



Orsted

Minimizing Self-Heating Risk in Wood Pellet Storages

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Laboratory Measurement of Wood Pellet Reactivity

Background & Motivation

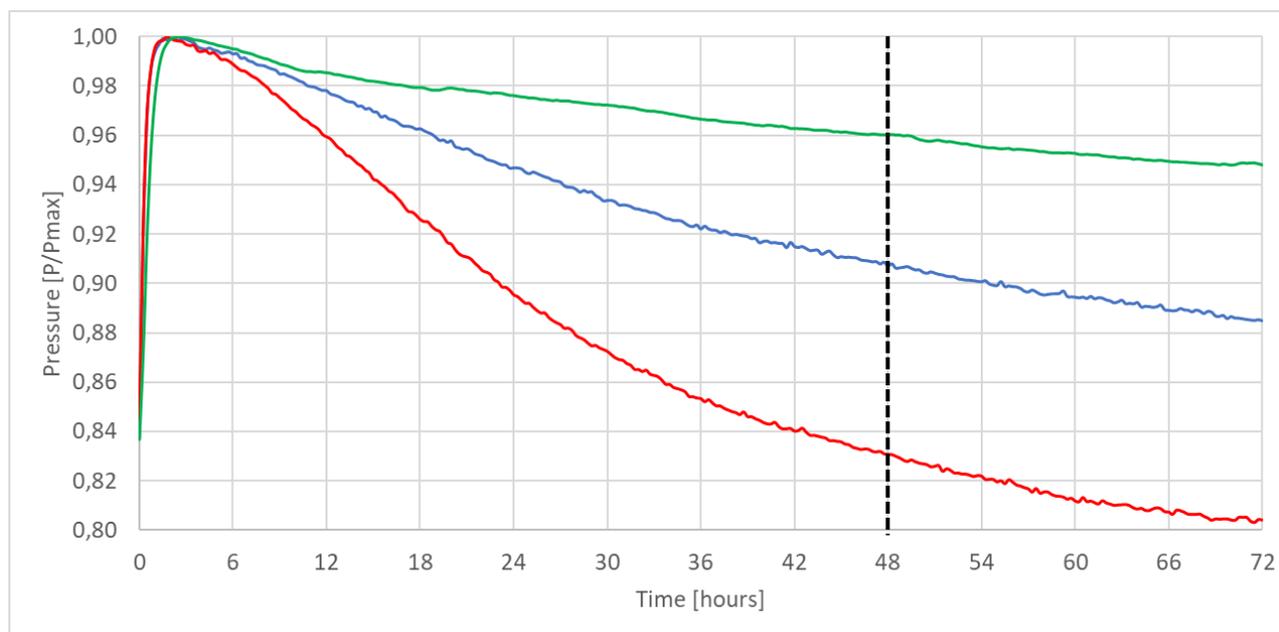
- Flexibility in using all types of wood pellets is vital for the industry
- Pellet reactivity is key to managing storage risks
- Core question: how to safely handle pellets with varying reactivity levels
- **Testing Approaches**
- Industry needs robust methods to benchmark pellet reactivity
- Self-heating reactions are slow at low temperatures, requiring sensitive or accelerated techniques

Two focus methods:

- **Isothermal Calorimetry** – direct measurement of heat release
- **Oxipres** – accelerated test of oxidation potential

The Oxipres method assesses the Oxidation Stability of Wood Pellets by Accelerating Oxidation at Elevated Temperatures and under Oxygen Over-pressure

