

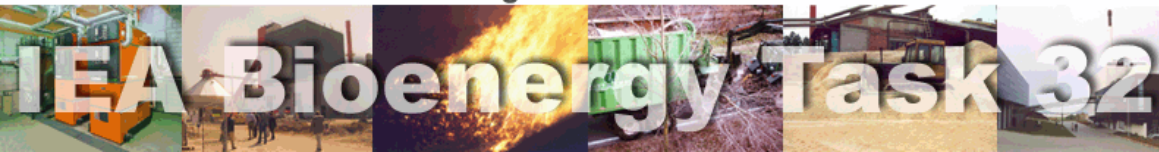
Safety aspects of solid biomass storage, transportation and feeding



Jaap Koppejan (Task 32)



Biomass Combustion and Cofiring



Safety aspects in small scale biomass combustion

Ingmar Schüssler

Per Blomqvist, Henrik Persson, Magnus Andreas Holmgren

SP Technical Research Institute of Sweden

Dublin, 18 October 2011



Background

- Some serious incidents have happened in the last decade in which workers were killed or injured
- Practical, easily accessible information needed by the market
- IEA Bioenergy will carry out a review on health and safety aspects of handling, storage and transportation of SOLID biomass fuels

Draft TOC for H&S project

- Summary
- Table of contents
- Introduction
- Fire related hazards
 - Self heating, off-gassing, dust explosions
 - Mitigation measures and fire fighting
- Health concerns
 - Exposure to airborne dust, fungi, moulds
 - Exposure to off-gassing emissions and oxygen depleted air
 - Other risks, including other exposure risks, trauma, etc.
- Transportation safety
- Conclusions
- Annexes



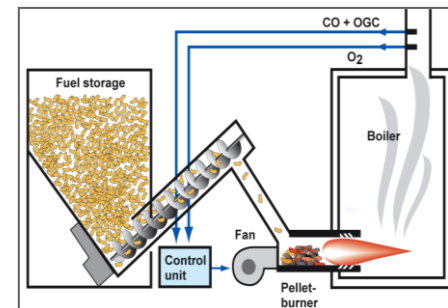
Advantages in using Pellets

Standardized Biomass

(Moisture Content, Heating Value, Size)

→ Practical fuel for development of transportation, storage and heating applications

→ Enable establishment of international market for large and small scale usage



Fires in storages of wood pellets (examples)

Fire	Type	Sizes
Esbjerg DK, 1998	Silo, wood pellets	85 m, 23 cells 2000 m ³
Härnösand, 2004	Silo, wood pellets	35 m, 5 cells 3000 m ³
Ramsvik, 2005	A-frame storage, wood pellets	43 000 m ³
Kristinehamn, 2007	Silo, wood pellets	47 m, one cell 1350 m ³
Laxå, 2010	Silo, wood pellets	20 m high x 20 m diameter silo
Hallingdal, 2010	Silo, wood pellets	20 m, 7745 m ³

Esbjerg 1999



Wood pellets

85 m high silo, 23 cells 2000 m³

Ramsvik 2005



Wood pellets from production
43 000 m³



Laxå 2010



Explosion during fire fighting damaged the silo structure

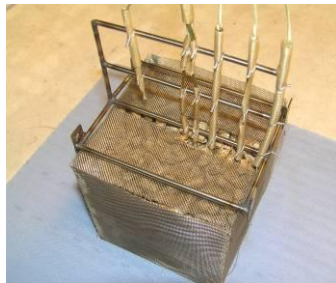
Experimental studies for determining self-heating

Scales

grams:



1 dm³:



1 m³:



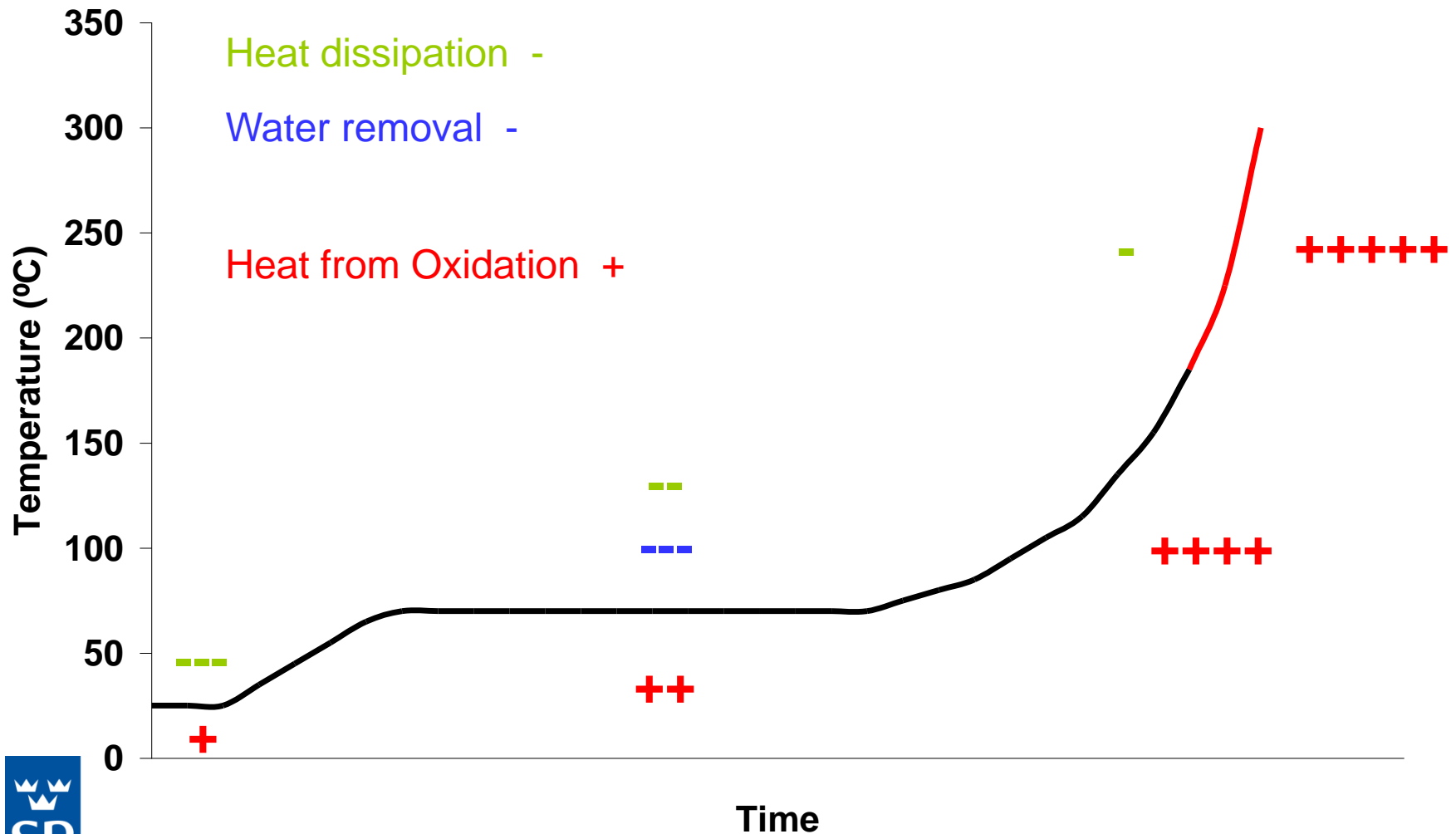
4 m³:



Self-heating and spontaneous ignition

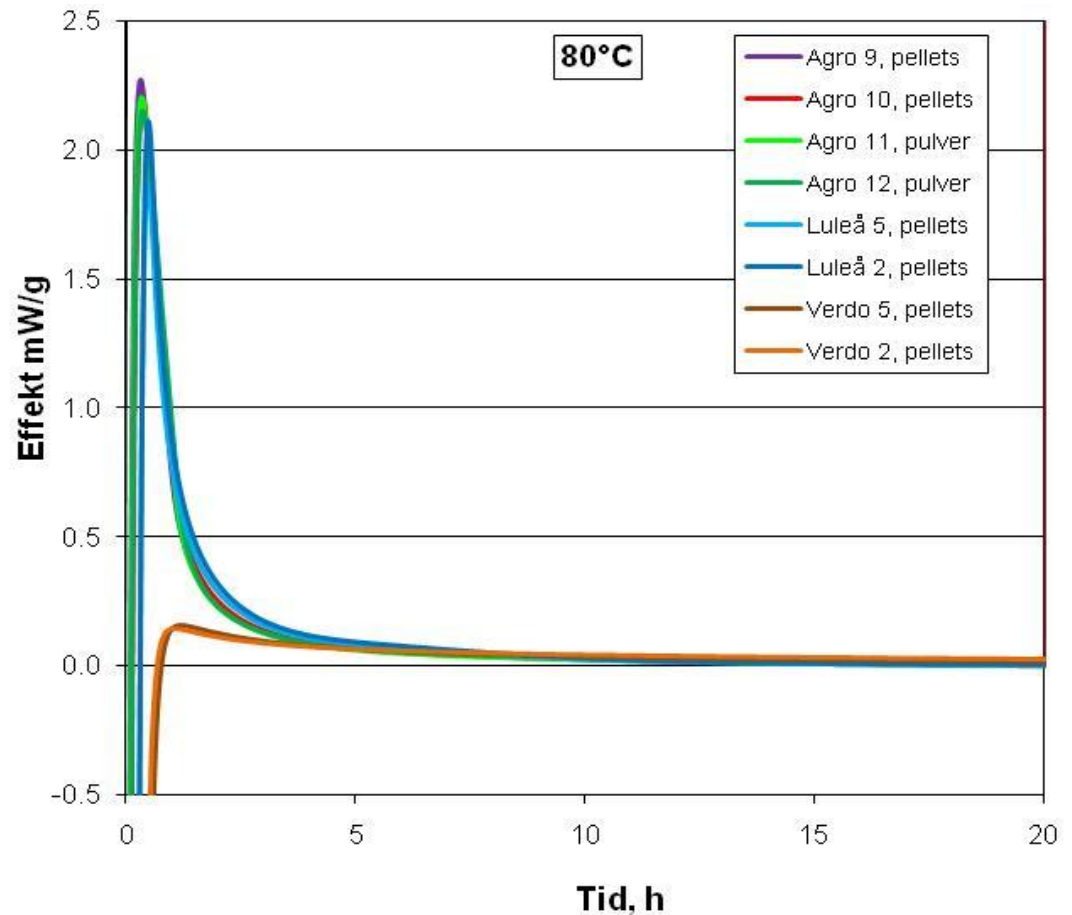
- Microbiological activity generally not significant (as in e.g. piles of wood chips)
- Heat from oxidation of wood constituents
- Oxidation of unsaturated fatty acids proposed to be major heat source
- Self-heating often seen shortly after production
- Some fuel qualities show higher heating activity and can during unfavorable conditions lead to spontaneous ignition

