	31	9	16	21	26	5	10	14	18
60	29	42	52	61	25	39	49	58	21	33	43	51	14	25	33	41
73	49	71	88	102	45	68	84	98	40	61	78	92	31	50	66	80
98	107	152	187	217	102	149	184	213	96	142	176	206	84	129	163	192

Table C.3 — Maximum milk flow and transient airflow per slope to ensure that stratified flow is the normal flow condition during milking of cows with high peak milk flow ~4,5 kg/min (air to milk ratio 2,2:1)

Values in kilograms per minute

Nominal internal diameter of milkline	Maximum milk flow per slope for a transient airflow per slope of															
	25 l/min				50 l/min				100 l/min				200 l/min			
	Slope, %				**Slope**, %				**Slope**, %				**Slope**, %			
mm	**0,5**	**1**	**1,5**	**2**	**0,5**	**1**	**1,5**	**2**	**0,5**	**1**	**1,5**	**2**	**0,5**	**1**	**1,5**	**2**
38	8	13	17	20	6	10	13	16	3	6	9	11	2	3	5	7
48,5	18	28	35	41	15	24	31	37	10	17	24	29	6	11	16	20
60	34	51	63	74	30	46	58	69	23	38	50	60	15	27	37	46
73	59	86	106	124	54	81	101	118	46	72	92	109	34	57	76	92
98	130	185	228	264	124	180	223	259	114	170	212	248	97	151	193	228

The design conditions in Tables C.2 and C.3 will ensure that stratified milk flow is the normal flow condition in the milkline for at least 99 % of the milking time for the herd. However, these design criteria will not prevent slugging in the milkline when a teatcup falls or is kicked off, unless effective, automatic shut-off valves are used. Airflow inlet during a fall-off without automatic shut-off valves varies between 700 l/min and 1 400 l/min depending on the type of unit and fittings and on the length and bore of the long milk tube. Thus, automatic shut-off valves markedly reduce the risk of slugging by limiting the period of transient air admission to 1 s or less when teatcups fall or are kicked off.

C.4 Example of calculations

Some examples of the maximum number of milking units per slope to ensure stratified flow for selected design criteria are given in Tables C.4 and C.5. To illustrate how the tables were derived, consider the following example for a 12-unit parlour for an average herd, with milking units attached at intervals of 10 s per slope.

Table C.1 indicates a maximum predicted milk flow of 24 kg/min per slope with 6 units on each slope for a herd with a mean peak flow of 4 kg/min per cow.

From Table C.3, one of the following options would meet the minimum design criteria given in C.3 for operators who planned to take reasonable care when attaching teatcups:

a) a looped 48,5 mm milkline with minimum slope of 1 % (i.e. a designed transient airflow of 100 l/min, which is equal to 50 l/min per slope);

b) two dead-ended 48,5 mm milklines with minimum slope of 1,5 % (i.e. a designed transient airflow of 100 l/min).

Table C.4 — Maximum number of units per slope for parlours with 10 s (5 s) attachment rate

Peak milk flow per cow	**Nominal internal diameter**	**50 l/min transient airflow per slope**				**100 l/min transient airflow per slope**				**200 l/min transient airflow per slope**			
		Slope, %				**Slope**, %				**Slope**, %			
kg/min	mm	0,5	1	1,5	2	0,5	1	1,5	2	0,5	1	1,5	2
2,5	38	1	3	4	5	1	2	3	3	0	1	1	2
	48,5	4	8	10	12	3	6	8	10	1	3	5	7
	60	10	16	22	28	8	13	19	23	5	10	13	17
	73	20	34	[a]	[a]	17	30	[a]	[a]	12	22	33	[a]
	98	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]
3	38	1	2	3	4	1	1	2	3	0	1	1	1
	48,5	3	6	8	10	2	5	6	8	1	3	4	6
	60	8	13	18	22	6	11	15	19	4	8	11	14
	73	16	30	[a]	[a]	15	26	[a]	[a]	11	20	31	[a]
	98	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]
4	48,5	3	6	7	9	2	4	6	7	1	2	4	5
	60	7	11	15	19	5	9	12	16	3	6	9	11
	73	14	26	[a] (25)	[a] (31)	11	21	[a] (25)	[a] (31)	8	15	25	[a] (25)
	98	[a] (33)	[a] ([a])	[a] ([a])	[a] ([a])	[a] (30)	[a] (60)	[a] ([a])	[a] ([a])	[a] (24)	[a] (45)	[a] ([a])	[a] ([a])
5	48,5	3	4	6	7	2	3	4	5	1	2	3	4
	60	6	9	11	15	4	7	10	12	3	5	7	9
	73	10	19	[a] (20)	[a] (23)	9	16	25	[a] (21)	6	11	17	25
	98	[a] (25)	[a] (48)	[a] ([a])	[a] ([a])	[a] (22)	[a] (43)	[a] ([a])	[a] ([a])	30	[a] (34)	[a] (58)	[a] ([a])

[a] An unlimited number of milking units and the figures given in parentheses indicate the maximum number of units at a mean attachment rate of 5 s per slope.