Higher pressure drop* – higher wood pellet reactivity

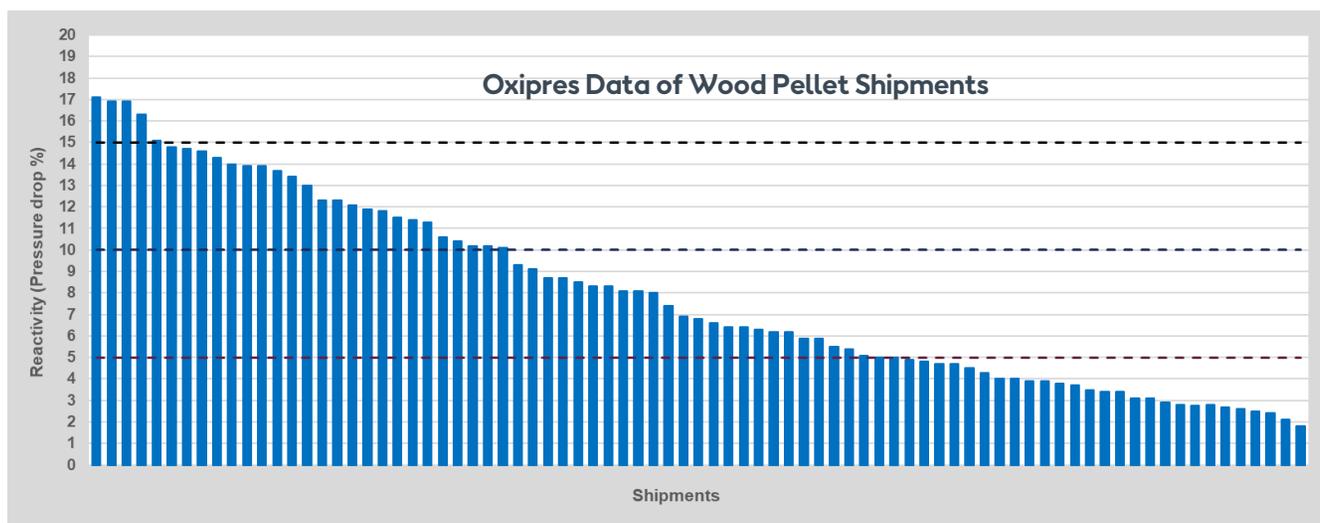


Provisional Ørsted Ranking System for assessing the Critical Self-heating Potential of Wood Pellets from Different Shipments

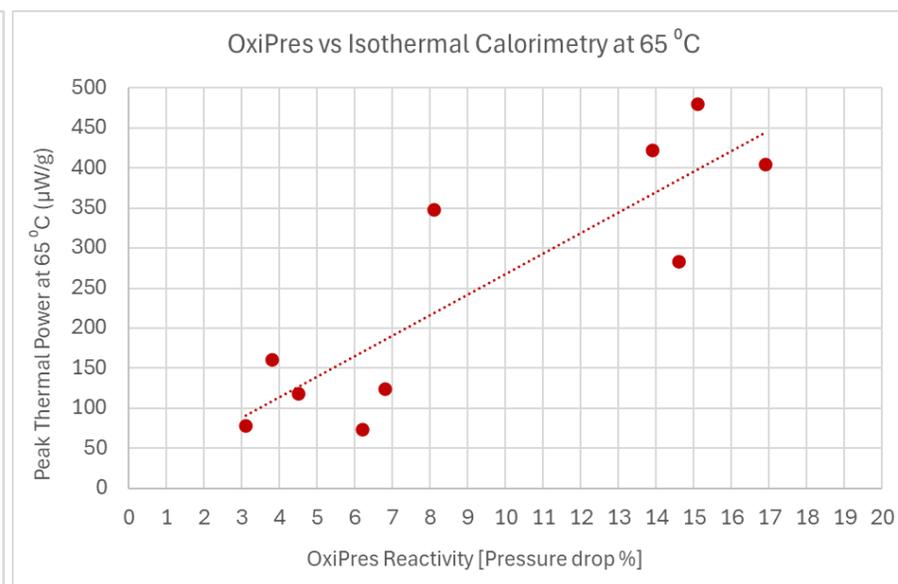
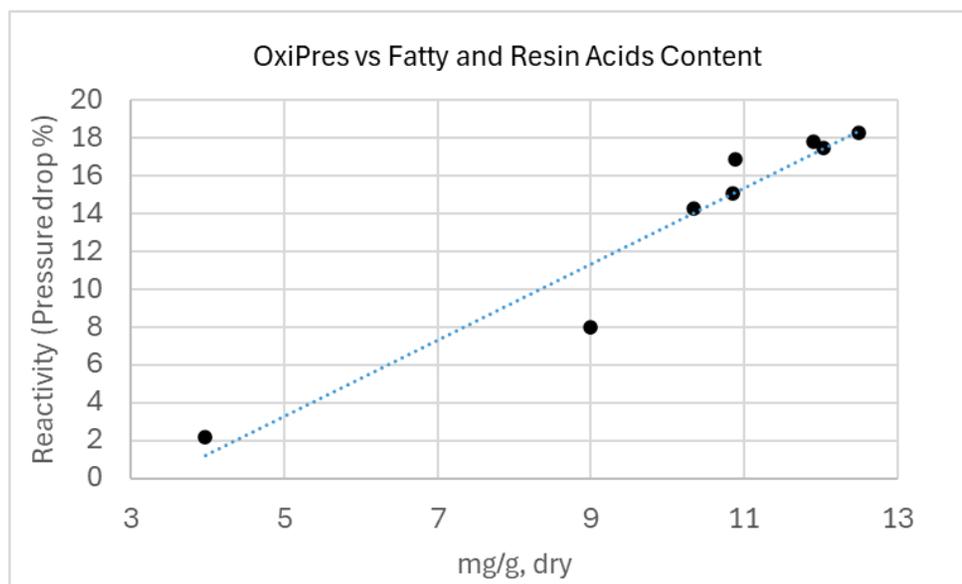
- Wood pellet shipments are analyzed prior to arrival in Denmark
- A risk assessment must be carried out before storing wood pellets with high or very high reactivity at Ørsted's storage facilities
- The ranking generally reflects practical experiences from storage operations

