

EPC Storage Guidelines

Recommendations on the design, installation and operation of fuel stores for pellet heating appliances

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1 Introduction

Pellet heating systems are a fairly new technology. Consequently there may be problems caused by the lack of experience with this technology. This also applies to pellet storage installations. Pellet stores have to fulfil a number of requirements to make sure that the pellet quality is maintained and safe operation is guaranteed.

The ENplus storage guideline describes the requirements to preserve fuel quality and provide safe storage of pellets for both professionals (such as installers) and consumers. It covers the technical properties of pellet stores as well as information on safe and adequate operation of these stores. They do not replace installation guidelines and instructions from pellet boiler/storage **manufacturers** but do take precedence over advice from installers/distributors. Planning aids and filling regulations from manufacturers of pellet storage, extraction systems and pellet boilers **must be** followed.

Professional practices are the cornerstone of successful market development.

2 Heating with wood pellets – General information

2.1 Pellet quality – what you should bear in mind

Wood pellets are a modern, eco-friendly and standardised wood fuel. Wood pellets are mainly pressed from bark-free wood residues from the wood-processing industry. During the pressing process, the lignin of the wood is activated and ensures the mechanical durability of the pellets, potentially aided by natural binding agents like starch. However, the durability is still lower than with other bulk materials. Logistic processes have to consider the high sensitivity of pellets to mechanical stress. Smooth pellet deliveries as well as properly designed stores are essential conditions for trouble-free heating with pellets.

2.2 ENplus – certified pellet quality

Pellets should only be bought from ENplus-certified sources. In contrast to other certificates, only ENplus covers the whole supply chain, including pellet production as well as the distribution. A list of certified companies as well as further information on pellet quality is available from www.enplus-pellets.eu.

The international standard, ISO 17225-2, defines the main product properties for different pellet quality classes. The classes differ primarily in the ash content and the ash melting behaviour (see Table 1). Both properties are important for reliable stove and boiler operation. Low ash content and high melting temperatures prevent sintering of the ash (forming of solid slag). The certification program ENplus has defined binding limits for the ash melting behaviour whereas the ISO standard does not.

The quality classes ENplus A1, ENplus A2 and ENplus B fulfil and exceed the corresponding quality classes of the standard. ENplus A1 is best in class and is highly recommended for small boilers. ENplus A2 which shows slightly lower requirements than ENplus A1 (mainly ash content) are suitable for quality tolerant appliances. ENplus B quality should be suitable for larger boilers (> 100 kW), but its use must be approved by the boiler manufacturer.

Table 1: Main properties of certified wood pellets^[GG1]

Property	Unit	ENplus A1	ENplus A2	ENplus B	Testing standard ⁷⁾
Diameter	mm	6 ± 1 or 8 ± 1			ISO 17829
Length	mm	3,15 < L ≤ 40 ⁴⁾			ISO 17829
Moisture	w-% ²⁾	≤ 10			ISO 18134
Ash	w-% ³⁾	≤ 0,7	≤ 1,2	≤ 2,0	ISO 18122
Mechanical Durability	w-% ²⁾	≥ 97,5			ISO 17831-1
Fines (< 3,15 mm)	w-% ²⁾	≤ 1,0 ⁵⁾			ISO 18846
Net Calorific Value	kWh/kg ²⁾	≥ 4,6			ISO 18125
Bulk Density	kg/m ³ ²⁾	600 ≤ BD ≤ 750			ISO 17828
Additives	w-% ²⁾	≤ 2 ⁶⁾			-
Nitrogen	w-% ³⁾	≤ 0,3	≤ 0,5	≤ 1,0	ISO 16948
Sulfur	w-% ³⁾	≤ 0,04	≤ 0,05		ISO 16994
Chlorine	w-% ³⁾	≤ 0,02		≤ 0,03	ISO 16994
Ash Deformation Temperature ¹⁾	°C	≥ 1200	≥ 1100		CEN/TC 15370-1
Arsen, As	mg/kg ³⁾	≤ 1			ISO 16968
Cadmium	mg/kg ³⁾	≤ 0,5			ISO 16968
Chromium	mg/kg ³⁾	≤ 10			ISO 16968
Copper	mg/kg ³⁾	≤ 10			ISO 16968
Lead	mg/kg ³⁾	≤ 10			ISO 16968
Mercury	mg/kg ³⁾	≤ 0,1			ISO 16968
Nickel	mg/kg ³⁾	≤ 10			ISO 16968
Zinc	mg/kg ³⁾	≤ 100			ISO 16968

2.3 Pellet deliveries – quality and safety issues

Wood pellets should be delivered using specialist silo vehicles. The vehicles are equipped with a device that provides compressed air for the transport of the pellets through a hose (blowing).

At shorter blowing distances it is useful to blow the pellets with higher pressure and just small amounts of air. This increases the solids loading factor (the ratio of pellets to air in the delivery pipe), while for longer distances or more bends the solids loading factor has to be reduced. The driver should choose the appropriate setting of pressure and blowing air on-site according to the specific conditions.

The delivery vehicle is also equipped with a calibrated on-board weighing system, coated hoses to minimize abrasion and an exhaust ventilator with a filter bag that is used to create a slight vacuum in the store. If the storage room is not airtight, no vacuum is created and air with dust particles will escape and can be a nuisance.

Many prefabricated stores do not need suction to be applied during delivery. In this case, the blowing air (up to 1500 m³/h) must exit through windows, doors or other openings. In order to enable the pellets to

be blown safely and with minimal damage, the operator of the heating system should respect the following:

- The filling instructions for the storage should be clearly visible for the pellet delivery driver
- The heating system should be turned off according to manufacturer instructions or at least one hour before delivery.

ENplus-certified pellet traders create and hand over a delivery record that contains all the important information on the pellets, the store and the blowing process.

The customer must turn off the boiler before the pellets are delivered. The exact timing should be included in the boiler manufacturers' instructions. The pellet supplier must be able to verify that the boiler is off. Otherwise the pellet supplier, for legal reasons, cannot make the delivery. Exception: the customer confirms in writing that the boiler manufacturer allows for pellet delivery without the boiler being turned off.

2.4 Pellet fines – small troublemakers

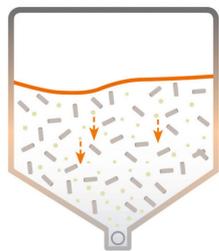
Fines refer to fragments of broken pellets that fall through a sieve with holes of 3.15 mm diameter. A partly high amount of fines may cause problems with the boiler or the pellet retrieval system.

Fines in the pellet store are caused mainly by mechanical stress during pellet delivery. Bends in the pipework, inadequate impact mats, obstacles in the route of the pellets, a high pellet velocity and a low solids loading factor during delivery, all increase the amount of fines.

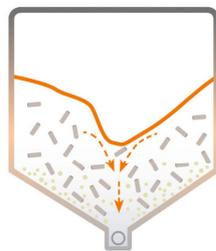
High fines at the boiler may also be due to damage from the extract system taking pellets from the store to the boiler. Through particle segregation processes in the store, fines will concentrate over time on the bottom of the pellet store (Figure 1). To ensure a smooth operation of the boiler, the storage should be emptied and cleaned completely at least once in the [previous two years](#)^[GG2]. This is best done in the summer.

[ENplus-certified suppliers accept complaints of more than 4 percent fines in the store under the following conditions:](#)^[GG3]

- blowing distance (including internal duct) < 30 m
- Compliance with this storage guideline
- Residual amount of pellets before delivery was less than ten percent of storage capacity
- Maximum of twenty percent of the new delivery has been used
- The frequency of the cleaning of stores has to be based on the annual consumption. Stores with an annual consumption of ≤ 15 metric tons have to be cleaned once every two years. Stores with an annual consumption > 15 tons have to be cleaned once per year. Entering in a storage room always presents a significant safety risk. For this reason, the number of interventions should be minimised and strict safety rules have to be observed (see chapter 7: for your safety).



