Silo Fire Suppression and Prevention Workshop-Part 2

Alternative firefighting strategy
Practical experience from silo fires
Preventative and preparatory measures

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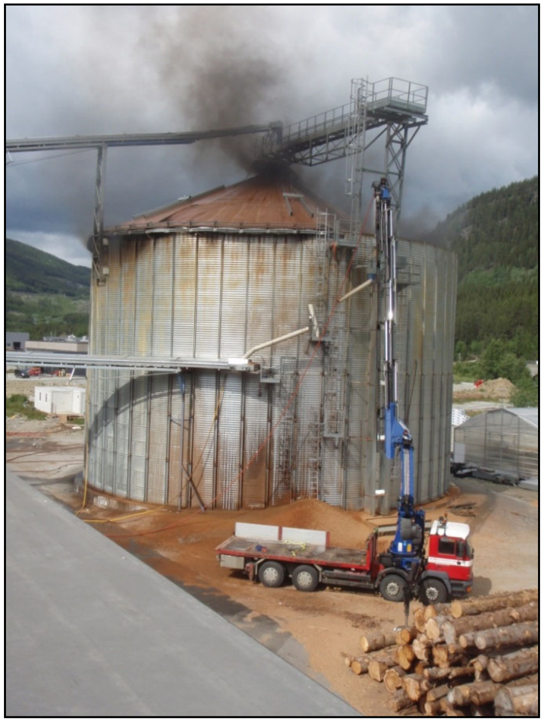
RISE Fire Research 2019

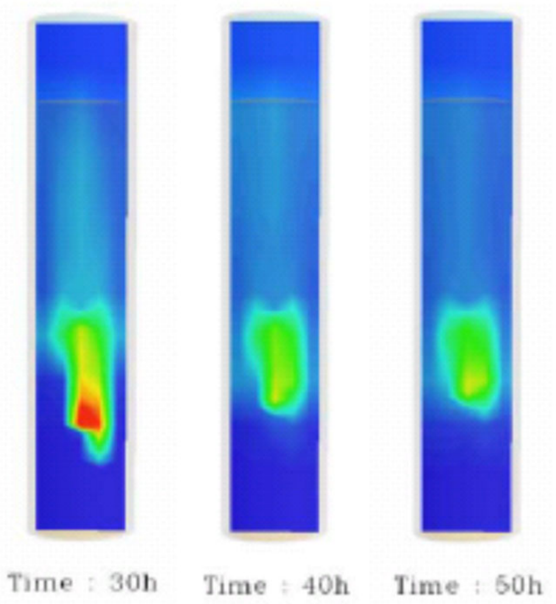


Alternative firefighting strategy

- Application of foam (or water) in the silo headspace
  - Preferably in combination nitrogen injection

- Injection of water into the bulk material
  - Most likely only effective in small diameter silos or a smouldering fire close to the silo wall

- **(NOTE: This is not a general option to inerting!)**



Alternative firefighting strategy

Might be used for specific fire scenarious or bulk materials, e.g.

- If the fire escalated to an open surface fire, e.g. large openings not possible to close
- In silos containing moist bulk material which is not affected by water and the silo construction can withstand the increased load
- In smaller silos, silos with limited filling degree or silos with a large discharge door construction
- *Very doubtful effect on a fire in large silos where the smouldering fire is located deep into the bulk material.*

Alternative firefighting strategy

Example: Dust explosion in bucket elevator released explosion vents both on elevator and silo roof. Entire silo roof out of position. Surface fire inside silo. Use of medium expansion foam and discharge using a wheel loader.

Alternative firefighting strategy

Remember.

Do not use large amount of water inside a silo with pelletised material. Expansion creates huge forces and might crack the silo construction.

Alternative firefighting strategy

Possible methods

- Foam application into the silo headspace from the silo top, preferably using CAF (Compressed Air Foam) or medium/high expansion (only fluorine-free foams)
- Fixed foam/water deluge system installed under the silo roof construction
- If the fire can be localized from the silo wall (e.g. using an IR-camera) enabling a targeted application throught the silo wall using foam or water.
- Keep the silo closed!

