UNIVERSITY of GREENWICH

The Wolfson Centre
for Bulk Solids Handling Technology

Best practice for biomass store fire protection

Richard Farnish CEng MIMechE

Vessel Geometry

Combustion events within storage schemes can be attributed to a variety of direct causes or contributory factors (the significance of which vary between fuel type and storage methods).

Irrespective of the fuel type, the way in which a material is handled and subsequently stored has a strong influence over the likelihood of an event occurring and scope for dealing with the problem efficiently.

Vessel Geometry

Comparing biomass fuel components and coal, biomass storage schemes are far more likely to hold more substantial volumes of material in many cases.

However, they are also far more likely to suffer an ‘event’ at some point in their service life.

Steel silos

Concrete domes/bunkers

Vessel Interior

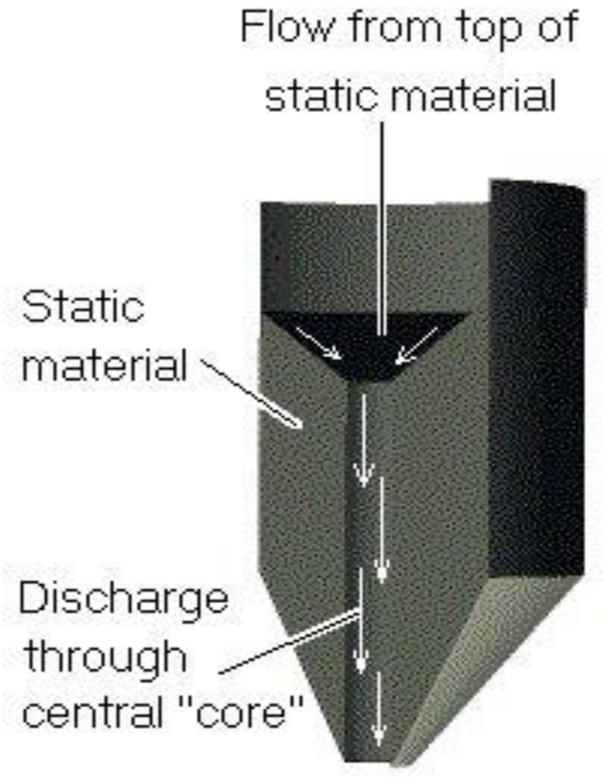
A very basic requirement for storing time dependant fuels such as biomass or coal is that the storage system should be designed such that the residence time for fuels is actively controlled during operation (i.e. first in, first out stock rotation).

This is of particular importance for the biomass which is invariably biologically active to some degree and thus potentially unstable if left in long term storage.

Vessel interior

A key defining feature for many storage systems is that they operate in core (funnel) flow.

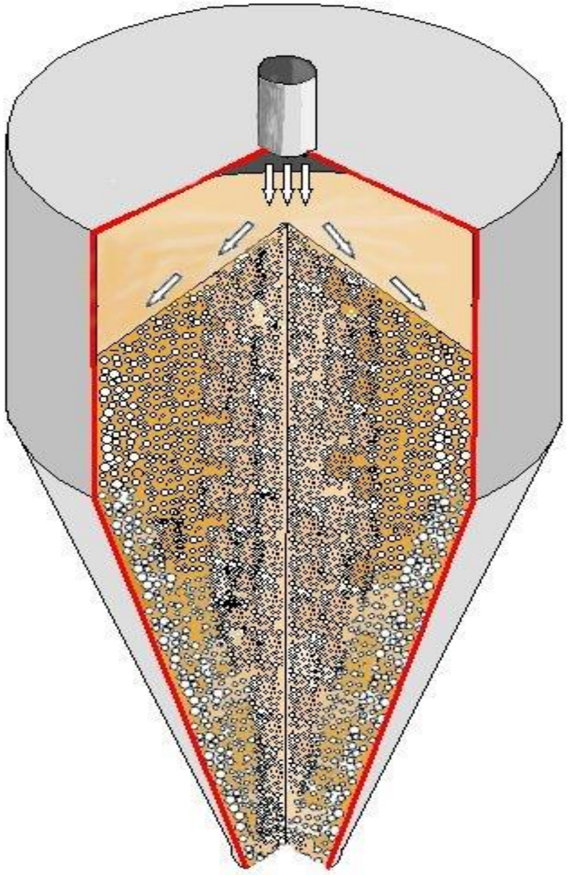
- “first in last out” discharge
- “dead” regions of product
- erratic discharge caused by product on product shear during emptying
- central discharge channel
- exaggerates segregation effects of particles
- hopper half angle to shallow for slip at the wall
- poor stock rotation
- high storage capacity for a given headroom