Table C.5 — Maximum number of units per slope in stanchion barns with 50 s attachment rate

Peak milk flow per cow	Nominal internal diameter	50 l/min transient airflow per slope		100 l/min transient airflow per slope		200 l/min transient airflow per slope	
		Slope, %		Slope, %		Slope, %	
kg/min	mm	0,5	1	0,5	1	0,5	1
2,5	38	2	4	1	2	0	1
	48,5	6	[a](14)	3	[a](9)	2	3
	60	[a](a)	[a](a)	[a](a)	[a](a)	6	[a](a)
3	38	1	3	1	2	0	1
	48,5	4	[a](8)	3	[a](6)	1	3
	60	[a](12)	[a](a)	[a] (6)	[a](a)	6	[a](12)
	73	[a](a)	[a](a)	[a](a)	[a](a)	[a](a)	[a](a)
4	38	1	2	0	1	0	0
	48,5	4	[a](6)	2	5	1	2
	60	[a](10)	[a](a)	[a](6)	[a](a)	4	[a](7)
	73	[a](a)	[a](a)	[a](a)	[a](a)	[a](a)	[a](a)
5	38	0	2	0	1	0	0
	48,5	3	[a](5)	2	3	1	2
	60	[a](6)	[a](a)	[a](4)	[a](a)	3	[a](5)
	73	[a](a)	[a](a)	[a](a)	[a](a)	[a](8)	[a](a)

[a] An unlimited number of milking units and the figures given in parentheses indicate the maximum number of units at a mean attachment rate of 30 s per slope.

Annex D
(informative)

Small ruminants

D.1 Effective reserve

The minimum effective reserve for milking small ruminants to fulfil the requirements in 5.2.4 is given in Table D.1 and in Tables D.2.1 to D.2.4

Table D.1 — Minimum effective reserve for different types of cluster

Number of units n	Minimum effective reserve [a] l/min of free air	
	Pipelines	**Buckets**
Non-conventional cluster with automatic teatcup valve and automatic cluster removal		
$n \leqslant 10$	200 + 20n	—
> 10	400 + 10(n – 10)	
Non-conventional cluster with automatic teatcup valves		
$n \leqslant 10$	200 + 20n + nE	100 + 20n + nE
> 10	400 + 10(n – 10 + nE)	300 + 10(n – 10) + nE
Conventional cluster with automatic shut-off valve		
$n \leqslant 10$	200 + 20n + 200M	100 + 20n + 100M
> 10	400 + 10(n – 10) + 200M	300 + 10(n – 10) + 100M
Conventional cluster without automatic shut-off valve		
$n \leqslant 10$	200 + 20n + 400M	100 + 20n + 200M
> 10	400 + 10(n – 10) + 400M	300 + 10(n – 10) + 200M

[a] Add the airflow required for ancillary equipment in accordance with A.3.

M = number of milkers.

E = extra airflow needed for clusters equipped with automatic teatcup valves.

Tables D.2.1, D.2.2, D.2.3 and D.2.4 give the calculated effective reserve derived from formulas in Table D.1 for different numbers of milking units between 2 and 36. For more than 36 milking units, the formulae in Table D.1 can be used.

Table D.2.1 — Minimum effective reserve — Conventional clusters without automatic shut-off valves

Values in litres per minute of free air

Number of units	Minimum effective reserve			
	Pipeline milking machines		Bucket milking machines	
	M = 1	M = 2	M = 1	M = 2
2	640	1 040	340	540
3	660	1 060	360	560
4	680	1 080	380	580
5	700	1 100	400	600
6	720	1 120	420	620
7	740	1 140	440	640
8	760	1 160	460	660
9	780	1 180	480	680
10	800	1 200	500	700
11	810	1 210	510	710
12	820	1 220	520	720
13	830	1 230	530	730
14	840	1 240	540	740
15	850	1 250	550	750
16	860	1 260	560	760
17	870	1 270	570	770
18	880	1 280	580	780
19	890	1 290	590	790
20	900	1 300	600	800
21	910	1 310		
22	920	1 320		
23	930	1 330		
24	940	1 340		
25	950	1 350		
26	960	1 360		
27	970	1 370		
28	980	1 380		
29	990	1 390		
30	1 000	1 400		
31	1 010	1 410		
32	1 020	1 420		
33	1 030	1 430		
34	1 040	1 440		
35	1 050	1 450		
36	1 060	1 460		
M = number of milkers.				