Segregation of fines and pellets



Core-flow as pellets are extracted;
- the upper pellets are extracted first
- separated fines accumulate on the slopes and at the bottom of the store

© Deutsches Pelletinstitut

Quelle: Deutsches Pelletinstitut (DEPI)

Figure 1 Illustration of particle segregation that leads to an increasing amount of fines in the lower part of a sloping floor store

N.B. Particle segregation will occur during delivery and the results can also be seen typically with the 'face' of a slope of pellets appearing dusty – the appearance of a dusty 'face' DOES NOT mean the pellets are outside the ENplus specification.

2.5. Off-gassing and odour from wood

Fresh pellets may lead to an unpleasant odour in the storage. This smell usually disappears within a few weeks. The odour comes from the so called off-gassing of wood materials. Off-gassing includes emissions from natural organic compounds as well as emissions from the slow natural decomposition of the wood.

Compared to other wood products, wood pellets have a larger surface and the cellular structure has been under heavy stress during production. This may result in faster dissipation of the volatile compounds – especially in fresh pellets and at high ambient temperatures. The emissions generally abate within a few weeks and the smell disappears completely.

Emissions from wood pellets consist of volatile organic compounds (VOCs), carbon monoxide (CO) and carbon dioxide (CO₂). The volatile compounds include so called terpenes that are responsible for an occasional "chemical" smell similar to turpentine. Other components such as aldehydes and carbon monoxide can be harmful to health and should not reach the living area. Hence, stores for bulk pellets have to be sealed from the living area. Ventilation of the store to the outside will help dispersal of the emissions and shorten the time until the odorous components have dissipated.

2.6. Water – no friend of pellets

Pellets are hygroscopic, meaning they absorb water rapidly, while increasing their volume at the same time. If large volumes of water enter a pellet store (e.g. during a flood) the silo fabric or walls can be damaged. Pellets will also lose their shape and clump together. In this case pellets cannot be used as a fuel anymore and have to be removed quickly before they dry and harden.

In contrast to heating oil tanks, flooded pellet stores do not cause any danger to the environment. It is nevertheless recommended to empty pellet stores if floods are expected.

3. Storage of wood pellets

3.1. Pellet stores – custom-made or prefabricated silo?

It has been common to build pellet stores in existing rooms or cellars, often designed and constructed by the property owner. The advantages of a custom built pellet store are good space utilization and – in the case of storage rooms with exterior walls – easy access to the filling and vacuum nozzles. However, inadequate self-constructed stores cause considerable problems and risks.

Prefabricated storage systems offer a well-planned solution including the appropriate filling and extraction devices that ensure that pellet quality is maintained and operation is safe. For this reason it is recommended the use of prefabricated pellet storage systems.

Custom built stores should generally be planned, built and equipped by qualified professionals. The National Pellet Associations of certain countries provide inventories of qualified professionals:

3.2.

3.3. Storage volume – how much is needed?

Pellet stores for consumers (<70 kW) should accommodate one year's pellet consumption. Hence, the recommended storage volume depends largely on the heating demand of the building. The heating demand can be calculated by experts or estimated from the fuel consumption of the previous heating system. If the heating system is retrofitted from heating oil, the pellet demand in kilograms is twice the oil consumption in litres. The values provided in Table 2 are based on an oil heating system with efficiency values similar to the new pellet system. When replacing inefficient oil heating systems, the values for pellet consumption and the recommended storage volume in the table can be reduced by up to 20 percent.

Table 2: Recommended storage volumes for pellet heating systems

Heat demand in kWh/year	5000	10000	20000	50000
Heating oil consumption in l/year	625	1250	2500	6250
Pellet demand in kg/year	1250	2500	5000	12500
Recommended storage volume in m ³	2.5	5	10	25

The real storage capacity is always smaller than the theoretical total room volume. Volume is lost beneath raised or sloping floors. The pellets will not fill above the bottom edge of the filling nozzles, and they will slope down from a peak in line with the filling nozzle.

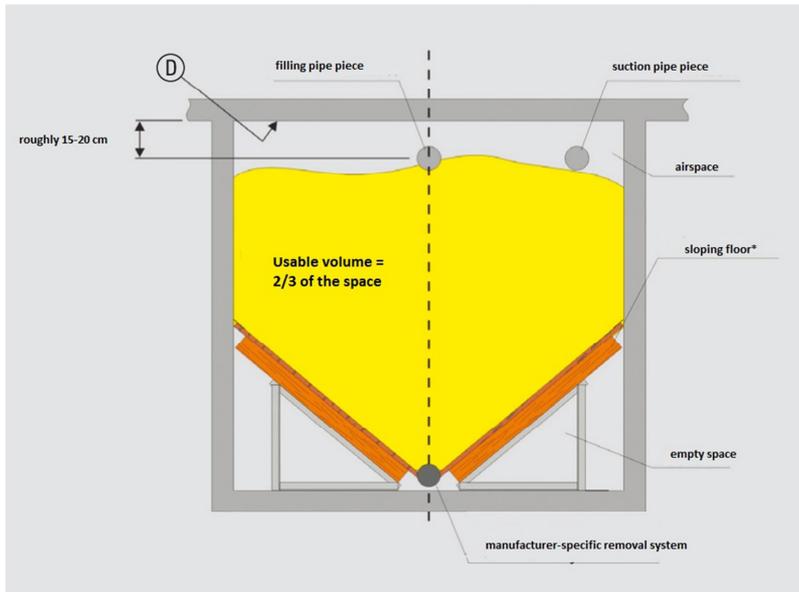


Figure 2: lost volumes in a store

When planning stores for larger heating systems (> 70 kW) other factors need to be considered. The storage capacity should be calculated so that it can accommodate more than the maximum capacity of the largest truck that is expected to deliver.

The capacity of the store needs to be more than the capacity of the truck so that full loads can be received without having to empty the store every time. Access will determine the largest truck that can deliver. It is recommended to get in contact with some pellet suppliers before ordering your heating system, to establish the capacity of the largest truck that can get to the store.

3.4. Pellet delivery in the store

Bulk wood pellets can be delivered either by tippers or by silo trucks that blow the pellets into the pellet store. Long blowing distances, changes of directions due to corners and height differences between vehicle and pellet store should be avoided as they increase the mechanical stress on the pellets during blowing and thus also increase fines. The filling hose and the installed filling duct should be as short as possible and not be longer than 30 m altogether. Clever planning can help to keep distances short and to arrange blowing conditions in a way that they do not compromise the quality of the pellets.

The following points should be considered:

- Access must be suitable for pneumatic delivery vehicles that could be either rigid or articulated. A road width of at least 3,5 m and without height limits (usually up to 4 metres) that may impede

access to the point of discharge. Consider the gradient and condition of the road in winter, and how the access may be limited by other vehicles parked along the route.

- The turning radius and gross vehicle weight of the vehicle must be taken into account.
- The truck must be able to park legally and without creating an unacceptable obstruction for the duration of the delivery (which may take over an hour).
- Blowing and exhaust nozzles should lead to the outside through permanently installed filling ducts. If permanent ducts are not possible, the connection should be close to an opening such as a cellar window or door, but not so close to the frame that the pipes cannot be connected.
- All changes in direction should be realised with less bends as possible and sufficient intake and outtake distance. Bends of 90 degrees should be avoided whenever possible. If the bend cannot be avoided a minimum internal radius of 200 mm is recommended.
- The filling couplings should be at a maximum height of 1.8 m so that filling hoses can be connected safely. Otherwise safe access by a ramp or a platform must be provided.
- Pipes, couplings and hoses should have an inner diameter of 100 mm and should be made from robust and earthed components.
- If no alternative National Standard exists, filling couplings must be of the type "Storz A" (100 mm).
- Blowing and exhaust couplings have to be labelled according to their function. A separate exhaust nozzle should be installed to prevent blown pellets from obstructing the vacuum duct when coupling. Blowing through the exhaust nozzle should be avoided.
- Permanently installed filling ducts must be conductive and have to be grounded with a cable (4 mm²) to the equipotential bonding bus-bar (Earth) by a professional electrician.

3.5. Ventilation

Off-gassing and malfunctions of the heating device may lead to dangerous amounts of dangerous gases such as carbon monoxide in the pellet store. Two simple safety rules should be observed to eliminate any risk:

- The store should be sealed air-tight from the living area of the building.
- The store has to be ventilated to the outside or at least into a well-ventilated room to avoid the accumulation of dangerous CO concentrations.