Conical silo shown – but same effect occurs with bunkers and ground stores

Segregation in processes

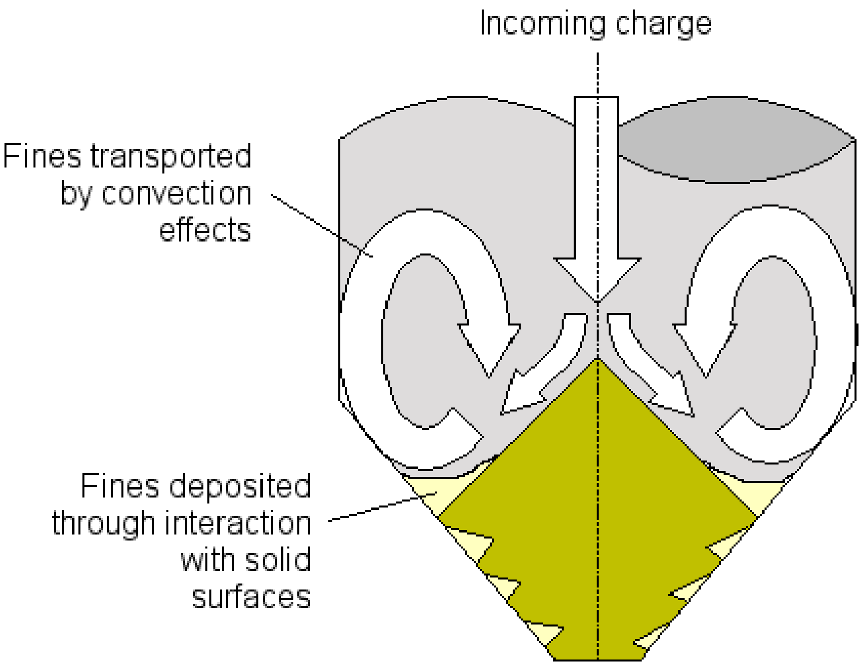
- Separation of material by size and shape during filling from empty or low inventory.
- Typically, finer sizes accumulate under fill point, while larger particle sizes mobilise towards the bottom of the heap flanks.
- Wider distribution of sizes leads to more pronounced separation across the heap.



Gravity filling & surface effect / rolling segregation

Segregation in processes

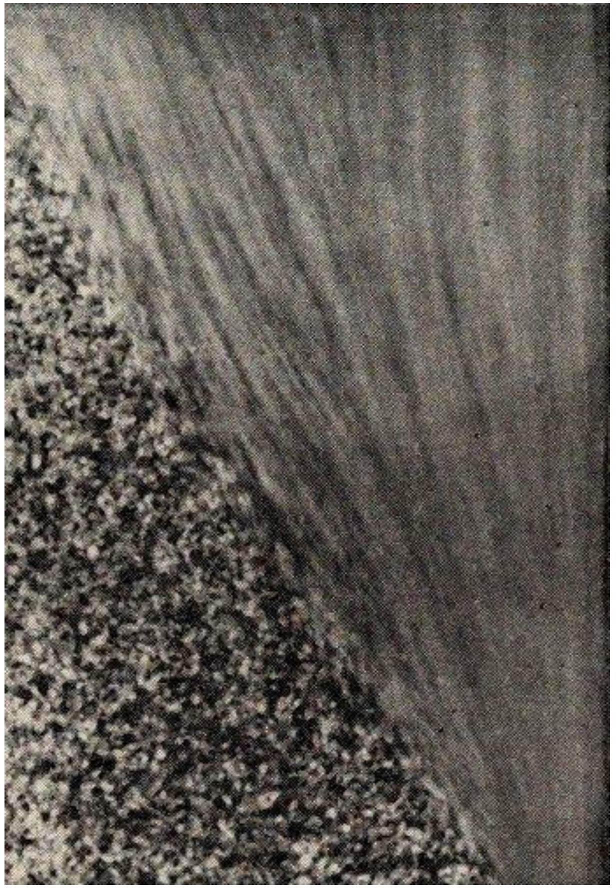
- Separation of material by drag factor / air convection effects.
- Finer particles transported away from fill point to periphery of storage chamber.
- Finer material deposited towards walls
- Settlement of dust (post filling) can also lead to surface blanketing.



Fines/dust migration during filling operations

Segregation in processes – post filling

- The style of filling method has a strong influence over the distribution of fines within the store.
- Most stores are operated at high inventory levels (i.e. only run down to empty infrequently).
- Multiple small storage schemes can support an SOP of running to empty to clear long term resident materials.
- Mega stores do not offer the same degree of flexibility to run to empty – but also often have more pronounced segregation effects present.



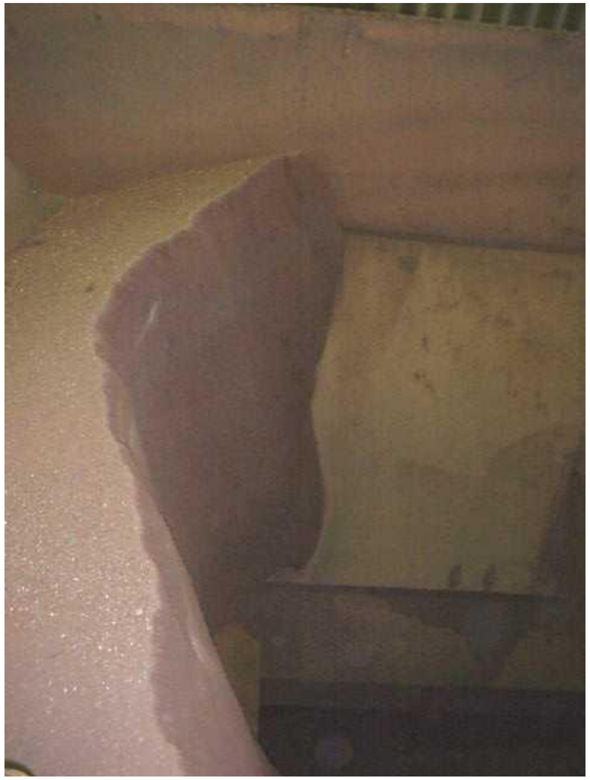
Fines migration into static regions adjacent to flow channels – an effect often exaggerated if vibration is applied to support flow