Table D.2.2 — Minimum effective reserve — Conventional clusters with automatic shut-off valves

Values in litres per minute of free air

Number of units	Minimum effective reserve			
	Pipeline milking machines		Bucket milking machines	
	M = 1	M = 2	M = 1	M = 2
2	440	640	240	340
3	460	660	260	360
4	480	680	280	380
5	500	700	300	400
6	520	720	320	420
7	540	740	340	440
8	560	760	360	460
9	580	780	380	480
10	600	800	400	500
11	610	810	410	510
12	620	820	420	520
13	630	830	430	530
14	640	840	440	540
15	650	850	450	550
16	660	860	460	560
17	670	870	470	570
18	680	880	480	580
19	690	890	490	590
20	700	900	500	600
21	710	910		
22	720	920		
23	730	930		
24	740	940		
25	750	950		
26	760	960		
27	770	970		
28	780	980		
29	790	990		
30	800	1 000		
31	810	1 010		
32	820	1 020		
33	830	1 030		
34	840	1 040		
35	850	1 050		
36	860	1 060		

M = number of milkers.

Table D.2.3 — Minimum effective reserve — Non-conventional cluster with automatic teatcup valves

Values in litres per minute of free air

Number of units	Minimum effective reserve			
	Pipeline milking machines		Bucket milking machines	
	E = 20 l/min	E = 40 l/min	E = 20 l/min	E = 40 l/min
2	280	320	180	220
3	320	380	220	280
4	360	440	260	340
5	400	500	300	400
6	440	560	340	460
7	480	620	380	520
8	520	680	420	580
9	560	740	460	640
10	600	800	500	700
11	630	850	530	750
12	660	900	560	800
13	690	950	590	850
14	720	1 000	620	900
15	750	1 050	650	950
16	780	1 100	680	1 000
17	810	1 150	710	1 050
18	840	1 200	740	1 100
19	870	1 250	770	1 150
20	900	1 300	800	1 200
21	930	1 350		
22	960	1 400		
23	990	1 450		
24	1 020	1 500		
25	1 050	1 550		
26	1 080	1 600		
27	1 110	1 650		
28	1 140	1 700		
29	1 170	1 750		
30	1 200	1 800		
31	1 230	1 850		
32	1 260	1 900		
33	1 290	1 950		
34	1 320	2 000		
35	1 350	2 050		
36	1 380	2 100		

E = Extra airflow needed for clusters equipped with automatic teatcup valves.

Table D.2.4 — Minimum effective reserve — Non-conventional clusters with automatic teatcup valves and automatic cluster removal (pipeline milking machines)

Values in litres per minute of free air

Number of units	Minimum effective reserve
2	240
3	260
4	280
5	300
6	320
7	340
8	360
9	380
10	400
11	410
12	420
13	430
14	440
15	450
16	460
17	470
18	480
19	490
20	500
21	510
22	520
23	530
24	540
25	550
26	560
27	570
28	580
29	590
30	600
31	610
32	620
33	630
34	640
35	650
36	660

D.2 Predicted maximum milk flow in milklines

Maximum milk flow in milklines can be predicted from typical flow curves for individual animals together with the expected average interval of attachment of milking units. It is not possible to make special calculations for each breed, thus two kinds of milking times (less than 120 s and more than 120 s) with 3 kinds of milk flow curve, corresponding to typical breeds of sheep and goats, have been chosen for calculations. Table D.3 is a non-exhaustive list of different breeds of sheep and goats classified according to typical maximum milk flow and milking time.

Table D.3 — Breeds of sheep and goats classified according to typical peak milk flow and milking time

Typical peak flow kg/min	**Typical milking time**	
	Short (⩽ 120 s)	**Long** (> 120 s)
	Sheep	
0,8	Lacaune	
1,3	Manchega, Churra, Latxa, East Friesian	
2,7	Sardinian	
	Goats	
0,8	Murciano-Granadina	Saanen
1,3	Canaria (2 milkings/day)	Alpine, Canaria (1 milking/day)

Table D.4 shows examples of the predicted peak milk flow of a group of sheep and/or goats with mean peak milking flow of 0,8 kg/min, 1,3 kg/min and 2,7 kg/min, for short and long milking times and for units attached at intervals of 5 s, 10 s, 15 s and 20 s.

