Silo fire guideline
13 measures and 4 warnings

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Abstract

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This is a guideline about silo fires, based on the handbook “Silo Fires”. The guideline summarizes 13 measures and decisions needed in connection with a suspected or confirmed silo fire and 4 warnings on what to avoid.

The handbook is available in Swedish and English. The guideline is available in Norwegian and English. The Norwegian version is presented in RISE rapport 2023:67 and the English version in this report (RISE report 2023:68), both are available at https://risefr.com/publications and www.diva-portal.org.

Sammendrag

Veileder silobrann, 13 tiltak og 4 advarsler

Dette er en veileder om silobrann, basert på den håndboken “Brand i silo”. Veilederen oppsummerer 13 tiltak og beslutninger som trengs i forbindelse med en mistenkt eller bekreftet silobrann og 4 advarsler om ting man ikke må gjøre.

Håndboken er tilgjengelig på svensk og engelsk. Veilederen er tilgjengelig på norsk og engelsk. Den norske versjonen er presentert i RISE rapport 2023:67 og den engelske versjonen i denne rapporten (RISE report 2023:68), begge er tilgjengelige på https://risefr.no/publikasjoner og www.diva-portal.org.

Key words:
Silo fire, smouldering, smoldering, flames, extinguishing, measure, warning, explosion, hazard, pellets, biomass, storage, safety.
Silobrann, ulmebrann, flammebrann, slokking, slokkeinnsats, tiltak, advarsel, eksplosjon, fare, pellets, biomasse, lagring, sikkerhet.

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Cover image: Silo fire in Sweden. Gunnar Stattin/Tidningen Ångermanland, with permission.
Trondheim 2023

Innhold

1 Introduction

1.1 Translated edition of the handbook “Silo Fires”

The handbook “Brand i silo” was made by RISE Research Institutes of Sweden for the Swedish Civil Contingencies Agency (MSB) in 2012. The handbook is available in Swedish and English. Commissioned by the Norwegian Directorate for Civil Protection (DSB), in collaboration with Fire Research and Innovation Centre (FRIC), RISE Fire Research in Norway has translated parts of the handbook to Norwegian (RISE rapport 2023:67) and to English (this report, RISE report 2023:68), with permission from RISE and MSB.

QR code, link to pdf of the Swedish version of the handbook “Brand i silo”.

Permanent link to the Swedish version:
http://urn.kb.se/resolve?urn=urn%3Anbn%3Ase%3Ari%3Adiva-62517

QR code, link to pdf of the English version of the handbook “Silo Fires”.

Permanent link to the English version:
https://urn.kb.se/resolve?urn=urn%3Anbn%3Ase%3Ari%3Adiva-67495

1.2 Purpose and area of use

This guideline is made to assist and facilitate the work during the emergency phase of a silo fire. The guideline summarizes 13 measures and decisions needed in connection with a suspected or confirmed silo fire and 4 warnings on what to avoid. If there is an action plan, it is used as the starting point. More detailed information about each point can be found in the handbook.

1.3 Target audience

The knowledge base presented in this guideline and more extensively in the Swedish handbook, is intended to be used both during operational efforts during a fire and in preventive work. The target groups are therefore the fire and rescue service, emergency call service, silo owners and fire safety engineers.

1.4 Short introduction to silo fires

A silo fire is an unusual event for most fire and rescue services and differs in many ways from conventional fires. In many cases, the silo fires occur as a result of self-heating of the stored material. Oxidation processes and biological activity can under unfortunate circumstances lead to a smoldering fire. The fire usually occurs deep inside the material and is therefore very difficult to detect.

In this context, measuring certain gas concentrations (e.g. CO and CO_2) in combination with temperature measurements inside the stored material is often the only way to detect a possible fire. Such measurements are therefore a very important part of the preventive work for which the silo owner is responsible. By studying the trend in the measurement data, you can often get an early indication of hazardous conditions.

Due to the fact that there are relatively few silo fires, there is little experience with this type of effort at the fire and rescue service and that there is also a lack of suitable extinguishing equipment. Both the course of the fire and the duration of the effort differ significantly from conventional fires. In order for the efforts to be as safe and effective as possible, it is important to take into account the special conditions that apply to silo fires.

The recommended basic method for extinguishing a silo fire is a combination of inertisation from the bottom of the silo, followed by controlled emptying of the silo with subsequent extinguishing. Inertisation is the use of inert gas (in this case nitrogen gas) to push aside oxygen and in this way dampen ongoing pyrolysis processes. Each facility has its own special conditions and each fire is unique, therefore specific assessments must be made regarding the details of extinguishing efforts in each case. Planning of the extinguishing effort should therefore always be done in collaboration between the silo owner and the fire and rescue service.