Storage rooms with a capacity of ≤ 10 t and filling ducts of up to 2 meters length must be equipped with ventilation caps on the filling and exhaust couplings. Ventilation caps are available from heating system suppliers or certified pellet traders. Prefabricated stores made of breathable fabric do not need ventilation caps. However, sufficient ventilation of the room has to be ensured.



Figure 3: ventilation cap

For larger storage rooms more complex ventilation solutions are necessary. Table 3 provides an overview of ventilation requirements for mid-size stores. The requirements for large stores are described in Table 7: Ventilation requirements for large stores

Table 3: Recommendations for the ventilation of pellet stores

Length of filling duct	Ventilation type	Storage size	
		Small (≤ 10 Tons)	Mid-size (> 10 tons and < 40 tons)
≤ 2 m	Ventilation cap	Ventilation cap on 2 couplings Ventilation to outside or well ventilated room	Ventilation cap on min. 2 filling couplings Cross-section min. $4 \text{ cm}^2/\text{t}$ pellets Ventilation to outside or well ventilated room
≤ 5 m	Separate Ventilation opening	Ventilation opening min. 100 cm^2 Clear opening min. 80 cm^2 Ventilation to outside	Cross-section min. $10 \text{ cm}^2/\text{t}$ pellets Clear opening min. $8 \text{ cm}^2/\text{t}$ pellets Ventilation to outside
> 5 m	Mechanical ventilation	Storage ventilation through ventilation duct with ventilator Function of ventilator should be linked to opening of storage room door	

Every pellet store must be ventilated. The ventilation openings should not be positioned directly under windows or inlet air openings.

3.6. Cleaning

In order to ensure safe and continuous operation the store should be periodically cleaned. The accumulated fines on the bottom of the store should be removed and the wood dust on walls, filling nozzles and other areas should be removed. When cleaning the following should be considered:

- **Entering in a storage room always presents a significant safety risk. For this reason, the number of interventions should be minimised and strict safety rules have to be observed (see chapter 7: for your safety):** boiler and pellet supply system are turned off, sufficient ventilation has been realized before entering (at least 15 minutes of ventilation) and a second person is present OUTSIDE the store (see chapter 7, 'For your safety').
- Cleaning of prefabricated stores should be done according to manufacturer's instructions
- Use a well-fitting dust mask with a P2 (EN 143) or N95 (US NIOSH Standard) filter, well-fitting goggles to keep the dust out of your eyes, and so far as practical keep your skin covered.
- The storage room should be vacuumed, not swept. Occupational health and safety standards require the use of an industrial vacuum cleaner with a class M (EN 60335) filter.
- Underground storage silos and storage rooms with a large capacity (usually > than 10 tons, see national regulations) may only be entered using a personal CO monitor.

At a minimum of every two years [GG4] the pellet storage should be cleaned before the next pellet delivery.

4. Prefabricated pellet stores

4.1. General remarks

Prefabricated storage systems reduce the planning and installation processes significantly compared to individual-constructed storage rooms and fulfil all necessary technical and safety requirements. They can be installed in cellars, in garages, under carports, in tool sheds, as underground tanks and in the open. Prefabricated stores have to be installed and operated according to the manufacturer's instructions.

The fuel store is an integral part of the heating system. The installer of the heating system is responsible for a smooth integration of the different components. He has to guarantee the interoperability of the boiler, pellet feeding device and the pellet store. He should document the components used and certify the installation as adequate.

4.2. Requirements regarding the installation room

The most important condition for the installation of a prefabricated pellet store is a solid and level base. If this is not the case, height differences must be corrected. The base must be suitable to carry the static loads at the contact points and for the overall weight of the store and its contents. Rooms with maximum humidity levels of up to 80 percent are suitable as long as air can circulate around the pellet store. The installation room must be ventilated to prevent the accumulation of harmful CO.

Distance from walls, ceiling, and installations

Many storage systems need sufficient distance between the surrounding walls, the ceiling, the floor and installations such as lamps and pipes. Fabric silos may need space to expand into during the blowing process. In some cases the fabric is inflated at the beginning of the delivery, so that the hanging fabric lifts upwards before the pellets enter the silo. In general, the inflated fabric should not touch fixtures and fittings, nor should it be limited by the ceiling height, except when explicitly allowed by the manufacturer. The following has to be considered too:

- Pipes may leak and condensation may occur.
- The fabric has to hang free to avoid an increase of fines.
- The fabric must not touch ceiling or wall lamps since it can be damaged by heat.
- A fabric silo should have space to unfold completely. Fabric must not develop folds into the blowing stream since this could damage the fabric.
- The blowing nozzles have to be positioned in a way that pellets impact only on the strengthened fabric areas and do not damage the seams.

Prefabricated stores without filling pipes to the outside need sufficient space around the couplings, to avoid the need for a narrow bend between filling coupling and the blowing hose. A distance of at least 1 metre should be kept between the coupling and the walls. It is recommended to install fixed filling pipes with couplings in the outside wall.

Since there are many different storage systems, a notice of the pellet filling instructions for the storage system should be easily visible to the delivery driver.

Ground connection (Earth)

Storage systems may be installed inside or outside. Many are made of a frame and a polyester fabric. Others are constructed from sheet metal. The storage system has to be earthed to divert the electrostatic charge that is created when the pellets are blown in. A qualified electrician must ensure that the system is earthed using a cable (4 mm²) from the couplings to the equipotential bus bar.

Ventilation

The installation room of fabric silos needs ventilation shafts to the outside and has to be sealed from the living area.

- Where there are short (< 2m) blowing and exhaust ducts leading to the outside, ventilation can be done by ventilation caps on the couplings.
- In all other cases the installation room has to have at least one opening to the outside which cannot be closed, see table 3.

In fabric silos without an exhaust nozzle the conveying air stream exits through the silo fabric. In this case the air stream during delivery (up to 1,500 m³/h) must be able to exit through windows, doors and other openings.

4.3. Exterior installations

Generally prefabricated stores can also be installed outside of a building. With exterior installations wind load has to be taken into account. Depending on the type of store and its materials, UV protection may also be necessary. Some stores also need protection from rain (see Table 4).

Table 4: Special requirements for exterior installation of prefabricated pellet stores

Type of storage	UV-protection	Rain protection
Fabric silo	Follow manufacturer's instructions	Essential
Above ground metal silo	Not necessary	Not necessary
Above ground GRP silo	Not necessary	Not necessary
Above ground plastic silo	Follow manufacturer's instructions	Not necessary
Above ground concrete silo	Not necessary	Not necessary

4.4. Underground silos

Pellet stores that are built into the ground have to fulfil special requirements. They have to

- be absolutely impermeable against moisture and intruding water,
- prevent condensation in fluctuating air humidity,
- be secured against buoyancy caused by rising groundwater,
- be nearly completely dischargeable.

Underground silos are made from concrete or plastic. Extraction is done by vacuum suction from above or below.

In the case of extraction from below, the silos are cone shaped in the lower silo section. The extraction of pellets to the conveyor system is done at the lowest point. Since the static pressure on the pellets is high in the extraction area, they have to be loosened by rotation, vibration, air or agitation.

Extraction from above can be done using a flexible mounted and rotating suction head. The device rests on the pellets and moves slowly through the storage room due to the rotation. In some systems the suction air is returned to the store.

Underground silos are airtight. During pellet delivery they have to be vacuumed with a mobile ventilator with a capacity that exceeds the maximum air flow rate (at normal temperature and pressure) of the blower on the pneumatic delivery vehicle. If the silo manufacturer has not provided a power connection (min. 16A 230 Volt AC), this has to be installed outside the store.

Due to airtight construction, high CO concentrations can occur in underground silos. For this reason underground silos may only be entered after sufficient ventilation and after measuring the CO content. A second person has to be present!