Self-heating and spontaneous ignition



Experimental studies for determining self-heating

**Micro calorimeter -
heat production (activity)
screening tests**



Experimental studies for determining self-heating

1-m³ spontaneous ignition experiments

- Critical conditions were achieved in relatively large scale experiments
- Spontaneous ignitions occurred within 35 hours in 1m³ wood pellets subjected to 105°C
- The experiments are suitable as validation data for models (well-described boundary conditions, detailed temperature and gas concentration data)



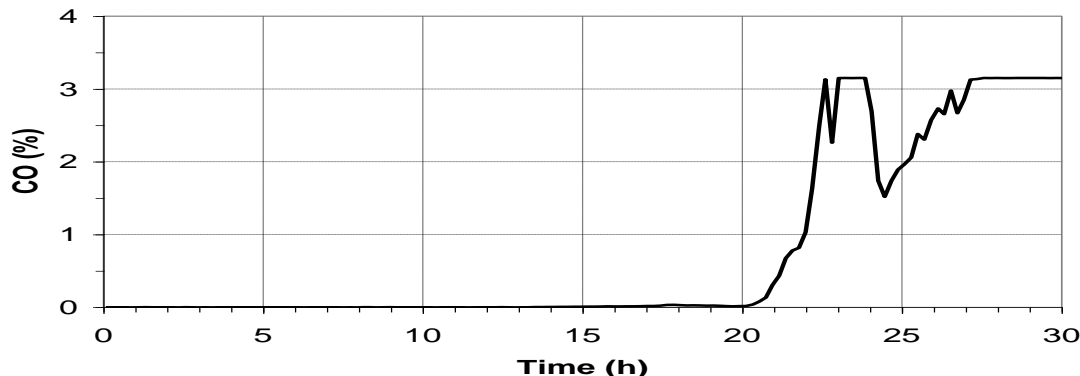
Centrally located pyrolysis core



Experimental studies for determining self-heating

Large-scale silo tests

- A smouldering fire can go on for a long time before it is detected
- Early detection requires reliable measurement of low concentrations
- The spread of the pyrolysis core is slow and downwards
- The upward transport of pyrolysis gases is slow
- Good repeatability of the experiments. Suitable as validation data for mathematical simulation.



Carbon monoxide in the top of the silo



Field measurements at pellet silos

May 2007: Silo building in Sölvesborg

- self-heating of imported wood pellets – Gas measurements to identify “problem silos” and to monitor occupational areas for health risks

October 2007: Silo building in Kristinehamn

- spontaneous ignition in silo cell containing domestic wood pellets – Gas measurements to guide during extinguishment of silo fire



Field measurements at pellet silos

Top of silos	Oxidation	Fire
CO (%)	~ 0.5-1	3 to >10
CO ₂ (%)	0-10	>10 to >30
O ₂ (%)	0-21	0-10
THC (ppm)	100-2500	>15000