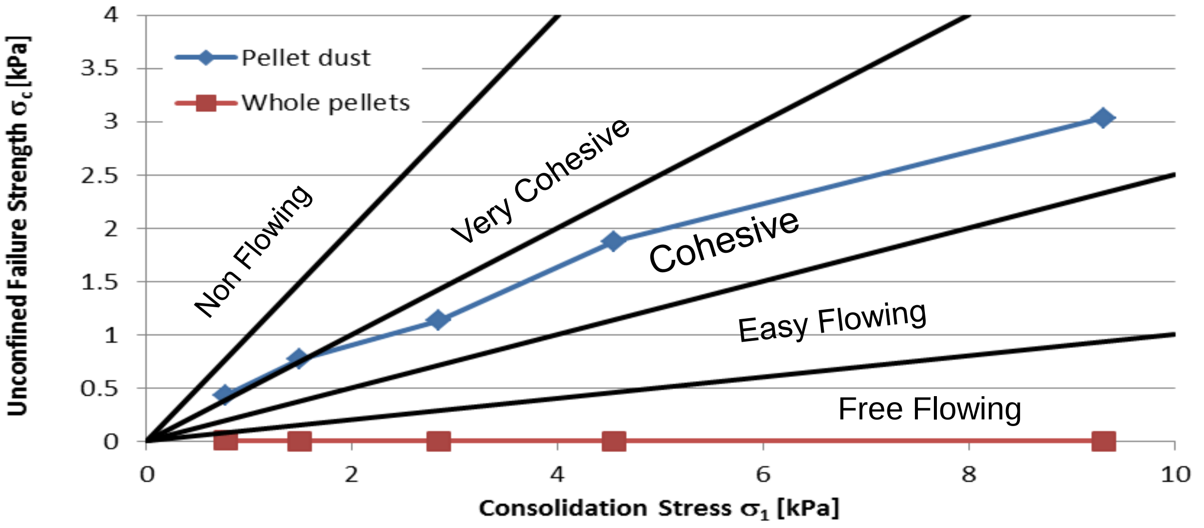
Segregation in processes

Why is an awareness of segregation relevant to the risk of a heating event or counter measures to deal with fire?

- Fines can become the controlling factor for bulk particles once the population rises to ~25% vol. (fines being defined here as the particle size that can pack between particles greater than the $_d50$).
- Flow behaviour will deteriorate
- Gas permeability decreases locally