4.5. Fabric silos

Storage systems are offered in a variety of materials and shapes: round, square or rectangular and with different heights. Fabric silos frequently have a cone on the lower part for pellet extraction. Other common designs include trough silos, elevating silos and silos with a flat bottom. The pellets are discharged either from the bottom via a conveyor screw (auger) or a suction device, or through a flexible vacuum device from the top. Table 5 provides an overview of the most common designs of fabric silos.

Table 5 Design examples of fabric silos

<p>Conical silos are formed similar to an inverted pyramid. Extraction is done at the lowest point through vacuum suction or short horizontal screws that connect to a suction conveyer or an extraction screw.</p> <p>Conical silos also allow for a modular design where several silo elements are connected in a row. In this case, the extraction points should be regulated by automatic switching devices. The modular principle allows for high storage capacities even in rooms with low ceilings.</p>	
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<p>Trough silos offer a high capacity in narrow rooms. Due to their shape they can generally be filled up to the ceiling. The extraction is done either by a screw that conveys the pellets to a vacuum point or directly to the pellet boiler, or through several suction devices.</p>	
<p>Silos with flat bottoms have no slopes. The design offers a good space utilisation and the weight is borne over a greater surface area</p> <p>The pellets are extracted from below through an agitator with screw extraction or using a suction device. Pellets can also be extracted from the top through a flexible suction probe. Systems with a flat bottom cannot be cleared completely easily. Depending on the construction between 2 and 15 percent of the pellets remain within the silo.</p>	
<p>Silos with spreading frame offer a smaller volume compared to a flat bottom silo since they need a small distance between the bottom of the silo and the floor. Therefore the silo can bend slightly towards the floor – assisted by a vibration-element good extraction is possible. This way the residual pellet amount can be reduced.</p>	

5. Custom-made storage rooms

5.1. General requirements

Pellet stores need careful planning and have to be designed and installed by professionals. Pellets can be stored in cellars, garages, lofts or other suitable rooms. However, legal requirements or other regulations (e.g. fire safety requirements) for fuel storage must be observed.

Usually the storage room has a rectangular ground plan (see Figure 4). Both the injection and suction couplings should be installed on the narrow side of the room. Easy access to the injection and suction couplings must be ensured. The designated storage room should preferably be free of electrical installations, air ducts and water installations. The impact of incoming pellets on the walls of the storage room must be mitigated by a suitable impact protection mat. Ceilings and walls should be constructed so that the pellets are not contaminated with loose materials.

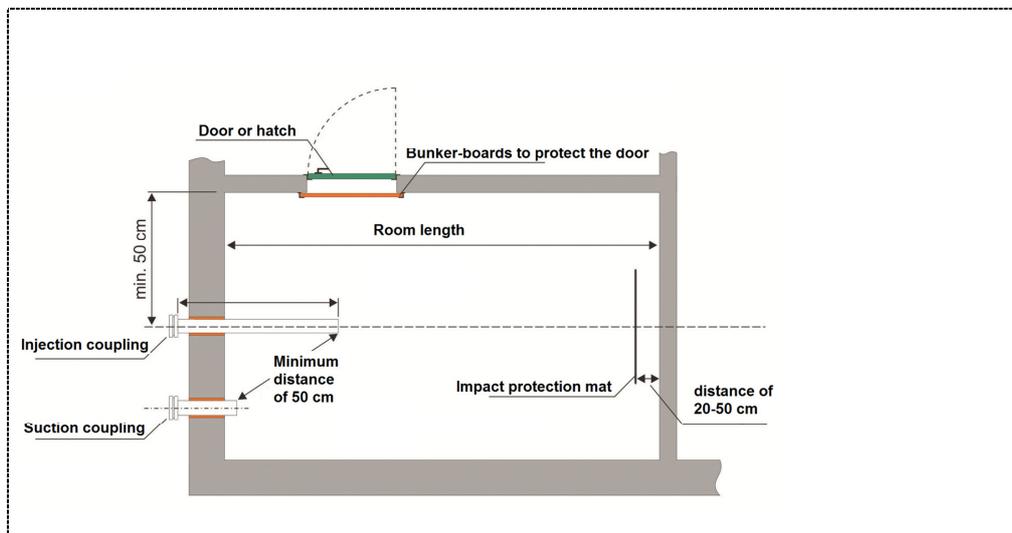


Figure 4 General layout of a custom-made pellet store

Regarding the risk of dust explosions, a pellet storage room is usually classified as an ATEX Zone 22 (i.e. might contain an explosive atmosphere for only short periods (during pellet injection)). All vertical surfaces inside the storage room must have a smooth surface to prevent dust accumulation. Horizontal surfaces should be avoided. All pipes and couplings have to be conductive and must be earthed by a professional.

The storage room should be airtight to other rooms in the building to avoid both infiltrations by gases and dust. The room must be ventilated according to the provisions in Table 3.

5.2. Load-bearing requirements

The enclosing ground, walls and ceiling must withstand the static and dynamic stresses imposed by both the pellets (bulk density of max. 750 kg/m³) and pressure fluctuations (0.05 bar over pressure must be tolerated (=500 kg/m²)) caused by the pellet injection process.

Walls made of autoclaved aerated concrete should not be used. Glass windows and large plastic panes should not be installed except if they are foreseen as predetermined pressure relief outlets. All connections to existing brickwork, corners and wall culverts must be dust-tight. For larger pellet stores a professional qualified in structural engineering and fire protection should be consulted.

For storage rooms with a capacity of up to 10 metric tons and a room height of up to 2 m, the following wall constructions have been proven to work flawlessly:

- Reinforced concrete with 10 cm thickness
- Brick wall with 17.5 cm thickness, bonded with mortar on both sides, reinforced corners and connected to ceiling
- Wood constructions with 12 cm beams, 62 cm clearance, sided with three-layered formwork panel on both sides or multi-layered plywood panels, joined to ceiling, floor and walls. Depending on construction design it may be necessary to use steel hinges.

5.3. Protection against condensation and intrusion of water

Pellets are hygroscopic. In contact with water and damp surfaces, they swell up, cannot be burned and will block transport lines. Therefore the following principles have to be obeyed:

- Pellet stores must be completely dry. Especially in newly-built houses the floor of the store may be humid and cannot be used until it is completely dried.
- Air humidity has to be kept below 80 percent
- If there is a risk of damp walls (even if only temporary) it is strongly recommended to use a prefabricated silo. Otherwise the storage room needs a cladding with air space to the wall.

5.4. Sloping floors

Sloping floors direct the pellets towards the auger or suction extraction system only by gravity and should enable complete emptying of the store.

The construction of sloping floor storage rooms (see Figure 5) should follow some major design rules:

- The sloping floors have to withstand the weight of the pellets. A strong, stable frame is absolutely necessary.
- The massive wood beams providing the framework for the sloping floor should use support angles every 60 to 70 cm.
- The sloping floor should have an angle of at least 45 to 50 degrees.
- The panels of the sloping floor need a smooth surface. Simple particle boards are not suitable. It is recommended the use of three-layered wood panels or multi-layered plywood.

- Augers should be shielded with an angular (steel) construction covering the whole length of the auger, to relieve the weight of the pellets above on the pellets in the auger. The gap between the shielding and the sloping floor should be 60-70 mm to allow a smooth flow of pellets.
- Edges, steps and flat areas around the auger or discharge point should be avoided.
- The sloping floors should be connected to the surrounding walls tightly so that pellets cannot fall into the empty space below the floor.
- The connection to the extraction system has to be done by a professional according to the manufacturer's instructions.
- To avoid the transmission of vibrations and noise from the storage room (e.g. caused by the extraction system) to the building structure, the installations should be acoustically decoupled from the building. Gaps between the sloping floors and the floor should be closed with a sealing tape.