Ranking	Risk	Reactivity
1	Very high	> 15
2	High	10 - 15
3	Medium	5 - 10
4	Low	0 - 5

All Oxipres data were obtained at 65 °C with the same analysis time of 48 hours



Data suggest a Linear Correlation between Oxipres Reactivity, Isothermal Calorimetry and the Levels of Fatty and Resin Acids



Storage Practices in Wood Pellet Silos and Flat Storages: Nitrogen Purging and Forced Aeration

Preventive strategies:

- Reduce oxygen concentration (suppress low-temperature oxidation) through nitrogen purging in silos
- Cool pellets using forced aeration in flat storages

Mitigating strategies:

- Suppress suspected critical self-heating or pyrolysis with enhanced nitrogen purging
- Avoid forced aeration if critical self-heating is suspected

Forced aeration considerations in Ørsted wood pellet silos

- The estimated critical airflow rate is ~ 0.05 m/s, equivalent to 170 m/h or 100 m³/h per m²
- For the Studstrup silo, the required aeration capacity would be at least 330,000 m³/h
- Since the total fan power demand would be in the megawatt range, and nitrogen would still be required as a mitigation barrier, Ørsted has decided to rely solely on nitrogen purging
- However, Ørsted uses smaller, portable aeration fans for localized cooling of wood pellets in flat storage facilities

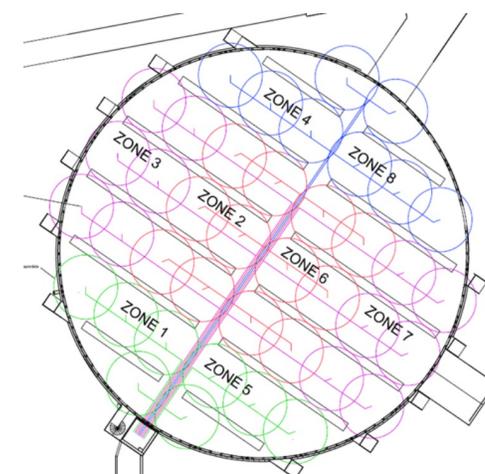
Nitrogen Purging as a Mitigating Measure in Wood Pellet Silos