Emissions measured in top compartment of silos at field and lab tests

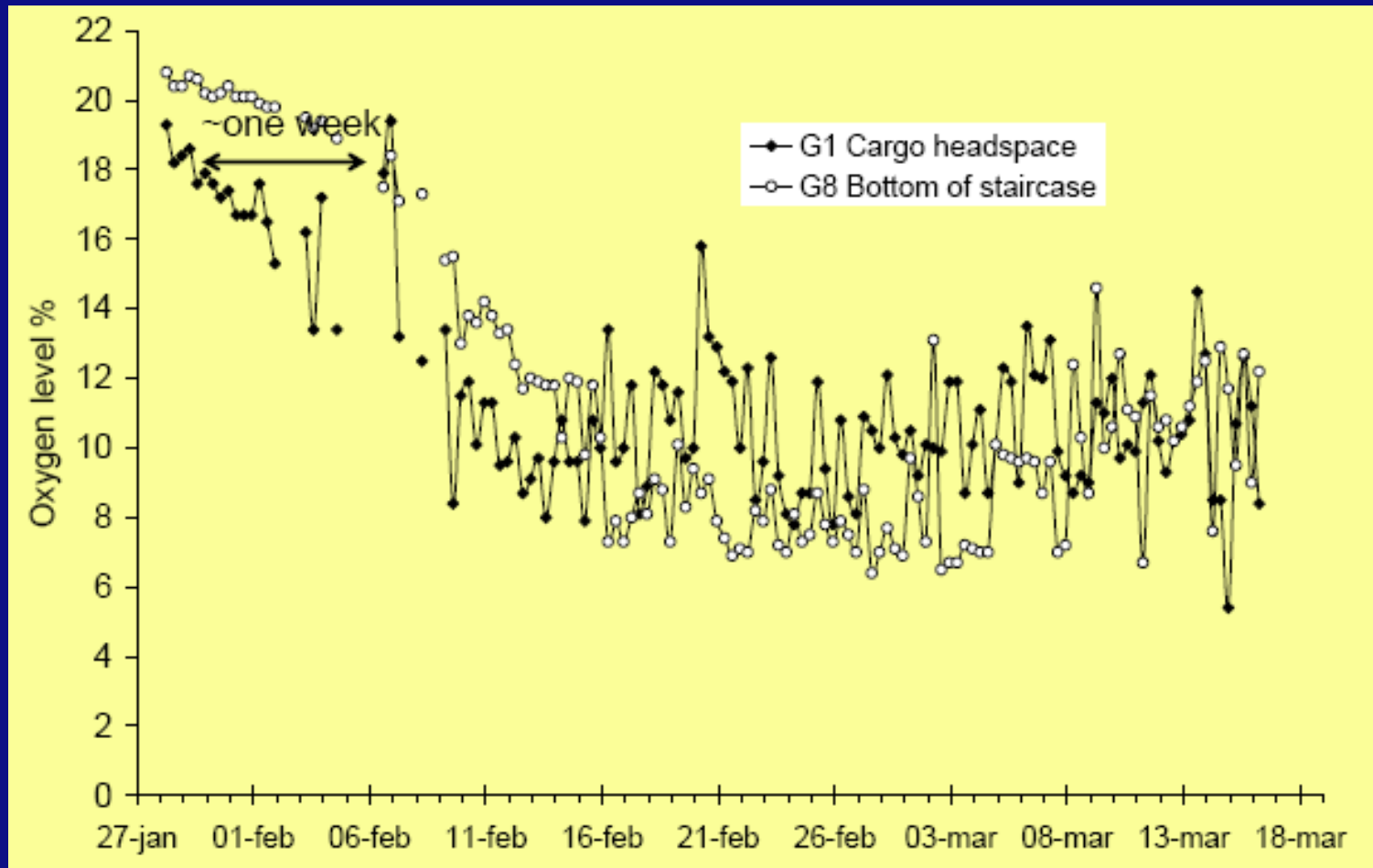
Measurement	Individual VOC species (toluene-ekv.)
6-m silo exp.* (test 3 before extinction, top of silo)	Aliphatic hydrocarbons (hexane, heptane, octane) - 970 µg/m ³ Aldehydes (pentanal, hexanal) - 470 µg/m ³ Terpenes (α -, β- pinene, 3-karen, limonene) - 410 µg/m ³ Methyl furan - 180 µg/m ³
Sölvesborg (meas. 1, top of silos)	<i>Silo 18, Russian pellets:</i> Aliphatic hydrocarbons (C5-C8) - 110 mg/m ³ Mono terpenes (α-pinene, β-pinene, 3-karene, limonene) - 28 mg/m ³ Aldehydes (pentanal, hexanal - 13 mg/m ³) <i>Silo 9, Polish pellets:</i> Aliphatic hydrocarbons (C5-C8) - 60 mg/m ³ Mono terpenes (α-pinene, β-pinene, 3-karene, limonene) - 130 mg/m ³ Aldehydes (pentanal, hexanal - 6 mg/m ³)
* Individual VOC may be underestimated due to sampling error.	