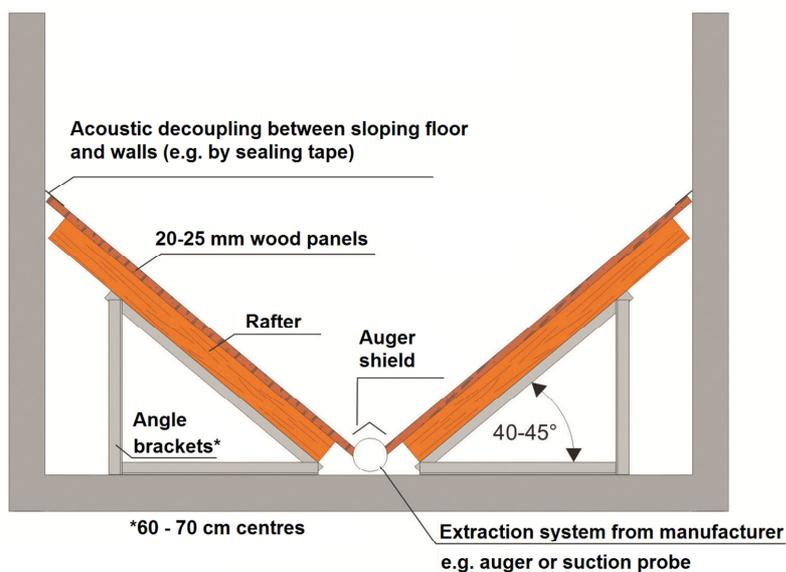


Figure 5 Recommendations for the installation of sloping floors

5.5. Impact protection mat

The impact protection mat reduces pellet breakage during delivery, protects the wall of the storage room and thereby prevents a contamination of the pellets with splintered wall particles (e.g. paint, mortar). Fixing screws, slats and brackets should be installed in such a way that they do not interfere with the pellet stream (see Figure 7 and 8).

The impact protection mat has to be placed vertically to the incoming stream of pellets at a distance of 20 – 50 cm from the wall opposite to the injection pipe. In general it should be hanging free so that the force of the incoming pellet stream lets the mat swing backwards. It is the swinging behaviour that ensures a proper dissipation of the kinetic energy of the pellets. A protection mat can't work if it is placed directly on the wall.

The protection mat has to be wide enough to catch the entire stream of pellets. It should be long enough to prevent the mat from being blown or pushed away but not too long (the risk of getting trapped and ripped down by the pellets increases with the length of the mat). During the first filling of the store, the function of the impact protection mat has to be tested - the incoming stream of pellets must hit the mat. If there is more than one filling pipe, it might be necessary to install more than one impact protection mat.

The impact protection mat has to be resistant against abrasion and tearing. Carpet, weaker plastic or rubber materials are **unsuitable** and can cause considerable damage if fibres or rubber parts fall into the pellets and enter the auger. It is recommended using HDPE-film of at least 2 mm thickness or **abrasion-proof** rubber of 1-3 mm thickness with a size of 1.2 m x 1.5 m.

5.6. Doors, windows and hatches

Doors and hatches should be constructed to be dust-proof (Figure 4). They must open outwards and need a dust-proof seal all the way around. Windows are usually already sealed by the manufacturer and have to be approved for this use (e.g. safety glass, since pressure peaks may occur). On the inside of the door frame, wooden or metal planks (bunker-boards) must be fitted to protect the door against the pressure from the mass of pellets. Locks should be dust-proof on the inside, so that the lock is not affected by pellet dust. The pellet supplier is not liable for damage or contamination caused by inadequate sealing.

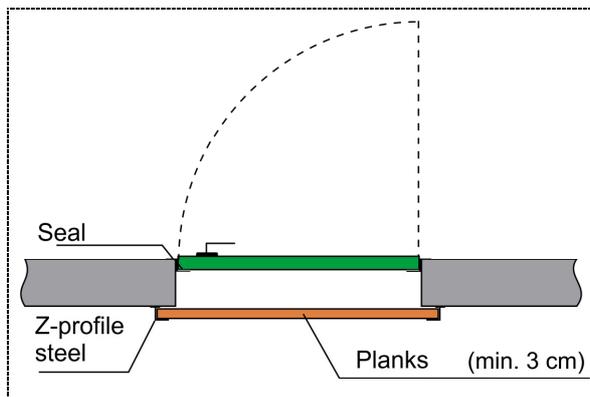


Figure 6 Pressure and impact protection for the door of the storage room

If possible, the door leading into the silo should be close to the injection coupling. This enables a longer period before the build-up of pellets would prevent access. The door should not be placed behind the impact protection mat! The storage room must be accessible for regular cleaning and for visual

inspection by the pellet delivery driver before filling. **Entering in a storage room always presents a significant safety risk. For this reason, the number of interventions should be minimised and strict safety rules have to be observed (see chapter 7: for your safety).**

It is recommended the provision of a sight-glass, e.g. a small viewing window in the wood planks. If clear plastic is used, the windows can accumulate fines, attracted by static electricity. The fines on a plastic sight-glass make it difficult to see the amount of fuel left in the store.

5.7. Fittings inside the storage room

Fittings in the storage room (such as water piping, sewage pipes, etc.) should be removed. If this is not possible without considerable effort and the fittings cross the flight path of the incoming pellets, then these fittings must be protected by inclined deflectors to minimize pellet damage.

Electrical installations such as switches, sockets, lights, and junction boxes **must not** be located in the storage room. Explosion-proof electric installations can be exempted from this rule, as well as extraction systems that have been especially constructed for this purpose.

5.8. Filling system

A storage room needs at least one coupling for pellet injection and one outlet coupling for the suction pipe. Their purpose should be clearly and permanently marked on piping and caps. The couplings should be mounted at least 15cm below the ceiling of the silo (measured from ceiling to top edge of the filling pipe). After a maximum distance of 50 cm, the filling pipes must be rigidly secured with a pipe clamp (see Figure 7).

The widely accepted standards for couplings have an internal diameter of 100 mm and are called 'Storz Type A'. These should be used for injection pipes as well as for the suction pipe. If couplings are installed in a light well, it should be easy to connect the filling hose to a straight section sticking out of the shaft without bending. The couplings should be rigidly fixed so that they cannot turn or twist when the coupling of the delivery truck is attached.

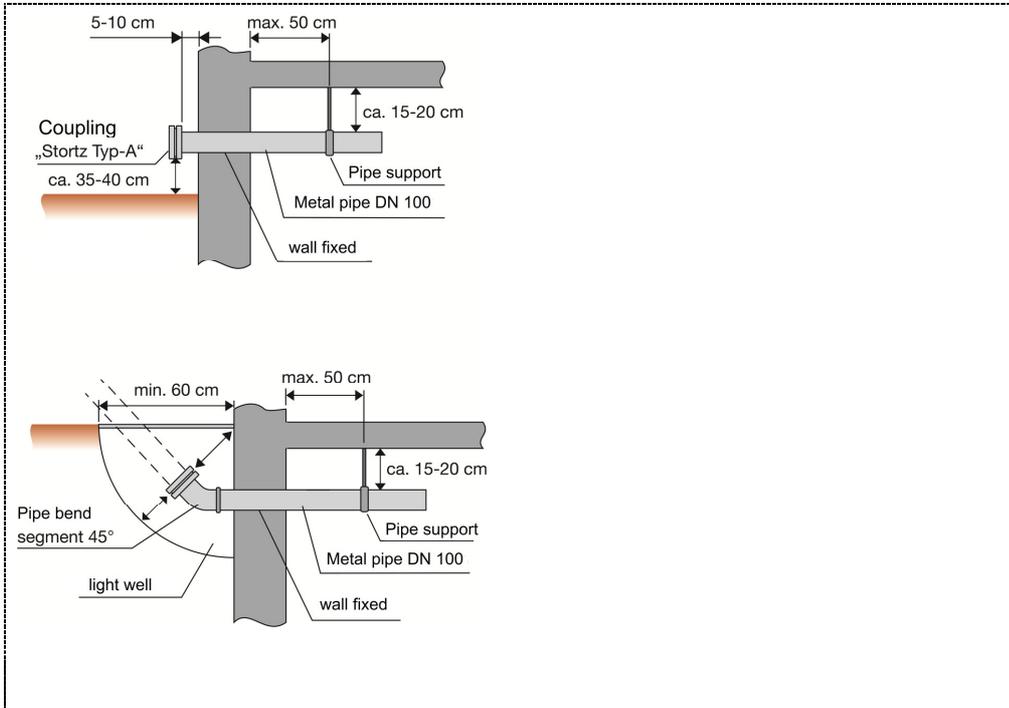


Figure 7 Design recommendations for couplings located either above or below the ground level

The filling system must comply with the following conditions:

- All couplings (injection and suction) should be “Storz type A” (or of equivalent quality). All pipes should have a diameter of 100 mm.
- Pipes have to be made from metal and must be resistant to over pressure of at least 1 bar.
- Pipes and bends should have a smooth inner surface, to avoid abrasion. Rivets or screws should not extend into the pipe! If the pipes are welded they have to be checked for pin-holes, slag and other damage on the inside of the pipes at the joints (welding joints). Steel pipes must be deburred.
- The pipes should be as short as possible. Changes in direction should be avoided. Only bends with a radius of more than 200 mm should be used.
- The injection pipe should have a straight end-section of at least 30 to 50 cm to overcome turbulence in the pellet stream that would lead to large scattering angles at the outlet. (See Figure 6).
- The filling system has to be earthed with a 4 mm² cable to an equipotential bus bar.
- Injection and suction couplings should be clearly labelled. Injection through the suction pipe should be prevented since pellets may block the suction pipe later on.