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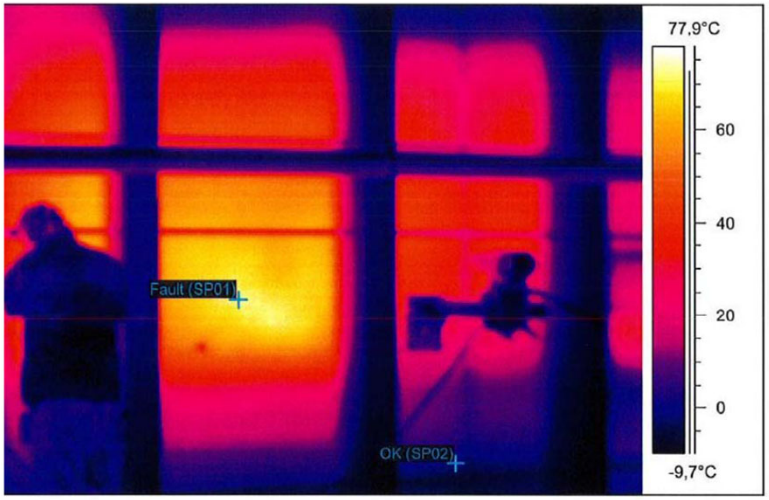
Alternative firefighting tactics

Foam successfully used for controlling a smouldering fire in a void close to the silo wall.



Alternative firefighting tactics

Cold Cut System (High pressure water) successfully used to controll a smouldering fire in a small silo containing wood dust

Avoid working on the silo top!

Learnings from real silo fire incidents

Experience and learnings from real fire incidents, both successful and failed fire suppression operations

Kristinehamn, wood pellets, Sept-Oct 2007

- Diameter: 8 m
- Height: 47 m
- Filling level: 40 m of wood pellets

- Thu- Increased temp
- Sat- Visible smoke
- Sat-Sun CO_2-application (tot 35 ton)
- Mon - N_2 injection
- Tue - Start discharge
- Thu – Silo empty

Summary of fire suppression and discharge operation

- Injection rate: 200-250 kg/h (approx. 4 kg/m^2 h)
- Injection time: 65 h
- Nitrogen consumption: 14 ton (approx. 5,6 kg/m^3)

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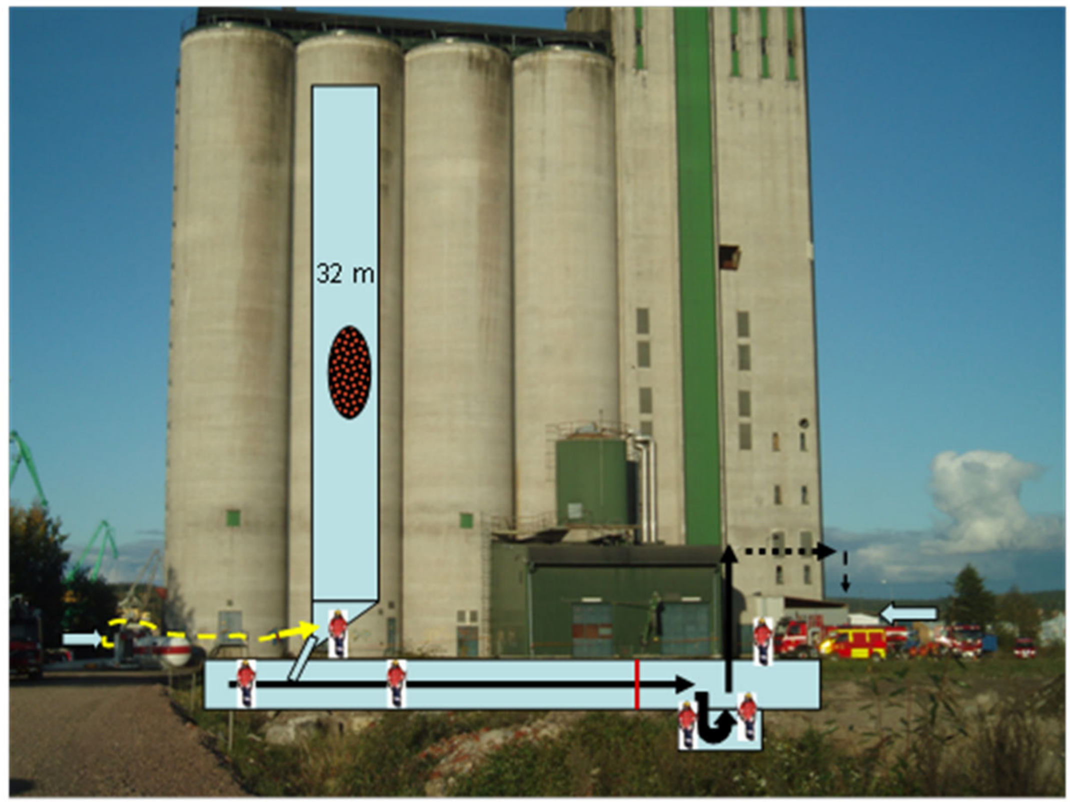
Summary of fire suppression and discharge operation

Silo discharged through ordinary conveyor system. Required several firefighters to control the operation.