The Swedish handbook (link above) provides extensive information on silo fires to provide an understanding of the expected course of fire, safety aspects that must be taken into account, suitable extinguishing tactics for various fire scenarios and certain preventive measures that can be put in place to avoid or minimize the consequences of a fire.

2 The 13 measures and 4 warnings of this guideline

An overview of the 13 measures and 4 warnings is given below. Details are given in the following pages.

Measure 1: Identify the type of silo and fire scenario

Measure 2: Carry out an initial risk assessment and establish access restrictions

Measure 3: Assess the risk of gas- and dust explosions

Measure 4: Minimize the air supply

Measure 5: Nitrogen gas equipment requisition

Measure 6: Insert nitrogen gas near the bottom of the silo

Measure 7: Requisition for gas measurement equipment

Measure 8: Use foam if needed

Measure 9: Start inertisation of the silo

Measure 10: Start unloading the silo when the fire is under control

Measure 11: Expect that the unloading will take time

Measure 12: Sort unloaded material

Measure 13: Continue inserting gas during unloading

Warning 1: Do not enter a building without personal gas measurement equipment or fresh air apparatus!

Warning 2: Do not use water inside a silo, especially if the silo contains pellets!

Warning 3: Do not open the silo!

Warning 4: Liquid nitrogen (-196°C) or very cold gas can cause injury!

Measure 1: Identify the type of silo and fire scenario

Is it a smouldering fire or a surface fire with open flames? Is the smouldering fire identified, e.g. through smoke development, or has glowing embers been discovered upon unloading the silo or similar? Is there a suspicion of a smouldering fire due to a sharp smell, elevated temperatures inside the silo, elevated levels of carbon monoxide (CO), heavy condensation at the top of the silo or similar? A smouldering fire often arises deep within the material and slowly spread outwards, while the pyrolysis/smoke gases and moisture slowly spread upwards and it can take several days before clear signs of fire can be observed. Which material is in the silo, and how full is the silo (filling height/ filling level)?

See chapters 5 and 6 in the handbook.