- A working area of about 40 cm around the couplings should be kept free, even if they are situated in a light shaft.
- The suction ventilator needs a power socket (230 Volt, 16 Ampere) not too far from the suction coupling. It has to be accessible for the delivery truck driver.
- Access to the couplings and their surroundings (shafts, gratings) must be free of snow and ice that could occur during winter.
- After the blowing operation the couplings should be closed using ventilation caps that preferably can be locked. The keys have to be available for the delivery truck driver.

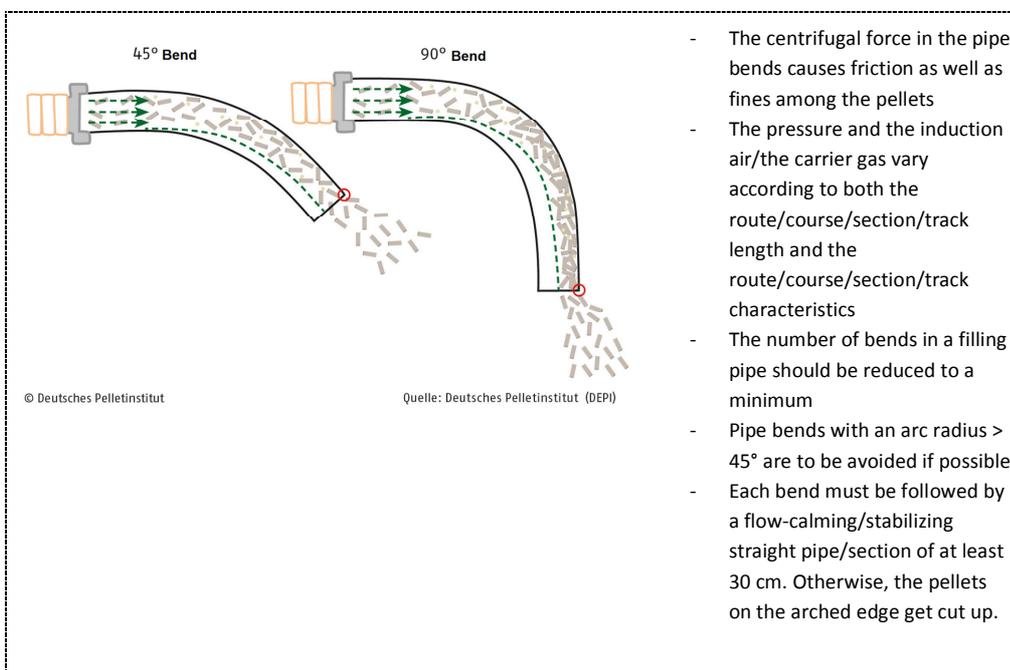


Figure 8 Discharge pattern for pellets blown through different bends without appropriate straight segment (= calming segment)

Pellet stores must be ventilated. For storage capacities of up to 40 t, with filling pipes of less than 2 m length to the outside, ventilation caps on the couplings provide sufficient ventilation. In all other cases additional ventilation ducts are necessary.

5.9. Best practise examples of custom-made storage rooms

The design of a pellet store should consider size and geometry of the room, especially the distance from the fill pipe to the opposite wall.

Small stores, with a room depth of less than 2 metres, present a high risk of broken pellets due to impact forces. A special design of the injection pipe and the impact protection mat (see Figure 9) helps to avoid excessive mechanical stress on the pellets:

- The outlet of the injection pipe should direct the pellet stream slightly downwards (see Figure 9). This should be realised using a tube bending of 15-20 degrees followed by a final straight length of 30 cm. The straight length can also be realised by using a properly fixed length of conductible injection hose. In this case the inner steel spiral must have a firm connection to the metal pipe to provide earthing of the entire injection line.
- The impact protection needs to be well fitted to fulfil its function. It is recommended to attach the mat to a support board of equal size. This construction should be fixed at the ceiling and the wall. The vertical angle should be roughly 15 degrees.

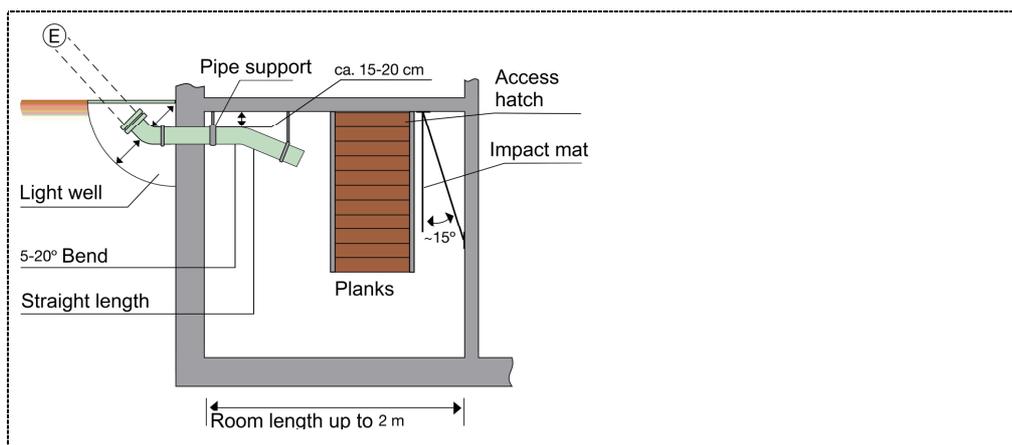


Figure 9 Best practise design of a storage room with a depth < 2m

The design of a rectangular pellet store with a room depth of 2 to 5 metres (Figure 10) should consider the following aspects:

- Injection pipes should be installed horizontally at a distance of 15 to 20 cm from the ceiling in order to prevent pellets from hitting the ceiling when they are blown in (scattering angle of 7°).
- The impact protection mat on the opposite side of the silo should be at a distance of 20 to 50 cm from the rear wall and be attached to the ceiling. It must be able to swing freely.
- The suction coupling should be mounted at least 0.5 m, preferably further, from the injection coupling and be clearly marked on both the cap and the pipe. Ideally, the suction coupling should be in a corner and slightly higher than the injection pipe.

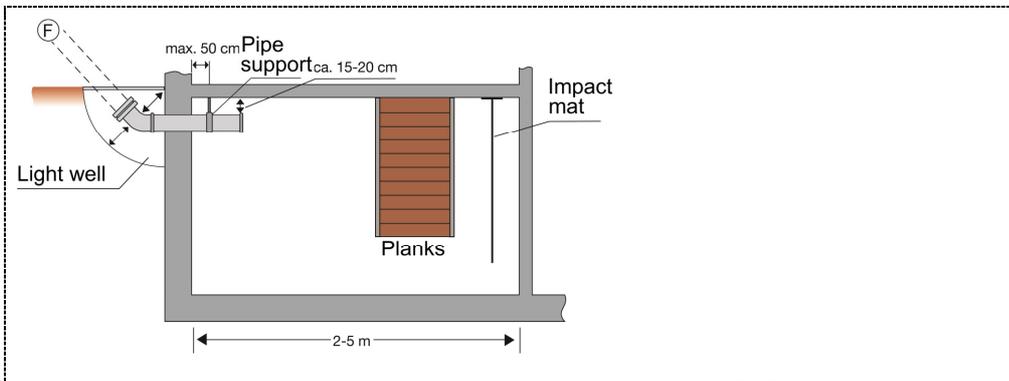


Figure 10 Best practice design of a storage room with a depth of 2 - 5 metres

The design of larger custom-made stores should consider the limits of a suitable pellet trajectory: the distance from the outlet of the injection pipe to the surface of the impact mat should always be within 2 - 4 metres.