Smouldered material blocking discharge opening



Falkenberg, oat shells, 2011

- Tower silo, one cell
- Filled with 73 ton of oat shell
- Technical failure on delivery truck during filling
- 7 ton nitrogen
- Total operation, appr 4 days

Jönköping, wood powder, May 2008

District heating power station

- Diameter 10 m, height 15 m
- 130 ton of wood powder (filling approx. 1 m below silo top
- Friction in discharge auger, embers distributed by a fan to the silo top
- Detection May 7-8, 2008
- Inerting May 8-16
- Start discharge May 21 (2 weeks)

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Jönköping, wood powder, May 2008

- Injection rate, approx. 250>>75 kg/h (3,2-1 kg/m^2 h)
- Nitrogen consumption 17 ton (approx. 14 kg/m^3)
- No damage on silo or wood powder

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Hallingdal, wood pellets, Norway 2010

- Diameter 24 m,
- Wall height 15 m (approx. 7750 m^3)
- Filling 3500 m^3 of wood pellets
- Spontaneous ignition

Source: Hallingdal Brann og Redningtjenste IKS

Hallingdal, wood pellets, Norway 2010

00:43 Alarm-high temperaure
01:41 Alarm CO-detector .
02:42 Visible smoke from silo top
06:35 CO_2 bottles and working platform available, N_2 delivey delayed. Decides to extinguish with CO_2 through a hatch at the silo roof .
08:49 Ignition of pyrolysis gases in silo headspace, 2 firefighters injured
09:00 Start to discharge through the conveyor system, but the belt is burnt off
Decides to open the silo and discharge with excavator and wheel loader.
22:33 Discharge operation finished

Source: Hallingdal Brann og Redningtjenste IKS

Hallingdal, wood pellets, Norway 2010

- Ignition while discharging CO_2 bottles into silo headspace
- Entire silo roof is lifted about 0,5 m
- No explosion vents open
- 2 firefighters injured
- Electrostatic discharge most likely ignition source

Source: Hallingdal Brann og Redningtjenste IKS

Full protection gear and SCBA equipment reduced injuries

Source: Hallingdal Brann og Redningtjenste IKS

Hallingdal, wood pellets, Norway 2010

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Source: Hallingdal Brann og Redningtjenste IKS

Laxå, wood pellets 2010

Photo Tove Svensson

- Spontaneous ignition
- Smouldering fire in several days
- Opened up to start discharge
- 5 hours later, explosion, steel door thrown about 80 m

Laxå, wood pellets 2012

- Smoke detected from silo
- Started to discharge silo, 35-40 ton/h
- Explosion in elevator after about 100 ton
- Discharge stopped

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Laxå, wood pellets 2012

- Perforation of silo wall at ground level for gas injection
- Explosion, part of roof thrown to the ground
- No explosion vent opened

Laxå, wood pellets 2012

- Extinguishment of open fire with water monitors during the night
- Silo construction collapsed due to expansion of pellets
- Fortunately no injuries

Gothenburg, wood pellets 2017

- Explosion in bucket elevator during filling of silo.
- Explosion vents released on elevator
- No vents released on silo but roof plates opened up

Gothenburg, wood pellets 2017

- Surface fire, nitrogen injection through by fixed system at silo base
- Full inerting difficult due to leakages in roof construction
- Some water injection through roof hatches
- Silo kept inerted for about two weeks before discharged

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Wood pellets, US 2017

- Smouldering fire
- Injection of CO_2 at silo base
- Construction cooled with water

- Silo collapsed

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Some typical causes for ignition

- Self-heating and spontaneous ignition
- Spark formation in various equipment (mills, pellet presses)
- Heat generation in conveyor systems (friction, overheated ball bearings/rollers, etc.
- Hot surfaces (lamp shades, motor casings, etc.)