Two people died here!

2007/ 6/17



Oxygen depletion



Emissions in storages of wood pellets

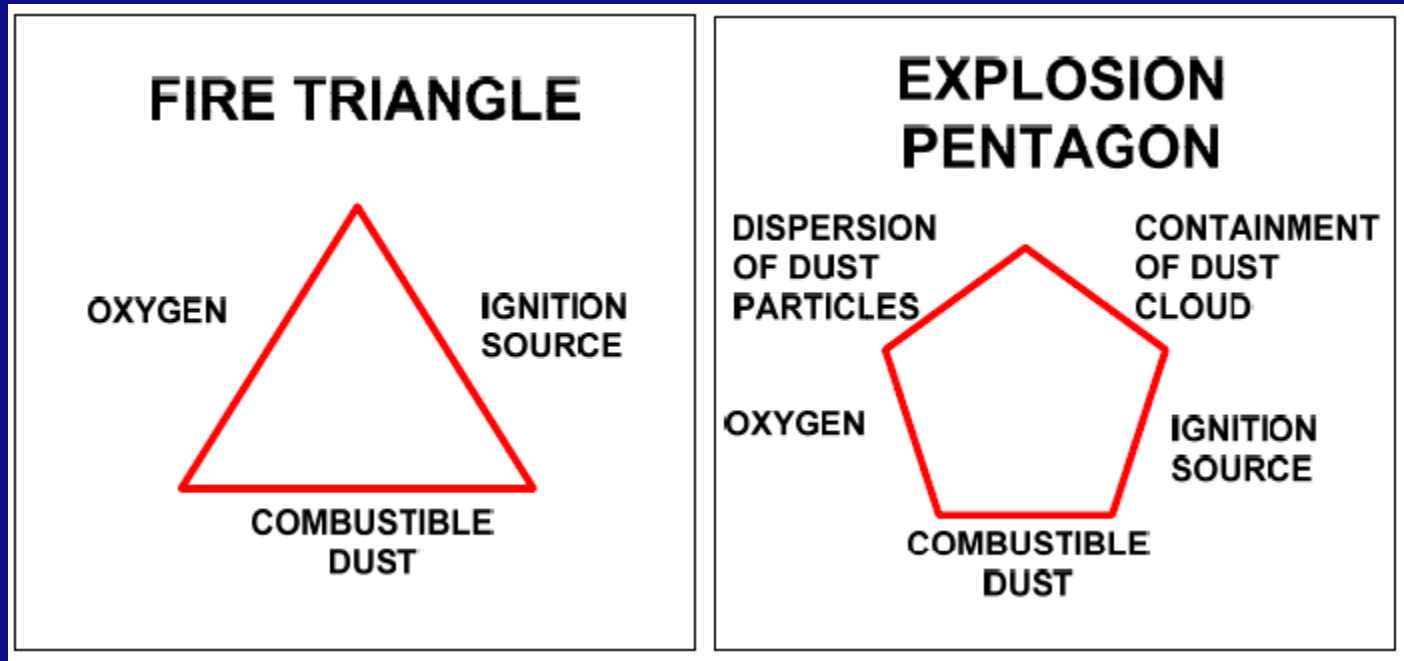
5.9 The port authority of Helsingborg had carried out measurements on the atmosphere of the cargo holds that containing wood pellets (cargo holds No. 5 and No. 6 of the Vessel) in different conditions. Following results were recorded:

	Oxygen (%)	Carbon monoxide (ppm ¹)	LEL ² (%)
At time of opening of hatch	15	> 1000	Max
After 5 minutes of discharging	20.9	0	0

When the cargo holds containing wood pellets had been closed for a period of time, the wood pellets would consume oxygen and emit carbon monoxide. The atmosphere inside the cargo hold could get into the enclosed stair trunk through gaps of the three access doors. Apparently, the atmosphere in the enclosed stair trunk contained a high level of carbon monoxide and depleted in oxygen.