Hence, stores with depth > 5 metres should be equipped with additional injection pipes that end deeper in the room. The couplings for these pipes should be clearly labelled (long/short). Pellet injection must start through the long filling pipe. N.B. the level of the pellets at the mouth of the longer pipe in an unlit store may not be visible so other ways of monitoring the fill-level should be provided.

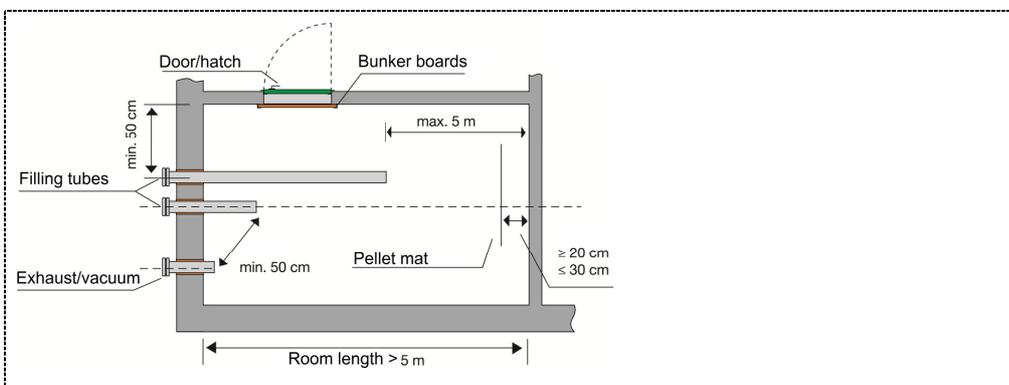


Figure 11 Best practice design of a store with room depth > 5 metres

When pellets are blown into the store they form a pile with an angle of repose of 45-60°. For a good utilisation of the storage volume, wide rooms (width > 3 metres) require additional injection pipes. The horizontal distance between the injection pipes should be 1.5 to 2 metres. Each injection pipe needs a separate impact mat in front of the rear wall.

In all three of the above examples, ventilation requirements can be fulfilled by equipping the filling ducts of the stores with ventilation caps on the fill and exhaust couplings. However, it is also possible to provide ventilation by implementing more complex ventilation solutions. The requirements for these are summarized in Table 3.

6. Large stores (up to 100 tonnes capacity)

6.1. General requirements

The basic requirements for pellet storage discussed in the previous chapters also apply to larger stores with a storage capacity up to 100 metric tons. The requirements for a gentle pellet injection also apply for large stores: adequate pipes have to be used, the parking position of the delivery vehicle should be close by and the fill-lines should be as straight as possible. Also, the distance between store and boiler should be kept short. But the design and operation of large stores also requires particular attention to a number of issues less relevant for small storage systems. Frequently, larger stores are equipped with different extraction systems compared to small stores and the risk of over pressure problems during pellet injection is much lower. The larger free volume prevents high pressure peaks and some stores are equipped with an on-site vacuum for the injection process.

The injection of the pellets from a silo vehicle containing 25 t of pellets may last up to two hours. During this time both motor and compressor of the truck are running. Therefore, noise protection must also be considered. A good parking position for the delivery vehicle can be challenging, especially near residential properties, hotels and hospitals. Pellet deliveries, by walking-floor trucks or tippers that dump the pellets into the storage room or on to a conveyor belt might be a favourable alternative that provides a substantially shorter on-site delivery time and far less noise.

6.2. Storage size

The dimensioning of large stores should consider the annual fuel demand (calculated from the thermal power of the boiler and expected capacity factor) as well as logistical issues. An important factor is the typical payload of 25 metric tons per delivery vehicle. Favourable storage capacities should be determined according to Figure 10. The diagram shows favourable storage capacities according to the boiler size.

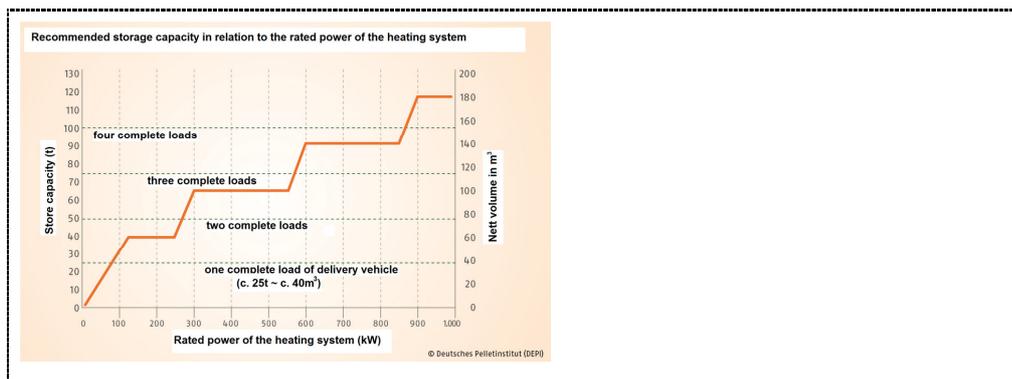
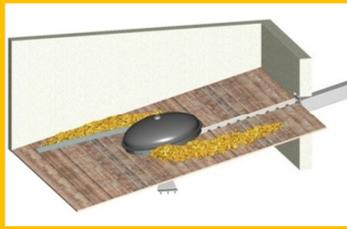


Figure 12 Determination of favourable storage capacities for large stores

6.3. Pellet retrieval systems

In contrast to smaller pellet heating systems the use of suction systems is not common for large systems. Table 6 presents typical pellet retrieval systems for large stores.

Table 6: Different types of pellet discharge systems for large stores

<p>Centred discharge auger</p>	<p>Cost-effective system for long storage rooms with sloping floors.</p> <p>Suitable for boiler < 100 kW.</p>	
<p>Spring core discharge</p>	<p>Cost-effective system for rectangular rooms that uses two spring arms to push the pellets to the discharge auger.</p> <p>Suitable for boiler < 200 kW.</p>	
<p>Telescopic arm discharge</p>	<p>Cost-effective system for round silos, telescopic arms push pellets to the discharge auger.</p> <p>Recommended for boiler up to 500 kW.</p>	
<p>Centred auger discharge</p>	<p>Efficient system for round silos that uses a rotating centred auger to pull the pellets to the central discharge point.</p> <p>Suitable for boiler > 500 kW.</p>	
<p>Moving floor discharge</p>	<p>Efficient, robust system for large rectangular storage rooms that is based on a hydraulic moving floor.</p> <p>Suitable for boiler > 500 kW.</p>	

6.4. Filling level measurement

In-situ measuring of the level of pellet stores is increasingly important for automated installation monitoring and scheduling of deliveries. Continuous monitoring of the fuel level can be achieved with a number of devices including mechanical sensors, capacitive sensors and ultra-sound systems. The fill-level of silos can also be monitored using load-cells. The fill-level of stores with sloping floors can be monitored with pressure sensors integrated within the floor boards.

6.5. Cleaning of the store

Large pellet stores (annual consumption > 15 tonnes) should be cleared and cleaned at least once a year. Cleaning personnel should always

- use industrial vacuum cleaners that are equipped with a class M Filter (EN 60335)
- use industrial vacuum cleaners that are rated for use in ATEX zone 22, container of the device ≤ 50 l and the motor power < 1.2 kW
- wear a dust mask of the type P2 (EN 143) or N95 (US NIOSH Standard)
- wear a personal CO gas detector

Entering in a storage room always presents a significant safety risk. For this reason, the number of interventions should be minimised and strict safety rules have to be observed (see chapter 7: for your safety).