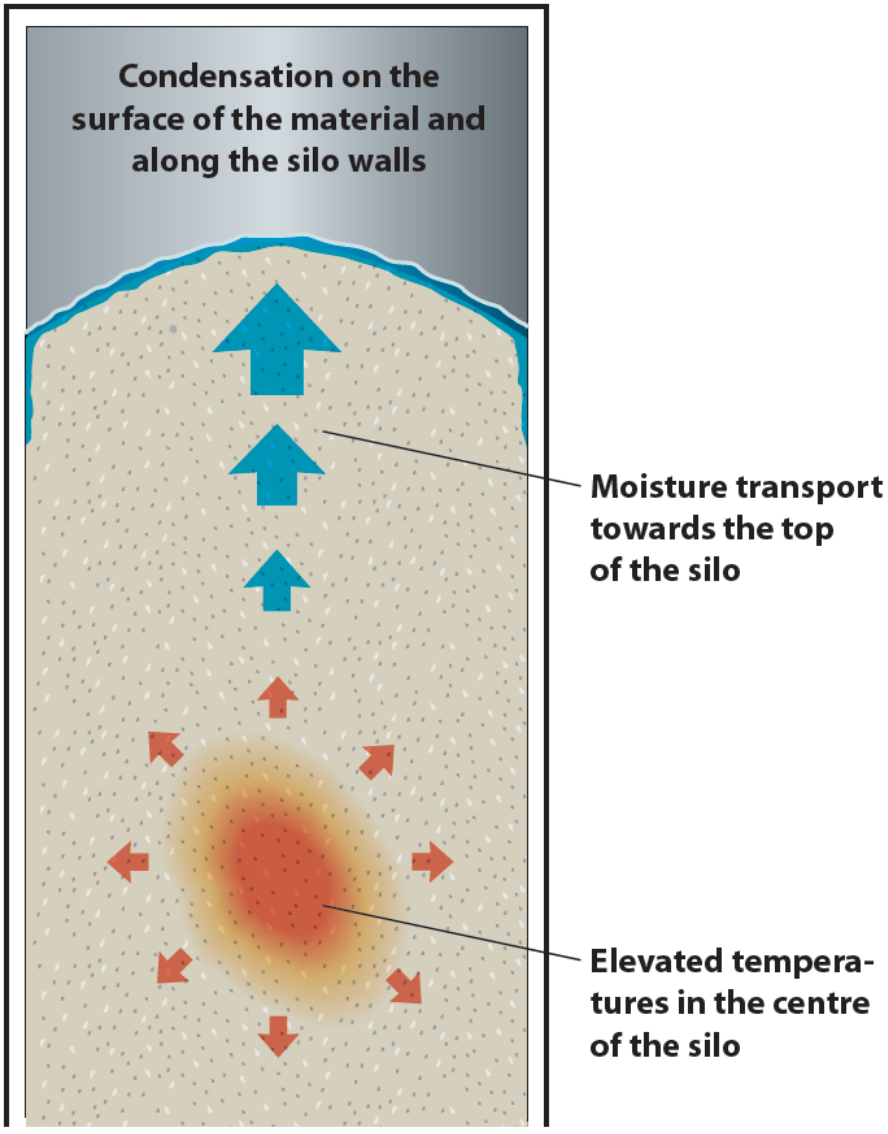

Illustration: Martin Ek, Eken Bild & Animation AB, with permission

Measure 2: Carry out an initial risk assessment and establish access restrictions

There can be very high levels of carbon monoxide in the facility both in the event of a suspected or verified smouldering fire. Hazardous levels can also occur in personnel areas, control rooms etc. Measurement instruments that show both carbon monoxide (CO) and oxygen content (O_2) must be used for continuous assessment of the risk. The measurement instrument must be calibrated regularly. If in doubt, wear full protective gear.

Establish access restrictions: Who have access and should/should not have access to different areas?

See chapter 3 in the handbook.

Photo: Bergslagens Räddningstjänst, with permission

Measure 3: Assess the risk of gas- and dust explosions

If possible, measure the CO and O_2 levels to assess the risk picture inside the top of the silo. If a strongly elevated CO level of the order of magnitude > 2–5 % is measured, and an oxygen content above 5 %, there is a risk that the smoke gases may be flammable. There is thus a risk of a gas explosion and you should not stay on top of the silo more than absolutely necessary. The safety zone should be expanded at ground level, considering the explosion hazard.

See chapter 3 in the handbook.

Photo: Räddningstjänsten Höga Kusten-Ådalen, with permission

Measure 4: Minimize the air supply

Close hatches, close openings on the silo, close ventilation, close dampers and close channels and connections. At the top of the silo there must be a small opening that can release smoke gases, but make sure that air cannot be sucked in. A heavy rubber sheet over an open top hatch can work as a valve to control the flow.

See chapter 2 in the handbook.

Photo: Ingvar Hansson, MSB, with permission

Measure 5: Nitrogen gas equipment requisition

Send a requisition for vaporizer equipment, nitrogen gas tank and a tanker truck with liquid nitrogen (N_2) as early as possible. The vaporizer equipment is necessary since the nitrogen must be in gas phase when inserted. In Norway, there is no national overview of such resources, but the emergency central (110) can often assist. In Sweden, the “RIB Ressurs” can be used to support requisition. Other countries may have other local or national resources available. Note that a relatively large parking space is needed for the equipment, and the location should be chosen so that it is outside the safety zone and so that hoses do not block necessary traffic in the area. Optionally, in the initial phase, gas can be taken out with a limited flow rate directly from the tanker.

See chapter 2 in the handbook.

Photo: Haugaland Brann og Redning IKS, with permission

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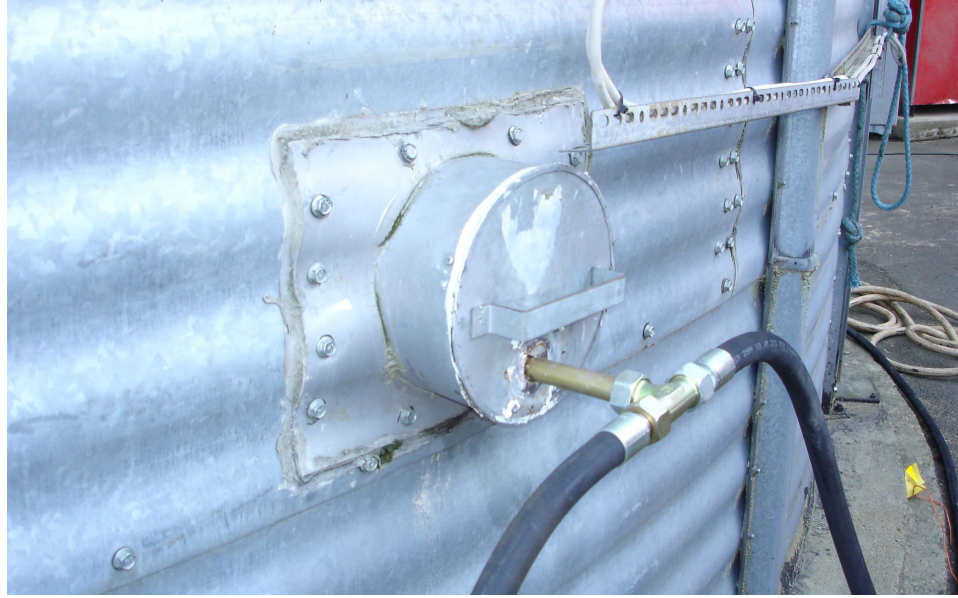
Measure 6: Insert nitrogen gas near the bottom of the silo