Table D.4 —Maximum predicted milk flow in milklines

Values in kilograms per minute

Attachment intervals	Milk flow [a]	Maximum milk flow for a number of units per slope of																			
s	kg/min	2	3	4	5	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36
Short milking times (⩽ 120 s)																					
5	0,8	1,6	2,4	3,2	4,0	4,8	6,2	7,3	8,2	8,7	9,0	9,2	9,2	9,2	9,2	9,2	9,2	9,2	9,2	9,2	9,2
	1,3	2,6	3,9	5,2	6,2	7,1	8,4	9,1	9,6	9,9	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0
	2,7	5,4	7,7	9,9	11,7	13,2	15,5	16,6	17,2	17,3	17,3	17,3	17,3	17,3	17,3	17,3	17,3	17,3	17,3	17,3	17,3
10	0,8	1,6	2,4	3,1	3,7	4,1	4,5	4,6	4,6	4,6	4,6	4,6	4,6	4,6	4,6	4,6	4,6	4,6	4,6	4,6	4,6
	1,3	2,6	3,6	4,2	4,6	4,9	5,1	5,2	5,2	5,2	5,2	5,2	5,2	5,2	5,2	5,2	5,2	5,2	5,2	5,2	5,2
	2,7	5,0	6,8	7,8	8,3	8,7	8,8	8,8	8,8	8,8	8,8	8,8	8,8	8,8	8,8	8,8	8,8	8,8	8,8	8,8	8,8
15	0,8	1,6	2,3	2,8	3,1	3,1	3,1	3,1	3,1	3,1	3,1	3,1	3,1	3,1	3,1	3,1	3,1	3,1	3,1	3,1	3,1
	1,3	2,6	3,0	3,4	3,5	3,6	3,6	3,6	3,6	3,6	3,6	3,6	3,6	3,6	3,6	3,6	3,6	3,6	3,6	3,6	3,6
	2,7	4,5	5,6	5,9	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0
20	0,8	1,6	2,1	2,3	2,4	2,4	2,4	2,4	2,4	2,4	2,4	2,4	2,4	2,4	2,4	2,4	2,4	2,4	2,4	2,4	2,4
	1,3	2,3	2,6	2,7	2,7	2,7	2,7	2,7	2,7	2,7	2,7	2,7	2,7	2,7	2,7	2,7	2,7	2,7	2,7	2,7	2,7
	2,7	4,1	4,4	4,4	4,4	4,4	4,4	4,4	4,4	4,4	4,4	4,4	4,4	4,4	4,4	4,4	4,4	4,4	4,4	4,4	4,4
Long milking times (> 120 s)																					
5	0,8	1,6	2,4	3,2	4,0	4,8	6,4	8,0	9,6	11,2	12,8	14,4	16,0	17,6	19,0	20,1	21,0	21,7	22,1	22,3	22,4
	1,3	2,6	3,9	5,2	6,5	7,8	10,4	13,0	15,6	18,2	20,1	21,3	22,3	23,0	23,6	24,0	24,2	24,2	24,2	24,2	24,2
	2,7	5,4	8,1	10,8	13,5	16,2	21,3	25,2	28,2	30,0	31,1	31,4	31,4	31,4	31,4	31,4	31,4	31,4	31,4	31,4	31,4
10	0,8	1,6	2,4	3,2	4,0	4,8	6,4	8,0	9,5	10,6	11,1	11,4	11,4	11,4	11,4	11,4	11,4	11,4	11,4	11,4	11,4
	1,3	2,6	3,9	5,2	6,5	7,8	10,4	11,5	12,1	12,4	12,4	12,4	12,4	12,4	12,4	12,4	12,4	12,4	12,4	12,4	12,4
	2,7	5,4	8,1	10,8	12,6	14,2	15,8	16,0	16,0	16,0	16,0	16,0	16,0	16,0	16,0	16,0	16,0	16,0	16,0	16,0	16,0
15	0,8	1,6	2,4	3,2	4,0	4,8	6,4	7,3	7,6	7,6	7,6	7,6	7,6	7,6	7,6	7,6	7,6	7,6	7,6	7,6	7,6
	1,3	2,6	3,9	5,2	6,5	6,8	7,6	8,1	8,2	8,2	8,2	8,2	8,2	8,2	8,2	8,2	8,2	8,2	8,2	8,2	8,2
	2,7	5,4	8,1	10,8	12,3	13,1	13,1	13,1	13,1	13,1	13,1	13,1	13,1	13,1	13,1	13,1	13,1	13,1	13,1	13,1	13,1
20	0,8	1,6	2,4	3,2	4,0	4,8	6,1	6,5	6,5	6,5	6,5	6,5	6,5	6,5	6,5	6,5	6,5	6,5	6,5	6,5	6,5
	1,3	2,6	3,9	5,2	5,8	6,2	6,4	6,4	6,4	6,4	6,4	6,4	6,4	6,4	6,4	6,4	6,4	6,4	6,4	6,4	6,4
	2,7	5,4	7,9	9,3	10,2	10,7	10,7	10,7	10,7	10,7	10,7	10,7	10,7	10,7	10,7	10,7	10,7	10,7	10,7	10,7	10,7

[a] Average peak flow per sheep/goat for different attachment intervals.