Recommendations from the *Silo Fires Report** (Henry Persson)

- Tests in a 4.5 m³ silo identified the **critical nitrogen flow** needed to quench a pyrolysis hotspot: **3 m/h**
- Recommended safety margin: **3 × critical flow = 9 m/h**
- In the test silo, this corresponds to a nitrogen injection rate of **5 kg/m² per hour**

Ørsted 100.000 m³ Studstrup Wood Pellet Silo

Operation mode	Nitrogen flow rate	Total nitrogen injection rate	Total nitrogen injection rate
Normal and deviating operation	Up to 1,6 m/h	~3.600 kg/h	3.000 m ³ /h
Escalated operation	~ 3,6 m/h	~ 8.000 kg/h	6.900 m ³ /h
Fire	~ 5,6 m/h	~ 12.500 kg/h	10.800 m ³ /h



Nitrogen purging zones in the Studstrup wood pellet silo

Portable Aeration Fans for “Localized” Cooling of Wood Pellets in Flat Storages

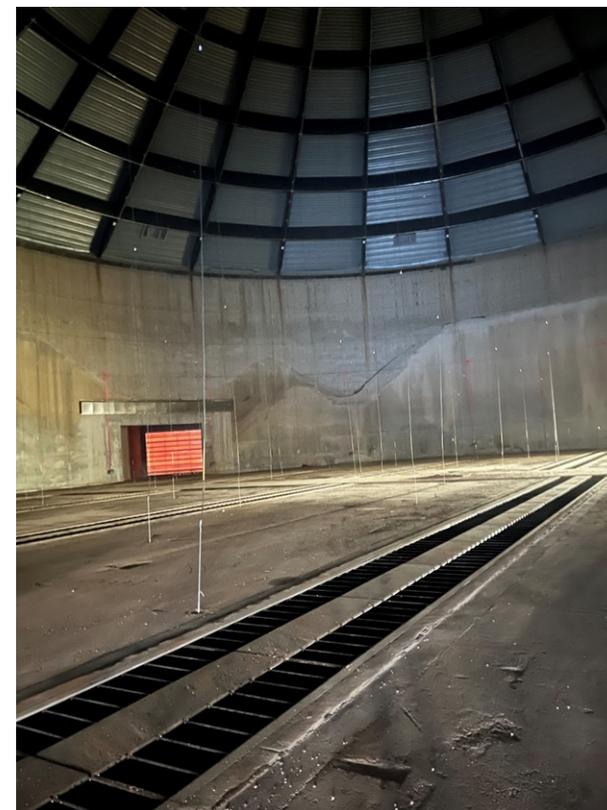


"Crocus" grain aerator. Airflow capacity of $\sim 1,500 \text{ m}^3/\text{h}$. Estimated effective aeration coverage: $5 \times 5 \text{ m}$ area to a depth of 5 m (depending on pellet porosity)



Storage Practices in Wood Pellet Silos and Flat Storages: Temperature Monitoring in Silos

- Monitoring the bulk temperature of the pellets is essential; Surface IR, gas monitoring, and aeration/purging are all indirect methods to varying degrees
- Where possible, temperature cables should be fixed to the silo floor, since freely hanging cables tend to shift and provide less reliable data
- At Studstrup, 65 thermocouple cables are installed and secured to the floor
- Data should be accessible via a dashboard with trend analysis functions



Storage Practices in Wood Pellet Silos and Flat Storages: Temperature Monitoring in Flat Storages

- Current equipment are temperature sensor spears/ IR-camera
- 1-2 m in depth/ IR only surface measurements
- Challenge: Slow heat transfer in the wood pellets pile
- Danger that a deep-seated hotspot is detected too late