- Can result in both open surface fires and deep-seated smouldering fires
- Significant risk for dust explosions and rapid fire escalation in conveyor and elevator systems

Explosion in chain conveyor for pellets

Heating power station

- Friction against a steel guide for the chain
- Smouldering nest ignite dust at point of discharge
- Explosion wave directed backwards along the conveyor

Explosion in chain conveyor for pellets

Explosion in a wood chips drying system

- Ignition in a rotating drying drum due to scrap metal
- Explosion wave transfered to dust collector located indoors
- Secondary explosion release explosion vents and destroy building construction

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Fires in flat storage

- Temperature and gas monitoring more difficult
- Use of inerting gas not effective
- Extinguishment by front loader discharge and foam/water application
- Fire development might be very rapid during discharge
- Firefighting resources must be standby

Fires in conveyor systems

- Overheated bearings, friction, etc.
- Ignition source detection important
- Risk for dust explosions
- Very fast fire development
- Risk for fire spread
- Accessibility often a problem
- Fixed sprinkler systems only realistic fire protection solution

Fire in conveyor system to a flat storage

Flat storage 20 000 m^2, 10 000 ton of pellets
Extremely rapid fire escalation via the conveyor system

Fire in conveyor system to silo storage

45 000 m^3 and 100 000 m^3 silos involved, conveyor system feeding burning pellets into the silos.
One silo destroyed, one silo inerted for many weeks.

Preventative and preparatory measures

ISO/TC238/WG7 – Safety of solid biofuels

Four standards under development

- ISO 20023 - Solid biofuels — Safety of solid biofuel pellets — Safe handling and storage of wood pellets in residential and other small-scale applications (Published)
- ISO 20024 - Solid biofuels — Safe handling and storage of solid biofuel pellets in commercial and industrial applications (DIS open for voting and comments until March 27, 2019)
- ISO 20048 - Solid biofuels — Determination of off-gassing and oxygen depletion (2 parts: Part 1-Laboratory method, Part 2-Operational method)
- ISO 20049 - Solid biofuels — Determination of self-heating (2 parts: Part 1- Isothermal calorimetry, Part 2-Basket heating tests)

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ISO/DIS 20024 Solid Biofuels-Safe handling and storage of solid biofuel pellets in commercial and industrial applications

Scope (extract, not complete):

This document **provides principles and requirements for safe handling and storage** of solid biofuels pellets in commercial and industrial applications. It **uses a risk based approach to determine what safety measures should be considered**.

This document also gives **specific guidance on detection and suppression systems and preparatory measures** to enable safe and efficient firefighting operations**. Guidance on the management of fire and explosion incidents is also specified.**

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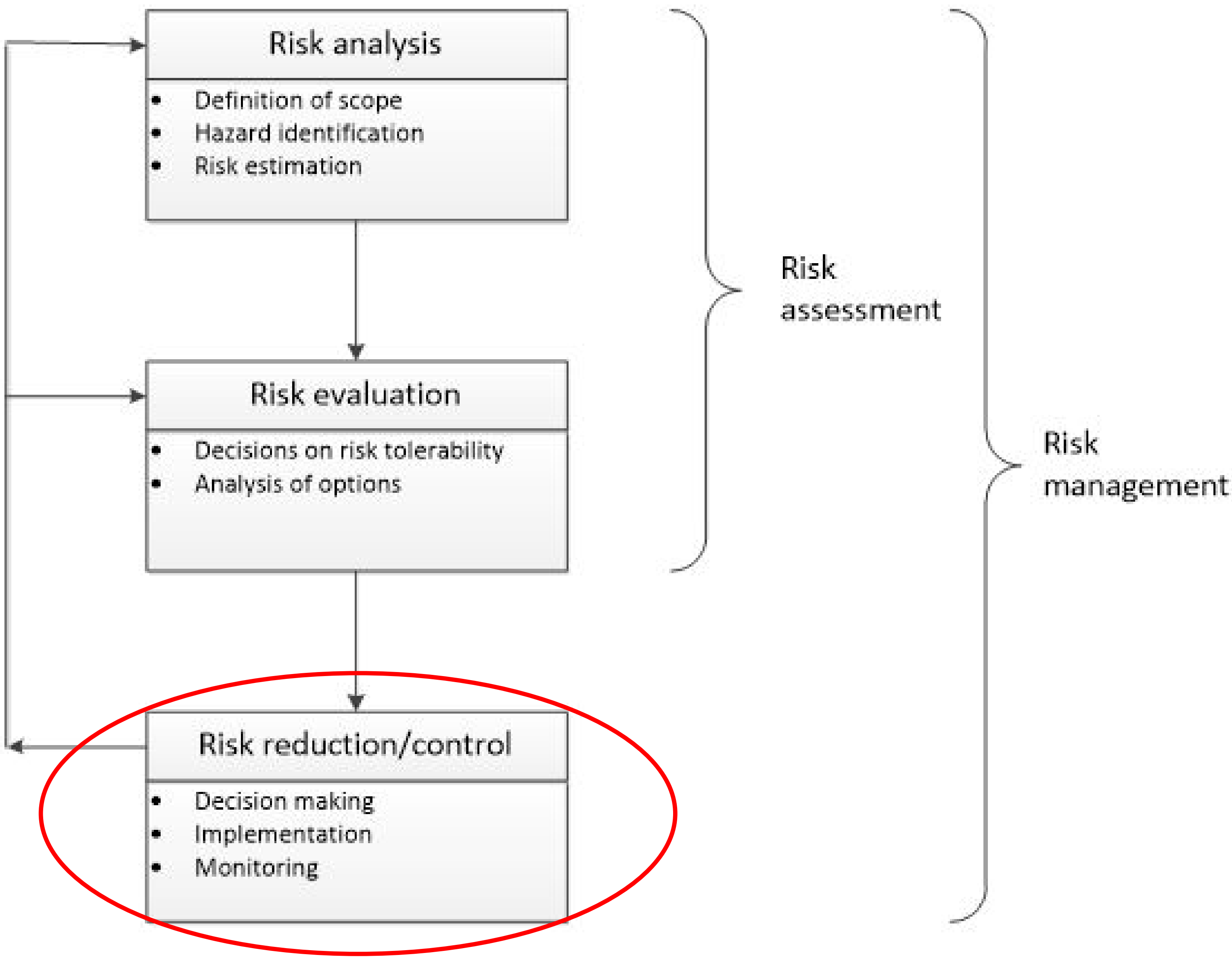
Preventative and preparatory measures based on a risk management process