D.3 Recommended minimum diameter for milklines

It is presumed that Equation (C.3) for cattle applies to small ruminants when the ratio between steady airflow and milk flow is chosen according to milking conditions of these species.

For small ruminants, peak flow and milking time show greater differences between species, and even within species between breeds, than is the case for dairy cattle. Furthermore, some goat breeds have similar milking characteristics to dairy sheep breeds (high peak flow rate and short milking time) and vice versa.

Thus, Equation (C.3) is applied for three different ratios based on 8 l/min steady airflow per unit and three milk flows: 0,8 kg/min for species and breeds with low peak milk flows, 1,3 kg/min for species and breeds with medium peak milk flows and 2,7 kg/min for species and breeds with high peak milk flows. This gives three air to milk flow ratios: 10:1, 6,15:1 and 3:1.

Table D.5 gives the maximum milk flow per slope to ensure that stratified flow is the normal condition during milking for the three ratios, in relationship with transient airflow and slope of the milkline.

Table D.5 — Maximum milk flow and transient airflow per slope to ensure that stratified flow is the normal flow condition during milking

Values in kilograms per minute

Milkline nominal internal diameter mm	Maximum milk flow for a transient airflow of																			
	25 l/min				50 l/min				100 l/min				200 l/min				400 l/min			
	Slope, %				Slope, %				Slope, %				Slope, %				Slope, %			
	0,5	1	1,5	2	0,5	1	1,5	2	0,5	1	1,5	2	0,5	1	1,5	2	0,5	1	1,5	2
Airflow/milk flow ratio = 10:1																				
38	5	7	9	11	4	6	8	10	3	5	6	8	2	3	4	6	1	2	2	3
48,5	10	14	18	21	9	13	17	19	7	11	15	17	5	8	11	14	3	5	8	10
60	17	25	31	36	16	24	30	35	14	22	28	33	11	18	24	29	7	13	18	22
73	29	42	51	60	28	41	50	58	26	38	48	56	22	34	44	52	16	27	36	44
Airflow/milk flow ratio = 6,15:1																				
38	6	9	11	13	4	7	10	11	3	5	7	9	2	3	5	6	1	2	3	3
48,5	12	17	22	26	10	16	20	24	8	13	17	21	5	9	13	16	3	5	8	10
60	21	31	38	45	20	29	37	43	17	26	33	39	12	21	27	33	8	14	20	25
73	36	52	64	74	34	50	62	72	31	46	59	69	25	40	52	62	18	31	41	51
Airflow/milk flow ratio = 3:1																				
38	7	12	15	18	5	9	12	15	3	6	8	11	2	3	5	6	1	2	3	3
48,5	16	24	31	36	13	21	27	32	9	16	22	27	6	10	15	19	3	6	8	11
60	30	44	55	64	27	41	51	60	21	34	44	53	14	25	34	42	8	15	22	28
73	51	74	92	107	48	70	88	103	41	63	81	95	31	52	68	82	20	36	50	63

Tables D.6 to D.11 give the maximum number of units per slope for milking installations that ensures that stratified flow is the normal condition in the milkline.

The calculations take into account pipeline slope, configuration of the milkline (looped or dead-ended) and type of cluster.

The designed airflow conditions are based on a steady air admission of 8 l/min through air vents and constant leaks, plus intermittent airflows associated with cluster attachment, liner slips and cluster removal. To simplify calculations for non-conventional clusters with automatic teatcup valves, only the case when all units are working together may be considered. This is the condition with the maximum milk flow, but only with steady air coming from air vents and leaks. Extra air used by units not on duty is not taken into account. However, calculations take into account transient air, which normally doesn't exist because of the design of the system.

The proposed guidelines for transient air are consistent with calculation of the effective reserve and are as follows:

— for conventional clusters without an automatic shut-off valve: 400 l/min for intermittent airflow into a dead-ended line or 200 l/min per slope for a looped milkline;

— for conventional clusters with automatic shut-off valve: 200 l/min for intermittent airflow into a dead-ended line or 100 l/min per slope for a looped milkline;

— for non-conventional clusters (with automatic teatcup valves): 50 l/min for intermittent airflow into a dead-ended line or 25 l/min per slope for a looped milkline.