Extract from “*Report of Investigation into the fatal accident on board the Hong Kong Registered ship “Saga Spay” on 16 November 2006*”

Dust explosions



Dust explosions



General storage recommendations, pellets

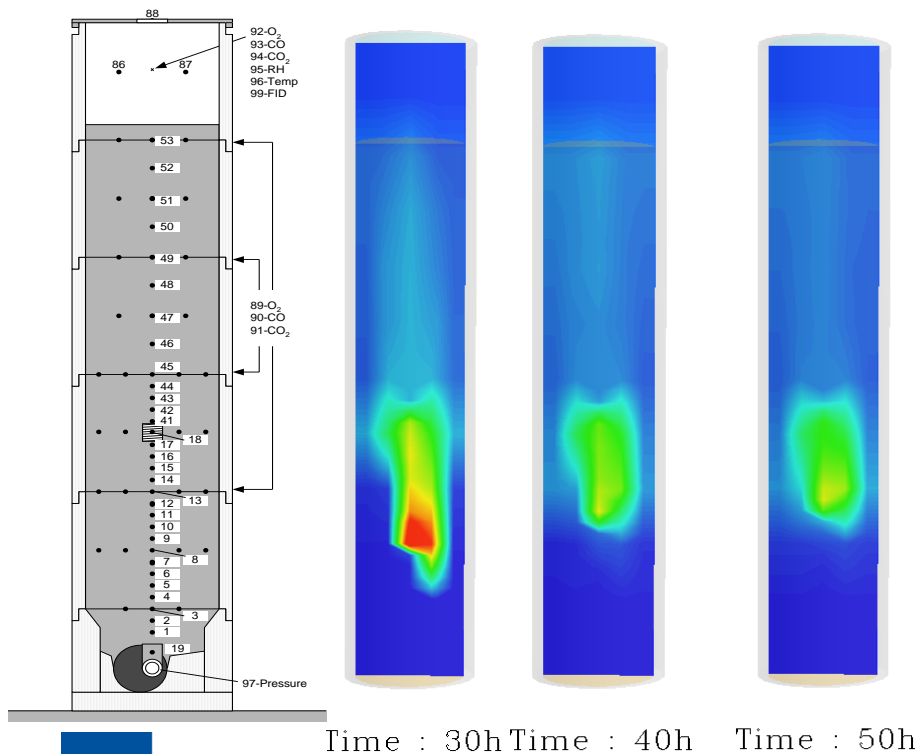
- Use protected storage (A-frame, silo)
- Do not mix different pellet qualities
- Avoid differences in moisture content
- Avoid fines
- Maximum storage volumes (pre-characterization of reactivity would be helpful)
- Gas detection and temperature monitoring
- Preparations for extinction (inertation) and removal of pellets

Fire Fighting - Water for extinction?



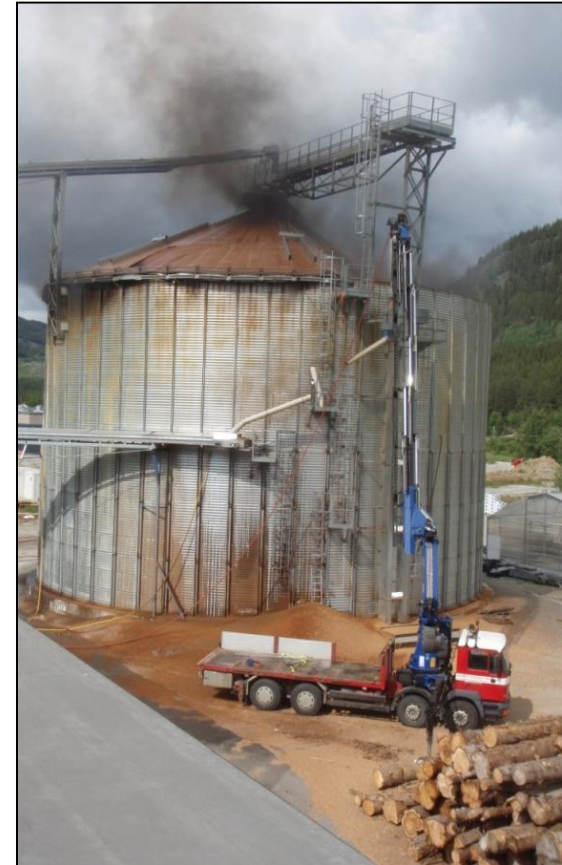
Extinction experiments in field and at lab scale

- Agents: N_2 , CO_2 , Foam
- Method: Gas application from base of silo, foam on top



Recommendations for Extinguishment of silo fires

- Prepare the silo for inert gas injection
- Prepare for emergency discharge of the silo content to a safe location outdoors
- Pre-plan for an extended incident operation (days)
- Gas injection recommended through the silo bottom
- Silo top should be inerted in the beginning of the operation
- Measure O_2 and CO in silo top during inertation and discharge phase
- Extinguish any burning material outside of silo if necessary