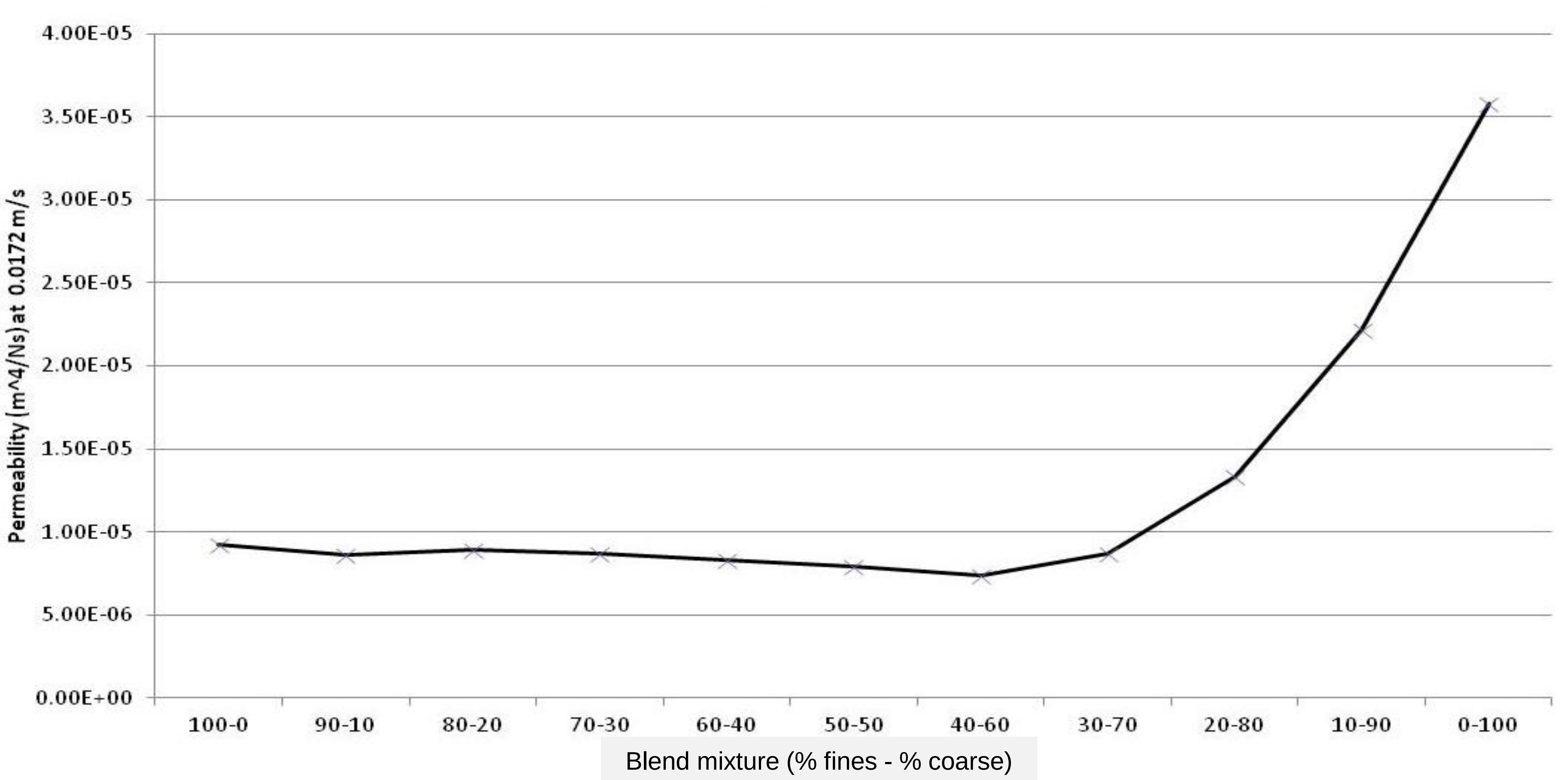
Deterioration in flow behaviour





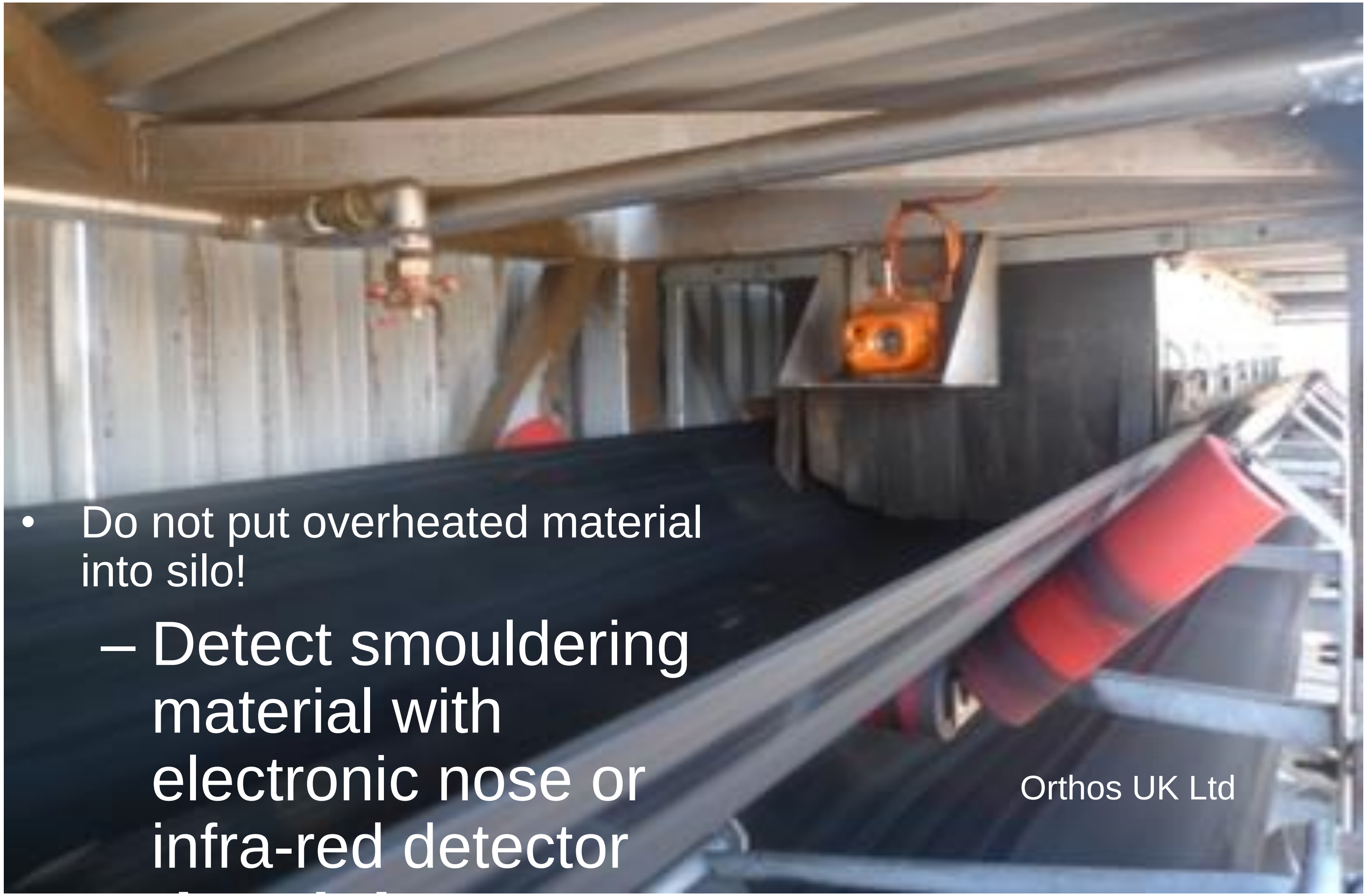
- Increasing fines typically correlates to reducing flowability.
- Variable flow behaviour in different regions of large bunkers or stores