Inserting nitrogen gas (N_2) near the bottom of the silo is in most cases the safest and most effective extinguishing method. The supply rate of nitrogen gas is based on the cross-sectional area of the silo and should be at least 5 kg/m^2 per hour, which gives an average vertical gas filling rate of approx. 8 meters per hour (given approx. 50 % porosity in the bulk material). The total gas requirement must be estimated from the silo's gross volume (empty silo) and you should expect a total gas requirement of 5–15 kg/m^3. If necessary, prepare holes at the bottom of the silo and make/use lances for supplying the gas.

See chapter 2 in the handbook.



Photos: RISE Research Institutes of Sweden, with permission

Measure 7: Requisition for gas measurement equipment

If possible, send a requisition for equipment to measure CO and O_2 concentration at the top of the silo during the inertization and unloading process. Note that the measurement instrument for CO must be able to measure very high levels, preferably at least 10 % CO, in order to provide relevant information. In Norway, there is no national overview of such resources, but the emergency central (110) can often assist. In Sweden, the “RIB Ressurs” can be used to support requisition. Other countries may have other local or national resources available. For safety reasons, the instruments must be placed at a safe distance from the silo, which requires a powerful gas pump. The gas line must also be fitted with condensation traps, particle filters and desiccants to protect the measurement instruments.

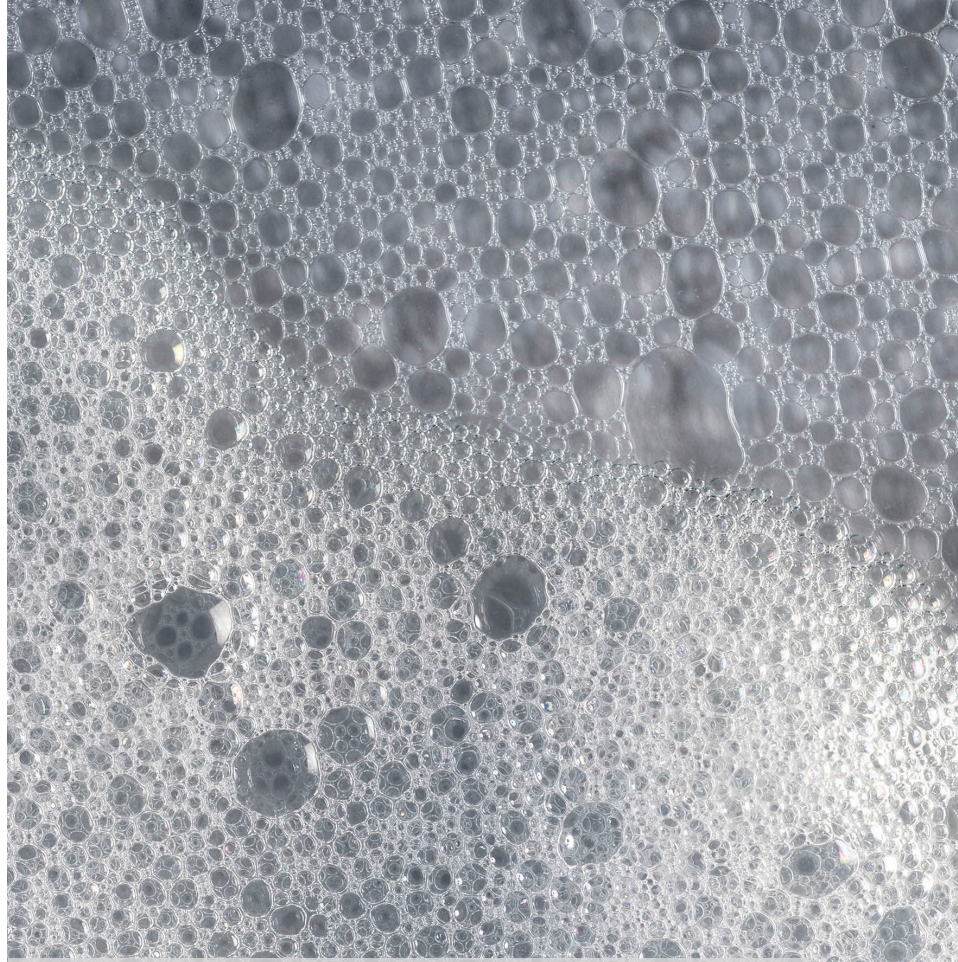
See chapter 2 in the handbook.