The recommended minimum diameter of the milkline can be derived from Table D.5 together with Table D.4.

Calculations are made for an attachment interval of 5 s and 10 s.

Table D.6 — Maximum number of units per slope for three peak milking flows — Conventional cluster without automatic shut-off valve

Attachment interval of 5 s (10 s within parentheses) — Animals with short (⩽ 120 s) milking times

Milkline type	Nominal internal diameter mm	Maximum number of units for a slope of			
		0,5 %	**1** %	**1,5** %	**2** %
Peak flow per animal = 0,8 kg/min					
looped	38	2 (2)	3 (3)	5 (5)	7 (a)
	48,5	6 (a)	11 (a)	a (a)	a (a)
	60	a (a)	a (a)	a (a)	a (a)
	73	a (a)	a (a)	a (a)	a (a)
dead-ended	38	1 (1)	2 (2)	2 (2)	3 (3)
	48,5	3 (3)	6 (a)	11 (a)	a (a)
	60	9 (a)	a (a)	a (a)	a (a)
	73	a (a)	a (a)	a (a)	a (a)
Peak flow per animal = 1,3 kg/min					
looped	38	1 (1)	2 (2)	3 (7)	4 (a)
	48,5	3 (7)	9 (a)	a (a)	a (a)
	60	a (a)	a (a)	a (a)	a (a)
	73	a (a)	a (a)	a (a)	a (a)
dead-ended	38	1 (1)	1 (1)	2 (2)	2 (2)
	48,5	2 (2)	3 (7)	7 (a)	a (a)
	60	7 (a)	a (a)	a (a)	a (a)
	73	13 (a)	a (a)	a (a)	a (a)
Peak flow per animal = 2,7 kg/min					
looped	38	1 (1)	1 (1)	1 (1)	2 (2)
	48,5	1 (1)	4 (a)	7 (a)	a (a)
	60	6 (a)	a (a)	a (a)	a (a)
	73	a (a)	a (a)	a (a)	a (a)
dead-ended	38	1 (1)	1 (1)	1 (1)	1 (1)
	48,5	1 (1)	2 (2)	3 (4)	4 (a)
	60	3 (4)	7 (a)	a (a)	a (a)
	73	7 (a)	a (a)	a (a)	a (a)

NOTE The figures given in parentheses indicate the maximum number of units per slope at a mean attachment interval of 10 s per slope.

[a] An unlimited number of milking units is possible.

Table D.7 — Maximum number of units per slope for three peak milking flows — Conventional cluster with automatic shut-off valve

Attachment interval of 5 s (10 s within parentheses) — Animals with short (⩽ 120 s) milking times

Milkline type	Nominal internal diameter mm	Maximum number of units for a slope of 0,5 %	1 %	1,5 %	2 %
Peak flow per animal = 0,8 kg/min					
looped	38	3 (3)	6 (a)	7 (a)	11 (a)
	48,5	9 (a)	a (a)	a (a)	a (a)
	60	a (a)	a (a)	a (a)	a (a)
	73	a (a)	a (a)	a (a)	a (a)
dead-ended	38	2 (2)	3 (3)	5 (5)	7 (a)
	48,5	6 (a)	11 (a)	a (a)	a (a)
	60	a (a)	a (a)	a (a)	a (a)
	73	a (a)	a (a)	a (a)	a (a)
Peak flow per animal = 1,3 kg/min					
looped	38	2(2)	3 (7)	4 (a)	7(a)
	48,5	7 (a)	a (a)	a (a)	a (a)
	60	a (a)	a (a)	a (a)	a (a)
	73				
dead-ended	38	1 (1)	2 (2)	3 (7)	4 (a)
	48,5	3 (7)	9 (a)	a (a)	a (a)
	60	a (a)	a (a)	a (a)	a (a)
	73	a (a)	a (a)	a (a)	a (a)
Peak flow per animal = 2,7 kg/min					
looped	38	1 (1)	1(1)	2(2)	3(4)
	48,5	2(3)	4 (a)	7 (a)	a (a)
	60	6(a)	a (a)	a (a)	a (a)
	73	a (a)	a (a)	a (a)	a (a)
dead-ended	38	1(1)	1 (1)	1(1)	2 (2)
	48,5	1(1)	4 (a)	7 (a)	a (a)
	60	6 (a)	a (a)	a (a)	a (a)
	73	a (a)	a (a)	a (a)	a (a)

NOTE The figures given in parentheses indicate the maximum number of units per slope at a mean attachment interval of 10 s per slope.