Segregation in processes



Local high fines content will result in air impermeable regions

Preventing fire in silos

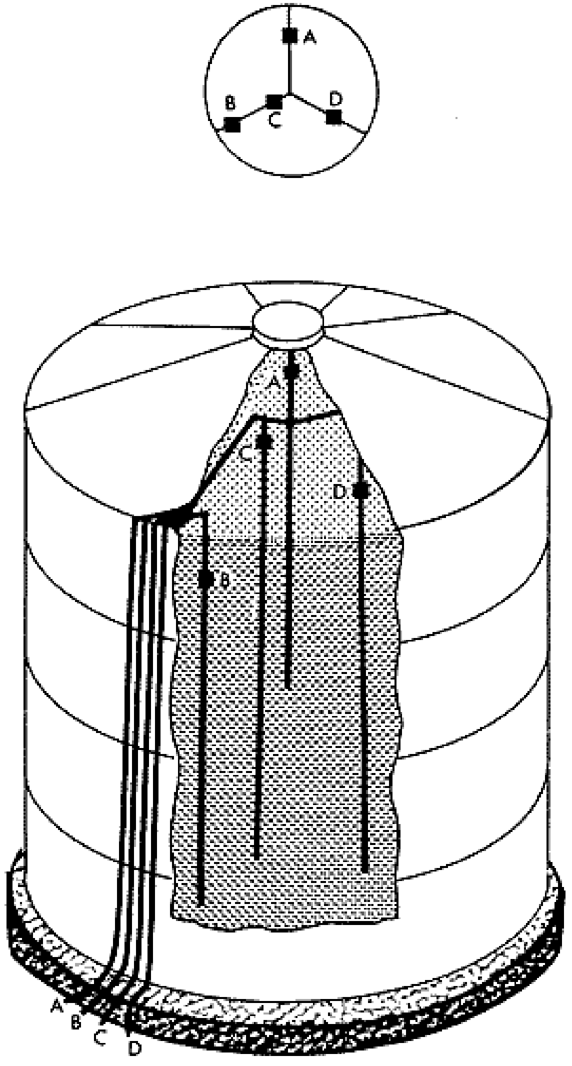


- Do not put overheated material into silo!
  - Detect smouldering material with electronic nose or infra-red detector