Photo: RISE Research Institutes of Sweden, with permission

Measure 8: Use foam if needed

If the delivery of the gas equipment takes time or there is an obvious hazard of an open flame fire, if safety permits, the material at the top of the silo may be coated with extinguishing foam in the form of semi-heavy foam or alternatively, light foam. The foam must be high-quality so that runoff is minimized and it can be beneficial to use a compressed air foam system (CAFS) if available. Be very careful not to open the silo more than necessary and thus provide oxygen to the pyrolysis gases at the top of the silo. Care must be taken to minimize the risk of dust being stirred up during foam application. The response personnel must wear full protective equipment.

See chapter 4 in the handbook.



* Semi-heavy foam: Extinguishing foam with a foam number between 20 and 200.
** Light foam: Extinguishing foam with a foam number higher than 200.
*** Compressed Air Foam System (CAFS): Extinguishing system where foam concentrate and air are mixed with water before the foam is pumped into the hose.
(source: http://kbt.no).

Photo: Powerpoint stock images via Microsoft 365 subscription licens

Measure 9: Start inertisation of the silo

Start the inertisation of the silo as quickly as possible when the gas equipment is in place. If the explosion hazard at the top of the silo is high (CO > 2–5 %, O_2 > 5 %), start the extinguishing work by introducing nitrogen gas into the top of the silo. This must be done with great care so that dust is not swirled up and poses dust explosion hazard. As soon as the nitrogen gas filling of the silo top has started, the inertisation via the silo bottom also can start, but to a limited extent if needed. When the oxygen content in the top of the silo falls below 5 %, the gas supply via the top should be stopped, using only insertion from the bottom, at the recommended application rate.

See chapter 2 in the handbook.