[a] An unlimited number of milking units is possible.

Table D.8 — Maximum number of units per slope for three peak milking flows — Non-conventional cluster with automatic teatcup valve

Attachment interval of 5 s (10 s within parentheses) — Animals with short (⩽ 120 s) milking times

Milkline type	Nominal internal diameter mm	Maximum number of units for a slope of			
		0,5 %	**1** %	**1,5** %	**2** %
Peak flow per animal = 0,8 kg/min					
looped	38	6 (a)	9 (a)	16 (a)	a (a)
	48,5	a (a)	a (a)	a (a)	a (a)
	60	a (a)	a (a)	a (a)	a (a)
	73	a (a)	a (a)	a (a)	a (a)
dead-ended	38	5(5)	7 (a)	11 (a)	a (a)
	48,5	16 (a)	a (a)	a (a)	a (a)
	60	a (a)	a (a)	a (a)	a (a)
	73	a (a)	a (a)	a (a)	a (a)
Peak flow per animal = 1,3 kg/min					
looped	38	4 (a)	9 (a)	a (a)	a (a)
	48,5	a (a)	a (a)	a (a)	a (a)
	60	a (a)	a (a)	a (a)	a (a)
	73	a (a)	a (a)	a (a)	a (a)
dead-ended	38	3 (3)	5 (a)	a (a)	a (a)
	48,5	a (a)	a (a)	a (a)	a (a)
	60	a (a)	a (a)	a (a)	a (a)
	73	a (a)	a (a)	a (a)	a (a)
Peak flow per animal = 2,7 kg/min					
looped	38	2 (2)	5 (a)	7 (a)	a (a)
	48,5	8 (a)	a (a)	a (a)	a (a)
	60	a (a)	a (a)	a (a)	a (a)
	73	a (a)	a (a)	a (a)	a (a)
dead-ended	38	1 (2)	3 (a)	5 (a)	7 (a)
	48,5	5 (a)	a (a)	a (a)	a (a)
	60	a (a)	a (a)	a (a)	a (a)
	73	a (a)	a (a)	a (a)	a (a)

NOTE The figures given in parentheses indicate the maximum number of units per slope at a mean attachment interval of 10 s per slope.

[a] An unlimited number of milking units is possible.

Table D.9 — Maximum number of units per slope for three peak milking flows — Conventional cluster without automatic shut-off valves

Attachment interval of 5 s (10 s within parentheses) — Animals with long (> 120 s) milking times

Milkline type	Nominal internal diameter mm	Maximum number of units for a slope of 0,5 %	1 %	1,5 %	2 %
Peak flow per animal = 0,8 kg/min					
looped	38	2 (2)	3 (3)	5 (5)	7 (7)
	48,5	6 (6)	10 (10)	13 (15)	17(a)
	60	13 (15)	22 (a)	a (a)	a (a)
	73	a (a)	a (a)	a (a)	a (a)
dead-ended	38	1 (1)	2 (2)	2 (2)	3 (3)
	48,5	3 (3)	6 (6)	10 (10)	12 (13)
	60	8 (8)	16 (a)	22 (a)	31 (a)
	73	20 (a)	a (a)	a (a)	a (a)
Peak flow per animal = 1,3 kg/min					
looped	38	1 (1)	2 (2)	3 (3)	4 (4)
	48,5	3 (3)	6 (6)	8 (9)	10 (a)
	60	8 (9)	13 (a)	a (a)	a (a)
	73	31 (a)	a (a)	a (a)	a (a)
dead-ended	38	1 (1)	1 (1)	1 (1)	2 (2)
	48,5	2 (2)	3 (3)	6 (6)	7 (7)
	60	5 (5)	10 (a)	13 (a)	19 (a)
	73	12 (a)	a (a)	a (a)	a (a)
Peak flow per animal = 2,7 kg/min					
looped	38	1 (1)	1 (1)	1 (1)	2 (2)
	48,5	2 (2)	3 (3)	5 (7)	7(a)
	60	5 (5)	9 (a)	a (a)	a (a)
	73	15 (a)	a (a)	a (a)	a (a)
dead-ended	38	1 (1)	1 (1)	1 (1)	1 (1)
	48,5	1 (1)	2 (2)	2 (2)	4 (4)
	60	2 (2)	5 (7)	8 (a)	11 (a)
	73	7 (a)	a (a)	a (a)	a (a)

NOTE The figures given in parentheses indicate the maximum number of units per slope at a mean attachment interval of 10 s per slope.

a An unlimited number of milking units is possible.