Ongoing and future projects to address open questions

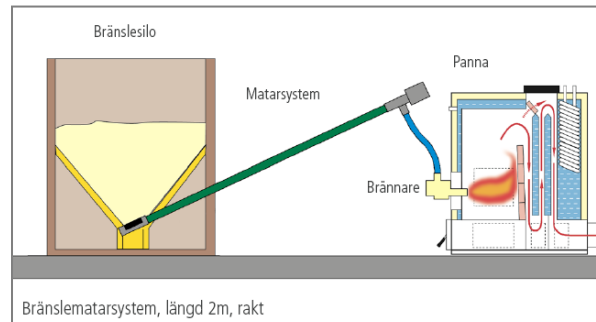
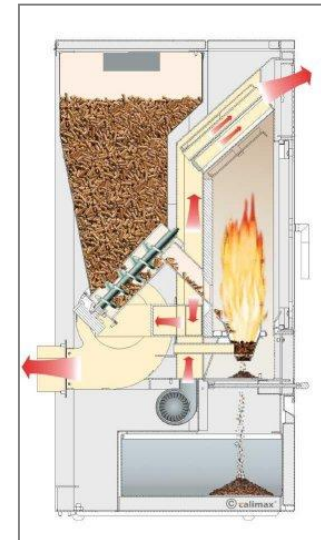
- *“LUBA-Large Scale Utilization of Biopellets for Energy Application”*
 - (ForskEL-DK, DTI, Aalborg U, DBI, SP, energy companies etc.) 2010-2013
- *SAFEPELLETS-Safety and quality assurance measures along with pellets supply chain”*
 - EU-project-Research for SME ass. (BE2020, SLU, SP, DTI, mfl, in total 20 partners, 2012-2014
- *“Fire safety in storage of biofuels and waste”*
 - (Brandforsk, Värmeforsk, etc.), 4-5 year research programme to be initiated
- *Fire safety and emissions of stored bales*
 - (Brandforsk, Värmeforsk, etc.), 4-5 year research programme to be initiated
- *“Development of methods and models to mitigate the risk of fires of organic materials and waste fuels”*
 - (applied to KK-stiftelsen), LNU, SP, Stena

Adaptation of results to small scale storage?

- Autoxidation of pellets occurs regardless of storage size
- Self-ignition potential low due to minor volume of stored pellets
 - heat dissipation higher than heat production from oxidation
 - be aware of additional heat sources
- **Emissions can be a direct health risk**
 - Even at small scale storages
 - Already reported incidents with fatal accidents
 - **Sufficient ventilation of storage area is crucial**

Heating applications using Solid Biomass

- Biomass: pellets
firewood
(wood chips)
- Applications: room heaters
heating boilers



Risk sources for solid biomass combustion

- Risk of gas explosion
 - due to poor fuel ignition, wet fuel, poor draft or blocked chimney
- Risk of gas leakage into boiler room / living area
 - e.g. due to over pressure in combustion chamber or flue gas exhaust, poor sealed connections
- Risk of chimney fires
 - applies mainly to firewood heaters due to usually higher flue gas temperatures
- Risk of fire or burns due to hot surfaces
 - applies mainly to room heaters
- Risk for back burning
 - applies to automatically stoked systems, due to thermal conductance, back flow of combustion gases or fire propagation into the fuel line

Safety applications to prevent back burning (examples)

Active systems

- water sprinkler
- Fire valve
- Temperature sensors
- Pressure sensors
- Gas warning sensors
- Emergency discharge device