6.6. Explosion protection

Explosion protection for large stores is based on both the avoidance of an explosive atmosphere by ensuring low dust concentrations and the avoidance of ignition sources at any point in the filling, storing and discharge systems. Only electrical appliances with a rating of at least IP 54 (preferably AP 65) are permitted inside the store. The storage room lighting and other fixed installations need an approval for ATEX zone 22 (North America: Class II Division 2).

Provided this guidance is fully adhered to, pellet stores do not need explosion protection measures.

6.7. Ventilation requirements

Pellet stores face two different sources that could emit harmful gases into the store's atmosphere: off-gassing from the pellets and the back-flow of flue gases from the pellet boiler in case of malfunctions. Accidents due to toxic gases are prevented by two different approaches.

- Permanent ventilation of the store that prevents the accumulation of gasses (e.g. CO) to harmful concentration levels
- Safety regulations covering access to the store, including personal protection with a CO detector, will prevent exposing personnel to a toxic atmosphere.

If the store is located close to the outside, storage ventilation should be realised with ventilation ducts shorter than 5 metres. The required ventilation area is calculated according to the provisions in Table 7.

In case of stores that need ducts with a length of more than 5 m to the outside, the ventilation has to be realised with a ventilation device.

The pellet store may only be entered

- after measuring the CO level and confirmation of a concentration not higher than 60 ppm
- while wearing a CO detector with a valid calibration

Table 7: Ventilation requirements for large stores

Length of ventilation duct	Requirement
≤ 2 m	Ventilation caps (only ≤40 tone) Cross-section min. 4 cm ² /t pellets
≤5 m	Separate ventilation opening to outside Ventilation duct ≥ 100 cm ² cross-section Cross-section min 10 cm ² /t Clear opening min 8 cm ² /t
>5 m	Storage ventilation through ventilation duct with ventilator Function of ventilator should be linked to opening of store door.

7. For your safety

The following instructions will help to ensure personal safety when dealing with pellet storage systems.

First and foremost, no-one should enter pellet stores except for necessary maintenance activities. Access should not be possible for unauthorised persons. Children should not have access to pellet stores at any time.

Secondly, before entering or working in pellet stores, the pellet boiler must be turned off. Follow the time specified in the manufacturer's instructions.

Thirdly, pellet stores must be sufficiently ventilated at all times. For small storage systems (<10t) ventilation caps are sufficient for this purpose. In addition, it is recommended to open the door to the pellet store at least 15 minutes before entering to provide the storage with an extra amount of fresh air.

Fourthly, before entering or working on pellet stores or containers an informed second person must be present outside of the storage to raise the alarm NOT TO attempt rescue.

Fifthly, pellet storage systems that are effectively air-tight and sealed systems, e.g. underground pellet stores made from concrete or plastic or with an electric ventilator, should only be entered by properly trained service personnel and only after determination of the oxygen and carbon monoxide concentrations inside the store. This is necessary, as these types of pellet stores are particularly prone to maintain high levels of CO AND low levels of oxygen at the same time because as there is virtually no air exchange with the outside.

Normative references

- ÖNorm 7137: Wood pellets– requirements for pellet storage at the consumer
- EN 303-5: Heating boiler for solid fuels
- EN 14961-2: Wood pellets for non-industrial use
- ENplus – Handbook for the certification of wood pellets for heating purpose, Version 3.0
- VDI Norm 3464 (Official draft 2014): Storage of wood pellets at consumer

**Sicherheitshinweise
für Pelletlager ≤ 10 Tonnen**

 Lebensgefahr durch geruchloses Kohlenstoffmonoxid (CO)

 Vor dem Betreten und Befüllen Heizung ausschalten!

 Vor dem Betreten mindestens 15 Minuten über die Einstiegstür lüften – während des Zutritts die Tür geöffnet halten!

 Dauerhafte Belüftung nach außen sicherstellen, z. B. über belüftende Deckel, Öffnung oder Ventilator!

 Verletzungsgefahr durch bewegliche Bauteile!

 Rauchen, Feuer und andere Zündquellen verboten!

 Türen verschlossen halten. Zutritt nur für Befugte unter Aufsicht einer außerhalb des Lagerraums stehenden Person!

 In den ersten 4 Wochen nach einer Befüllung nur mit mobilem CO-Warngerät betreten!

Siehe beachten Sie auch die Richtlinie VDI 3464
Deutscher Energieholz- und Pellet-Verband e.V. (DEPV) | www.depv.de

**Sicherheitshinweise
für Pelletlager > 10 Tonnen und
erdvergrabene Lager**

 Lebensgefahr durch geruchloses Kohlenstoffmonoxid (CO)

 Vor dem Betreten und Befüllen Heizung ausschalten!

 Vor dem Betreten mindestens 15 Minuten über die Einstiegstür lüften – während des Zutritts die Tür geöffnet halten!

 Betreten nur mit mobilem CO-Warngerät!

 Dauerhafte Belüftung nach außen sicherstellen, z. B. über belüftende Deckel, Öffnung oder Ventilator!

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Deutscher Energieholz- und Pellet-Verband e.V. (DEPV) | www.depv.de

**Safety instructions
for pellet stores < 10 tons**

- Danger to life from odourless carbon monoxide (CO)!
- Ventilate for at least 15 minutes via the access door before entry – Keep door open while in the store room!
- Ensure continuous venting to the outside atmosphere; e.g. via ventilated caps, openings or fan!
- Risk of injury from moving parts!
- No smoking, naked flames and other ignition sources!
- Keep doors closed. Access only by authorised persons under the supervision of an attendant positioned outside the store room!
- Shut off pellet boiler at least 1 hour before pellet delivery!
- In the first 4 weeks after filling, enter pellet store only with a personal CO detector!

**Safety instructions
for pellet stores > 10 tons and underground storage silos**

- Danger to life from odourless carbon monoxide (CO)!
- Ventilate for at least 15 minutes via the access door before entry – Keep door open while in the store room!
- Entry only with a CO detector!
- Ensure continuous venting to the outside atmosphere; e.g. via ventilated caps, openings or fan!
- Risk of injury from moving parts!
- No smoking, naked flames and other ignition sources!
- Keep doors closed. Access only by authorised persons under the supervision of an attendant positioned outside the store room!

8. Handover certificate for pellet stores

8.1. Customer/ heating operator

Installer

Name: _____

Address: _____

Tel.: _____

Heating

Boiler type: _____ Power: _____ kW

Solar support: Yes No Buffer reservoir: _____ l

Storage Prefabricated Storage room

Prefabricated silo:

Manufacturer / Model: _____ Capacity: _____ t

Material: _____ Permeable to air? Yes

Location: Building Exterior Below ground

External venting? Yes Clear opening: _____ mm²

Location dry (< 80% AH)? Yes Exhaust during pellet injection needed? Yes

Storage suitable for use with impregnated pellets? Yes

Custom-made storage room:

Location: Cellar room Living area Attic

Wall material: _____ Wall thickness: _____ mm

Room size (Lx W xH): _____ m x _____ m x _____ m Storage capacity: _____ t

Access: _____ m x _____ m Door Window

Storage ventilation: Ventilation lid other Clear opening: _____ cm²

Storage room sealed dust-proof from adjacent rooms: Yes

Protection mat: Distance to wall: _____ cm Trajectory clear? Yes

Lighting: Yes with ATEX

Walls/Floor dry? Yes humidity barrier

Injection blowing conditions / access

Internal filling pipe: Yes Material: _____

conductive earthed

Length: ____ m Diameter: ____ mm bends: ____x 45° ____ x > 45°

Nr of injection couplings: ____ Exhaust coupling? Yes power outside? Yes

Coupling labelled? Yes Coupling earthed?

Parking area for silo vehicle? Yes Tractor-truck adequate? Yes

Injection distance (hose and filling duct): ____ m Height difference: ____ m

Layout with parking area for truck and location of injection couplings:

Pellet extraction: Auger Suction at bottom Suction at top

Filling instructions: placed Where? _____

Cleaning instructions: Written Orally

Briefing on operation of storage /extraction system? Yes

(Place and Date)

(Installer)

(Customer)