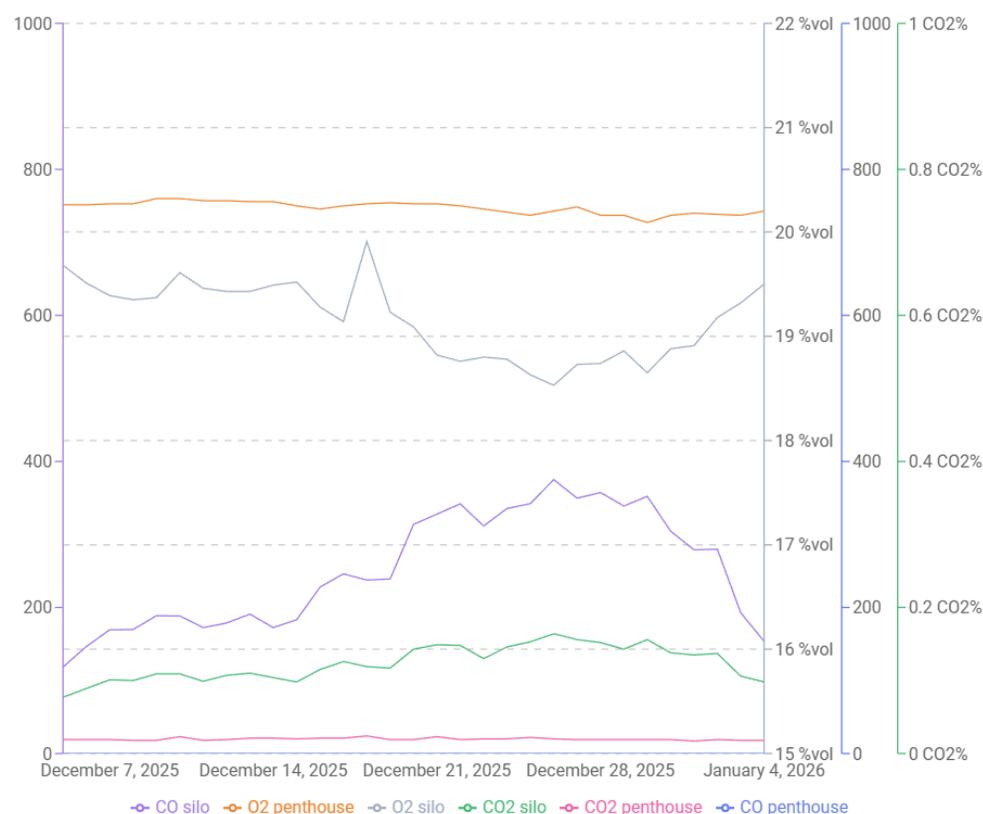


Recommended temperature thresholds and preventive actions

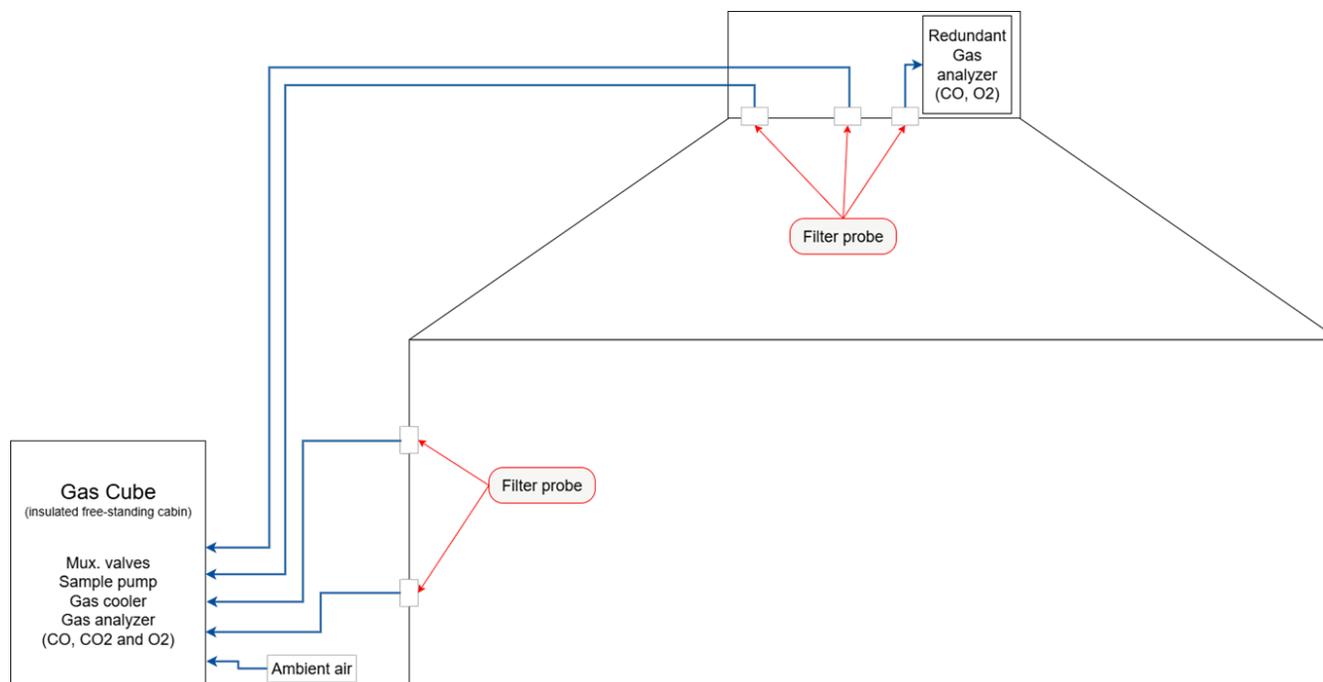
Flat Storages		
Reactivity level	High to very high reactivity	Low to medium reactivity
Storage time	No long-term storage: maximum 3 months; for storage beyond 3 months, maximum pile height 4 meters	Up to 12 months
Forced aeration	Required if bulk temperature exceeds 50 °C	Required if bulk temperature exceeds 55 °C
Consider extraction of wood pellets	If bulk temperature exceeds 55 °C	If bulk temperature exceeds 60 °C

Storage Practices in Wood Pellet Silos and Flat Storages: Gas Monitoring

- Install a robust gas monitoring system with analysis equipment outside the silo or storage area
- Monitor **O₂**, **CO**, and **CO₂** with wide ranges:
 - CO: 0–100,000 ppm
 - CO₂: 0–30%
 - O₂: 0–25%
- System should allow easy setup of warning/alarm thresholds and support data trending
- Use multiple sampling points for accuracy
- Understand system limits; be cautious with auto-calibration and sensor saturation, which can cause false readings



The Gas Monitoring System



Design Considerations

- Operation during normal and fire conditions**
 The gas composition is monitored both during "normal" off-gassing and in fire events. This is achieved using a free-standing system ("Gas Cube") with sampling through high-temperature-resistant tubes and filters, combined with a wide measuring range.
- Redundant gas analyzer in penthouse**
 Provides detection of measurement errors and ensures continuous monitoring during calibration and maintenance of the primary analyzer.

Storage Practices in Wood Pellet Silos and Flat Storages: Gas Monitoring



Operation Modes Introduced as Part of Updated Fire Strategy for the Studstrup Wood Pellet Silo

In previous fire strategies, only two operation modes were defined: Normal Operation and Fire. The updated fire strategy now includes four distinct operation modes

Normal Operation

- Silo runs under standard conditions; temperature and gas levels within normal range

Deviating Operation

- One or more parameters reach alarm level for deviating operation (e.g., elevated temperature, CO)
- Focus: Investigate cause and take preventive action

Escalated Operation

- One or more parameters reach alarm level for escalated operation; possible repeated spark detector alarms, but no flames observed
- Focus: Reduce risk — consider preventive emptying, increase nitrogen purging, notify fire department

Fire

- Fire assumed if:
 - Alarm level for fire reached by two independent systems,
 - Alarm from aspiration system, or
 - Direct observation (embers, flames, smoke, extreme heat)
- Action: Alert fire department, ensure safety of people and assets

Thank you

Questions?

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