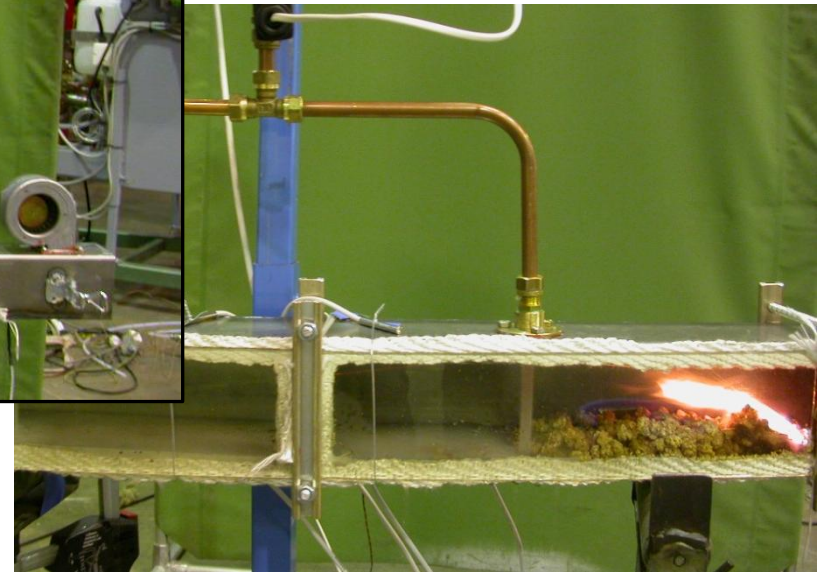
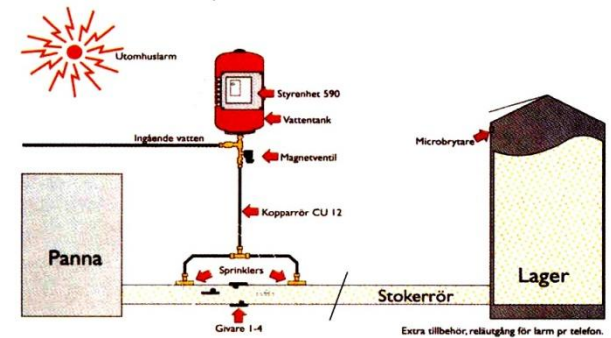
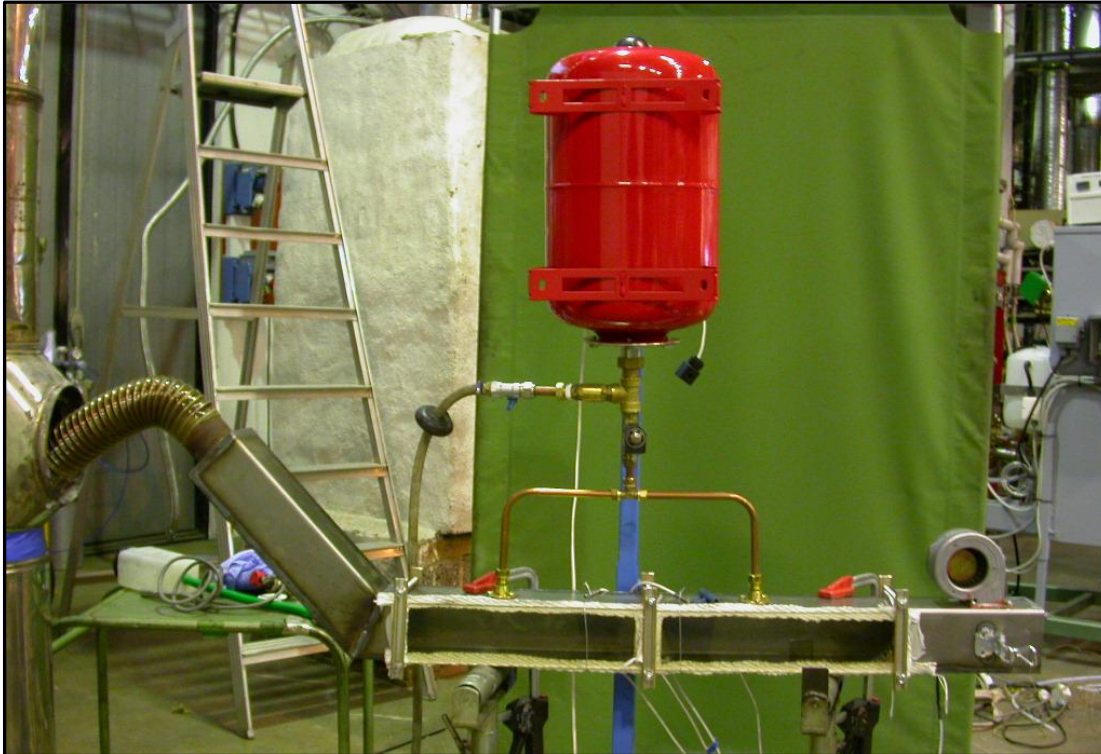
Passive systems

- Fuel chute
- Tight fuel hopper lid
- Cell feeder
- Inclined auger
- Naturally ventilated space between hopper and boiler
- Flexible hose, which can melt / burn off



- Right placement of active safety systems is important
- Safety issues are addressed by European and National standards and additionally by certification labels

Water sprinkler system (example)



Open Stoves or Fireplaces using Alcohol Fuels

- Different types and sizes
 - In-/outdoor
 - free-standing or wall-mounted
 - Small mainly decorative units or bigger ones with sufficient supplements to room heating (up till 3-5 kW)
- Usually without connection to chimney
- Fuel mainly ethanol or gel (outdoor)
- Increasing popularity



Important safety aspects and known risks

3 major risk sources

- risk of fires
 - Surrounding/flammable material in touch with the flame or hot parts
- risk of burns
 - User gets in contact with hot parts (during or after operation), appliance falls over during operation, backfiring/re-ignition during fuel refill
- risk of intoxication
 - gas (carbon monoxide, nitrogen oxides and volatile organic components) produced during normal and poor operation and released directly into the room