Table D.10 — Maximum number of units per slope for three peak milking flows — Conventional cluster with automatic shut-off valve

Attachment interval of 5 s (10 s within parentheses) — Animals with long (> 120 s) milking times

Milkline type	Nominal internal diameter mm	Maximum number of units for a slope of			
		0,5 %	**1** %	**1,5** %	**2** %
Peak flow per animal = 0,8 kg/min					
looped	38	3 (3)	6 (6)	7 (7)	10 (10)
	48,5	8 (8)	13 (15)	18 (a)	21 (a)
	60	17 (a)	31 (a)	a (a)	a (a)
	73	a (a)	a (a)	a (a)	a (a)
dead-ended	38	2 (2)	3 (3)	5 (5)	7 (7)
	48,5	6 (6)	10 (10)	13 (15)	17 (a)
	60	13 (15)	22 (a)	a (a)	a (a)
	73	a (a)	a (a)	a (a)	a (a)
Peak flow per animal = 1,3 kg/min					
looped	38	2 (2)	3 (3)	5 (5)	6 (6)
	48,5	6 (6)	10 (a)	13 (a)	17 (a)
	60	13 (a)	a (a)	a (a)	a (a)
	73	a (a)	a (a)	a (a)	a (a)
dead-ended	38	1 (1)	2 (2)	3 (3)	4 (4)
	48,5	3 (3)	6 (6)	8 (9)	10 (a)
	60	8 (9)	13 (a)	a (a)	a (a)
	73	a (a)	a (a)	a (a)	a (a)
Peak flow per animal = 2,7 kg/min					
looped	38	1 (1)	2 (2)	2 (2)	4 (4)
	48,5	3 (3)	5 (a)	8 (a)	11 (a)
	60	7 (a)	a (a)	a (a)	a (a)
	73	a (a)	a (a)	a (a)	a (a)
dead-ended	38	1 (1)	1 (1)	1 (1)	2 (2)
	48,5	2 (2)	3 (3)	5 (7)	7 (a)
	60	5 (5)	9 (a)	a (a)	a (a)
	73	15 (a)	a (a)	a (a)	a (a)

NOTE The figures given in parentheses indicate the maximum number of units per slope at a mean attachment interval of 10 s per slope.

[a] An unlimited number of milking units is possible.

Table D.11 — Maximum number of units per slope for three peak milking flows — Non-conventional cluster with automatic teatcup valve

Attachment interval of 5 s (10 s within parentheses) — Animals with long (> 120 s) milking times

Milkline type	Nominal internal diameter mm	Maximum number of units for a slope of			
		0,5 %	**1** %	**1,5** %	**2** %
Peak flow per animal = 0,8 kg/min					
looped	38	6 (6)	8 (8)	11 (11)	13 (15)
	48,5	12 (13)	17 (a)	22 (a)	28 (a)
	60	21 (a)	a (a)	a (a)	a (a)
	73	a (a)	a (a)	a (a)	a (a)
dead-ended	38	5 (5)	7 (7)	10 (10)	12 (13)
	48,5	11 (11)	16 (a)	21 (a)	24 (a)
	60	20 (a)	a (a)	a (a)	a (a)
	73	a (a)	a (a)	a (a)	a (a)
Peak flow per animal = 1,3 kg/min					
looped	38	4 (4)	6 (6)	8 (9)	10 (a)
	48,5	9 (11)	13 (a)	19 (a)	a (a)
	60	17 (a)	a (a)	a (a)	a (a)
	73	a (a)	a (a)	a (a)	a (a)
dead-ended	38	3 (3)	5 (5)	7 (7)	8 (9)
	48,5	7 (7)	12 (a)	15 (a)	26 (a)
	60	15 (a)	a (a)	a (a)	a (a)
	73	a (a)	a (a)	a (a)	a (a)
Peak flow per animal = 2,7 kg/min					
looped	38	2 (2)	4 (4)	5 (7)	6 (a)
	48,5	5 (a)	9 (a)	15 (a)	a (a)
	60	14 (a)	a (a)	a (a)	a (a)
	73	a (a)	a (a)	a (a)	a (a)
dead-ended	38	1 (1)	3 (3)	4 (4)	5 (7)
	48,5	4 (5)	7 (a)	11 (a)	a (a)
	60	11 (a)	a (a)	a (a)	a (a)
	73	a (a)	a (a)	a (a)	a (a)

NOTE The figures given in parentheses indicate the maximum number of units per slope at a mean attachment interval of 10 s per slope.

a An unlimited number of milking units is possible.

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