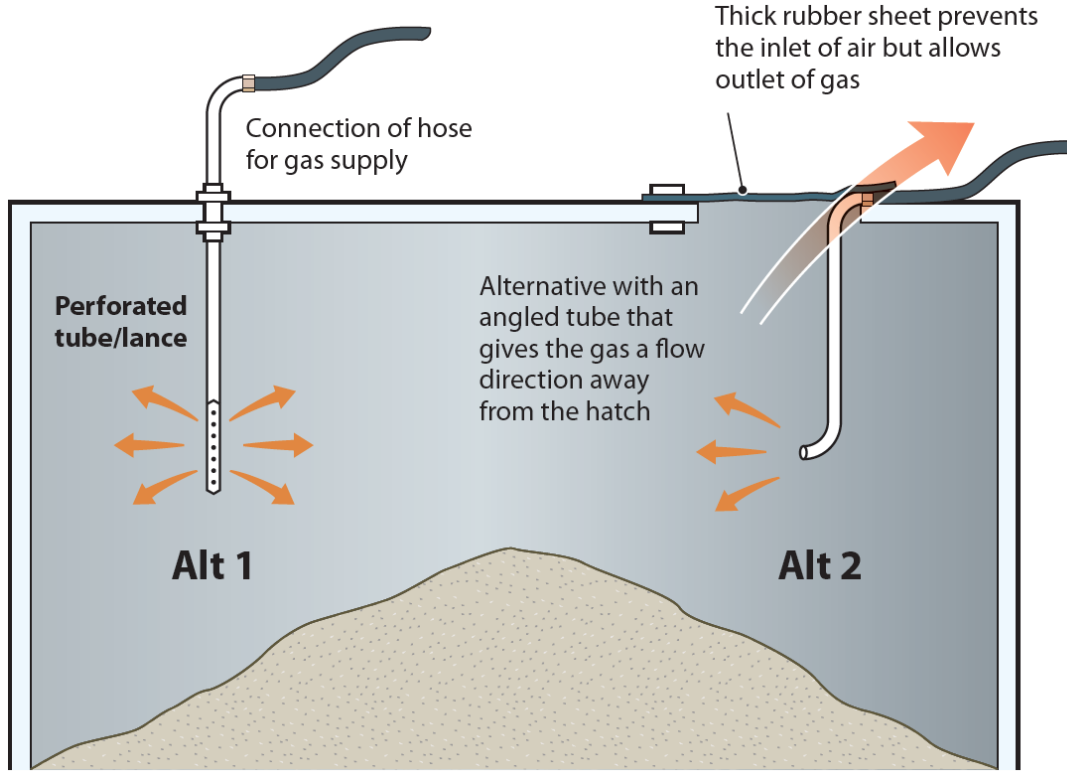


Illustration: Martin Ek, Eken Bild & Animation AB, with permission

Measure 10: Start unloading the silo when the fire is under control

Only start unloading the silo when the silo is completely inert and the fire is considered to be under control, i.e. when the oxygen content is below 5 % and the CO concentration is significantly reduced. Firefighters with full protective equipment must be near the discharge opening to be able to extinguish any glowing material and, if necessary, to be able to clear the opening of lumps of soot/charred material. Assess the situation continuously inside the silo using the gas measurements at the top of the silo. An increasing level of carbon monoxide indicates increasing activity inside the silo, while increased oxygen content may be due to air entering. If the oxygen content in the top of the silo exceeds 5 %, the unloading should be paused and the supply rate of nitrogen gas should be increased until the levels drop and the oxygen content falls below 5 % again. If possible, gas supply can also take place at the top of the silo when the oxygen content is elevated. Be aware of any arch formations or overhangs inside the silo that can cause problems during unloading and make extinguishing work more difficult. See chapters 2 and 6 in the handbook.

Photo: RISE Research Institutes of Sweden, with permission

Measure 11: Expect that the unloading will take time

Expect the unloading and emptying to take many hours, sometimes several days. Assume maximum unloading speed and expect unloading to take at least 2-4 times longer. As the fire and rescue service must be present at the silo opening for unloading (and possibly other places during the unloading process), it will require a lot of personnel to take turns. There will also be a need for a many refills of fresh air for their breathing apparatuses.

Photo: RISE Research Institutes of Sweden, with permission

Measure 12: Sort unloaded material

Sort the material taken out of the silo so that undamaged material/pellets are separated from material/pellets that are discolored or contain pyrolysed material/pellets, often in the form of large, charred lumps. Monitor the pile and carry out additional extinguishing if necessary. Undamaged material/pellets can be covered to protect from rain. The handling may require large storage areas.

Photo: RISE Research Institutes of Sweden, with permission

Measure 13: Continue inserting gas during unloading

Continue the gas supply via the silo bottom throughout the unloading process. The supply quantity should be regulated using the oxygen measurements in the top of the silo and the oxygen content should not exceed 5%.

Photo: RISE Research Institutes of Sweden, with permission

Warnings!

Warning 1: Do not enter a building without personal gas measurement equipment or fresh air apparatus!

High levels of carbon monoxide (CO), carbon dioxide (CO_2) and other pyrolysis products, sometimes in combination with very low oxygen content, is a health hazard, and in the worst case can lead to unconsciousness and death.

See chapter 3 in the handbook.

Warning 2: Do not use water inside a silo, especially if the silo contains pellets!

There is a high likelihood of pellets swelling and arch formations or overhangs may form in the silo. In the worst case, swelling can lead to the collapse of the silo structure. Using water can also lead to the formation of carbon monoxide (CO) and hydrogen gas (H_2). However, there are some situations where water or foam may be useful.

See chapters 3 and 6 in the handbook.

Warnings!

Warning 3: Do not open the silo!

Air access provides a supply of oxygen and increased intensity in the fire, which in turn can contribute to rapid fire spread in e.g. transport system before and after the silo, and lead to serious gas and dust explosions.

See chapter 2 in the handbook.

Warning 4: Liquid nitrogen (-196°C) or very cold gas can cause injury!

Therefore, check the temperature of the gas after the evaporator so that hoses and other equipment are not damaged by liquid nitrogen coming out of the pipe system. Liquid nitrogen on body parts quickly causes very serious frostbite, and full-coverage protective clothing must therefore be used near liquid-filled pipes and cables. High levels of nitrogen gas in enclosed spaces can quickly lead to suffocation.

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