Main content in ISO/DIS 20024

- 5 Risk management
- 6 Design and construction
  - e.g. Specific risk considerations, risk areas, safe handling
- 7 Safe operation and maintenance
  - e.g. safety during operation, pre-planning of emergency operations, personnel risks,
- 8 Conveyor systems
- 9 Silos
- 10 Large scale bunkers
- 11 Warehouse

Main content – Annexes to ISO/DIS 20024.

- A- Pellet supply chain and general safety guidelines for unit operations
- B- Self-heating and off-gassing
- C- Dust as fire and explosion hazards and mitigation of risks
- D- Safety aspects and guidance on handling emergency situations
- E- Ventilation for cooling of bulk material
- F- Principal design of inert gas distribution and inlet openings
- G- Examples of various sensors and detection systems
- H- Example for the risk assessment in a commercial medium size wood pellet store

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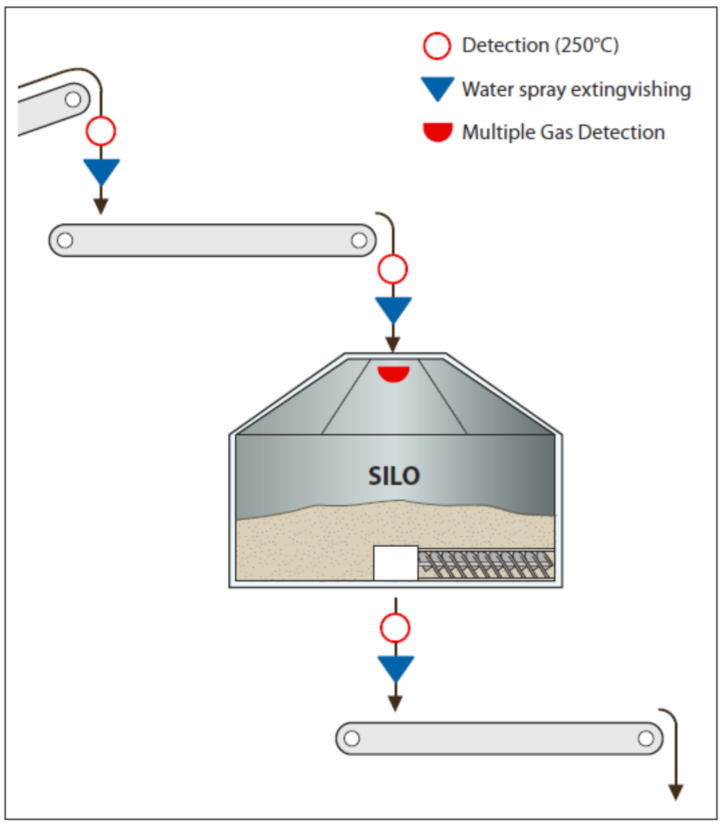
Safe operation and maintenance