Fire detection

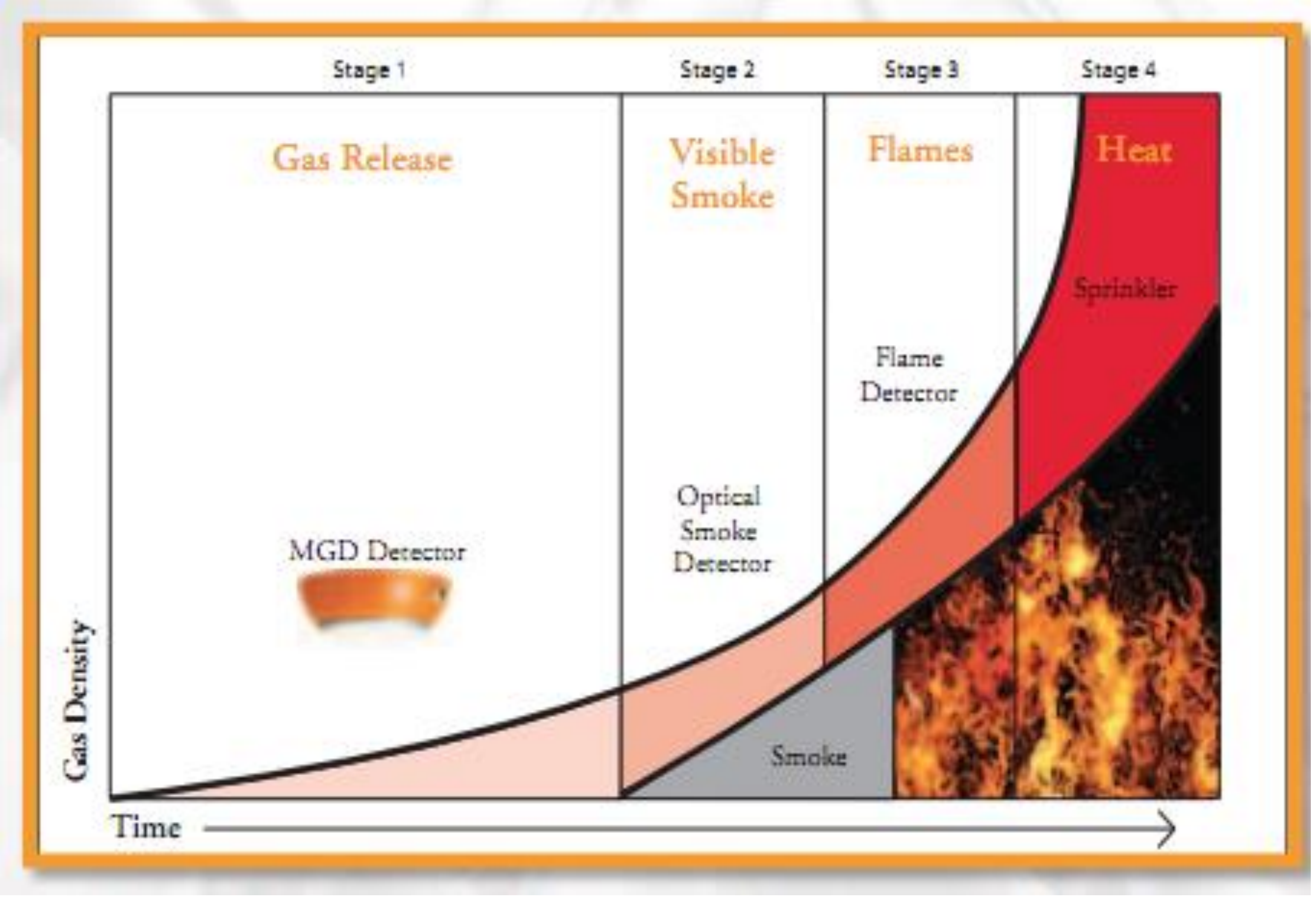
- Silo fires develop very slowly
  - Often over weeks
- Smoke may go un-noticed for some time
- By the time it is visible, fire may be well established and hard to fight

Temperature sensing cables



- Retention can be a problem
- Gives a good idea of overall self-heating tendency before combustion begins
- Can miss localised self-heating or fire

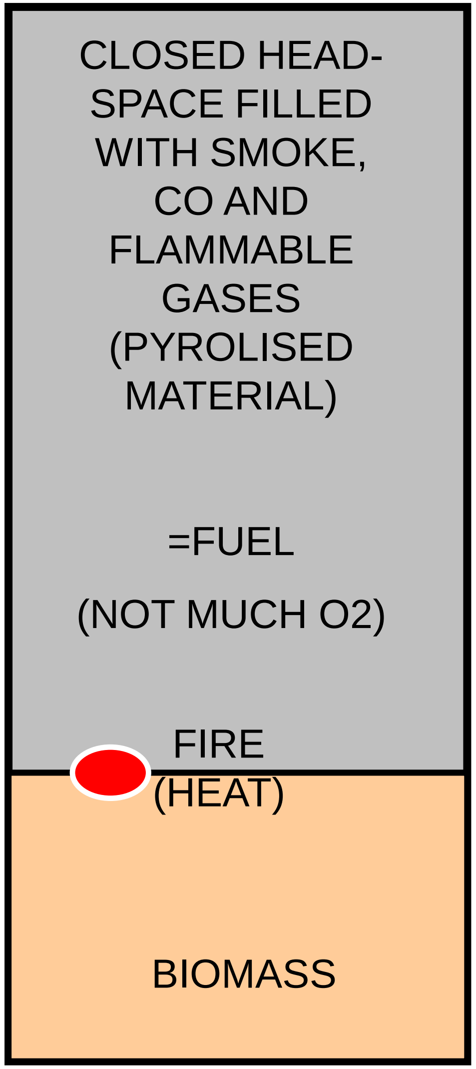
Gas detector (CO or multi-gases)



Fire fighting in silos

- Extreme care must be taken!
- A slow and thoughtful approach is best
- Silo fires are generally slow:
  - Time is available to consider options
- One particular danger should be borne in mind: **BACKDRAFT**
  - Do not just rip open the hatch and put a hose in!