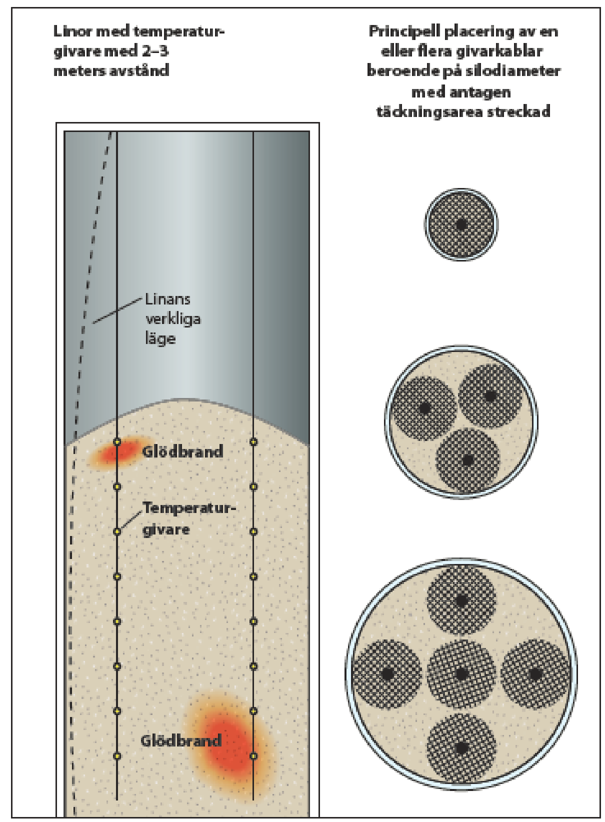
- Regular inspections of the entire handling system and pellet storage
- Monitoring of temperatures and gas concentrations to ensure ”normal conditions”
- Housekeeping, prevent dust accumulations
- Maintenance plan for mechanical equipment, strict control of hot works, etc.
- Pre-planning of emergency operations
- Personnel risks (toxic gases, low O_2 concentrations, etc)

Silos - Prevention and preparations

Detection systems to achieve early warnings

- IR-detectors on conveyor systems before and after silo
- Gas detection in silo headspace
- Temperature sensors inside bulk material





Silos - Prevention and preparations

General design of silo (examples)

- Air tightness of general silo construction
- Nominally airtight valves at inlet and discharge outlet
- Possibility to close/seal ventilation system (both free convection or forced ventilation)
- Installation of fixed gas distribution system at silo base and in silo headspace
- Arrangements for emergency discharge
- Explosion protection arrangements

Silos - Prevention and preparations

Are there any size limitations of silos for fire suppression by inerting?

- Preventative and preparatory work extremely important
- Injection of inert gas in case of tendency to self-heating
- Use continous inerting (inert gas generator) to reduce risk for self-heating and spontaneous ignition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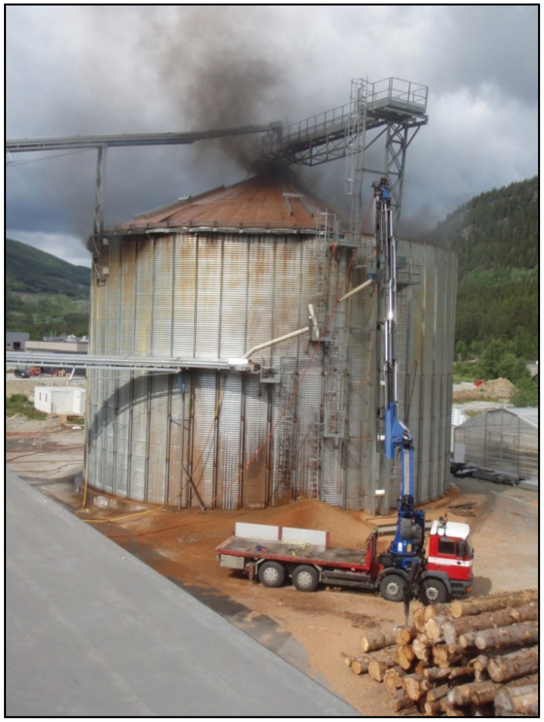
Thank you, questions?



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