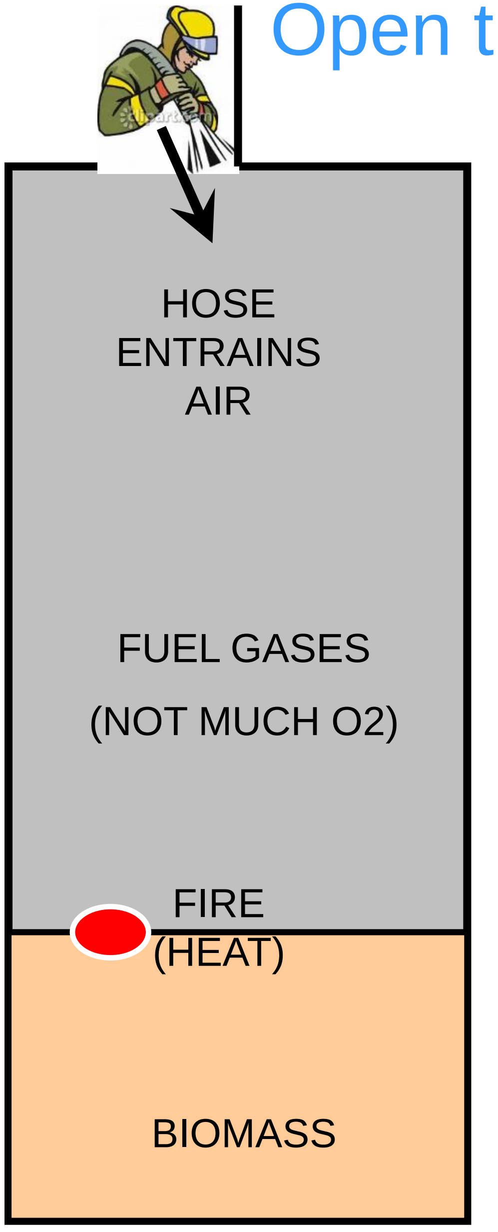
Ventilation-limited fire

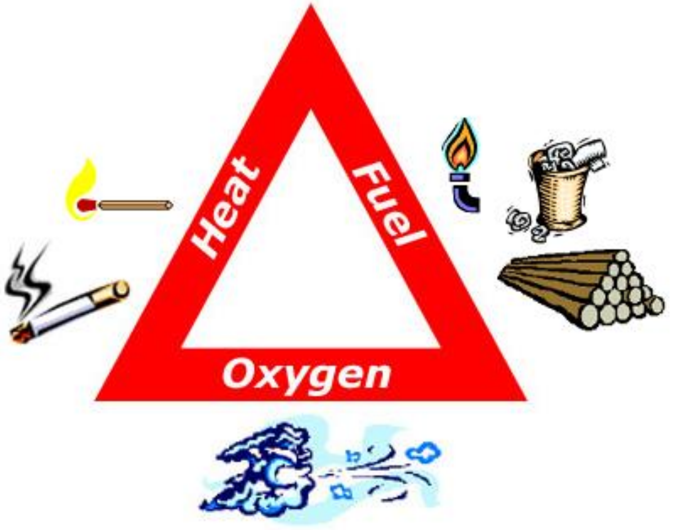


Fire triangle:

Restricted availability of oxygen limits the fire
Plenty of heat (embers) and fuel (gases)
Burning very slow
For biomass - the silo becomes a gasifier!
Fills with flammable/explosible gases

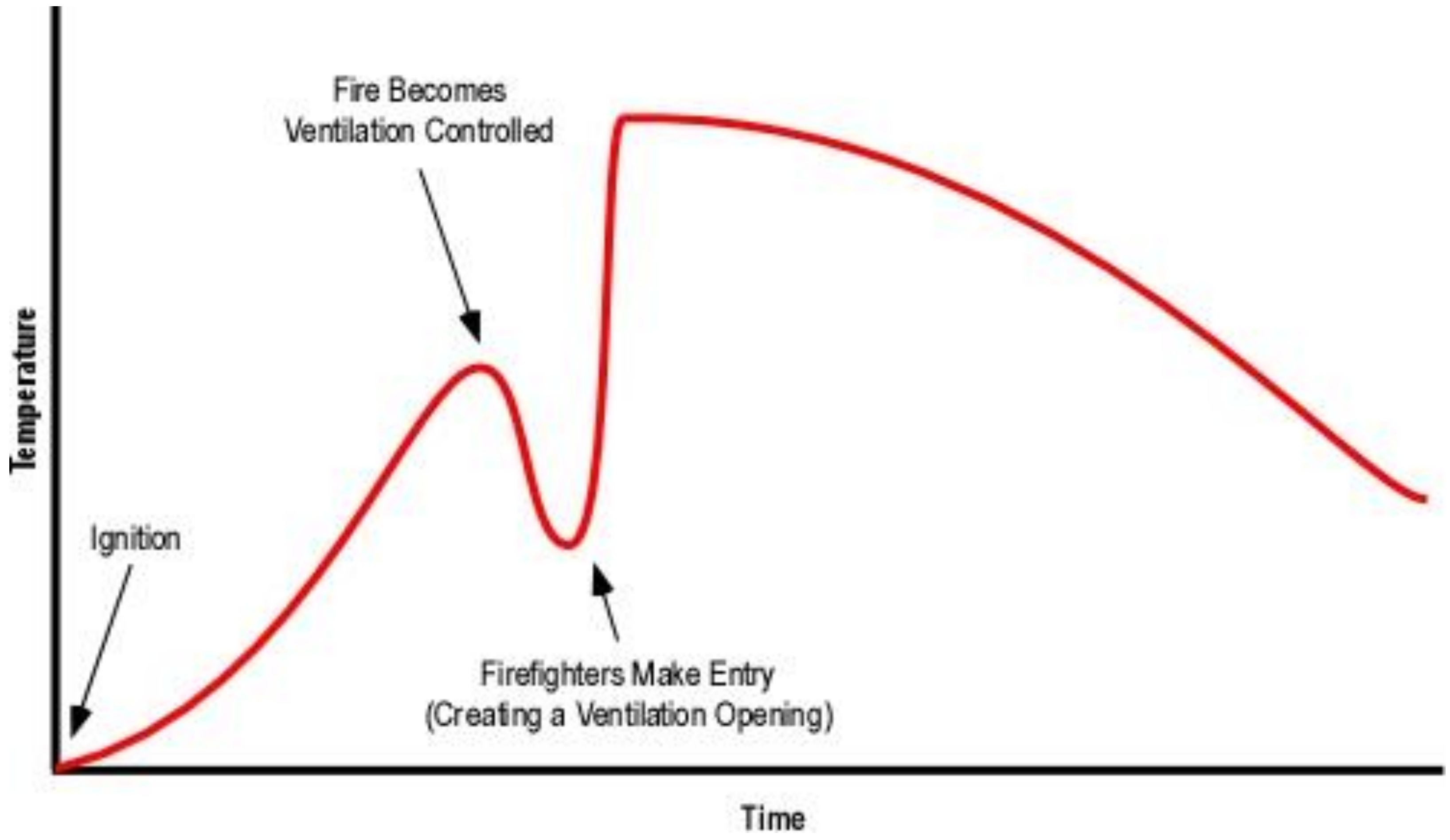
Open the hatch and use hose:





Water jet sprayed in from outside entrains air
Completes fire triangle
Gas fuel + air + heat = BACKDRAFT

Backdraft or flashover event



NIST *Fire Dynamics for the Fire Service*, D. Madryzkowski

Non-access fire fighting: Inert Gas

Injection of inert gas to kill fire

- Nitrogen
- Carbon dioxide
- Injected from bottom (blanketing will not kill fire)
- Outlets must be sealed off
- Care with asphyxiation hazard (especially nitrogen as human body does not register low oxygen in nitrogen-rich atmosphere)
- Will lead to oxygen-starved fire – care to manage backdraft potential

Internal water deluge spray

- Questionable in its rationale
- Will kill flaming material on surface
- Water unlikely to penetrate biomass due to absorption by top layer causing swelling
- Creates more wet material – harder than ever to discharge, and will itself self-heat
- May put silo under excessive structural load
  - Weight of water
  - Hydrostatic pressure distribution
  - Swelling biomass

Explosion risk when discharging material from silo with fire in

- Burning material tends to cake together
- As does that which has fermented
- Arching or rat-holing is a real likelihood, even in material originally free-flowing
- Arch may collapse
  - Dust cloud + incandescent material

  =Dust explosion!

Killing the fire

- To stop a smouldering fire requires an oxygen content below about 2%
- Gas must be injected through the material – e.g. from the bottom up (ensuring the outlet is sealed)
- Blanketing on top will NOT kill the fire in the material

Recommended integrated plan for silo fire protection

Historic experience shows that having the following facilities in place gives a suitable range of options to cope with many eventualities. Having all of these does not *guarantee* success in preventing and fighting fires, but ***omitting any one of the following has been seen to give rise to an opportunity to lose control.***

1. Heat detection on infeed
    1. Infra-red – more than one sensor in case hot material is hidden behind cool material
2. Storage time and temperature for self heating must be investigated (basket test)
    1. In relation to CORE FLOW or MASS FLOW
3. CO trending (not just level alarm) as a minimum, multi-gas analysis preferred
4. Foam dry riser to combat surface fires, especially if explosion vents blown
    1. Arrange with fire brigade to use High Expansion ("HEX") foam ONLY!
5. Ability to inert head space against dust explosion ($<8\%$ O_2)
6. Ability to inert interstitial gas in bulk solid to much lower level to smother the fire ($<2\%$ O_2)
    1. Inert gas injection from bottom through pipe network
7. Need to measure O_2 concentration in both – in several places
8. Bottom sealed to contain gases, small vent area on top for inert gas outflow
9. Fire will take considerable time to cool
    1. Inerting must continue for some time (weeks)
10. Be VERY cautious about using water:
    1. Only a FINE MIST (NOT sprinkler) in headspace to keep temperatures here under control
11. Care to avoid backdraft danger
    1. Keep sealed with inert gas flow on until FULLY cooled
12. Direct disposal route to open air to discharge overheated material

Practical Considerations

- Detecting overheated material on belt at low enough level
- Detecting fire early enough – in large volume
- Differential permeability – poor dispersion of inert gas due to segregation
- Temperature sensing cables – forces?
- Inert gas hazards (more deaths than silo fires!)
- Getting enough inert gas

UNIVERSITY of GREENWICH

The Wolfson Centre
for Bulk Solids Handling Technology

Best practice for biomass store fire protection

Richard Farnish CEng MIMechE

R.J.Farnish@greenwich.ac.uk

bulksolids.com

Further reading:

Silo fires: fire extinguishing and prevention and preparatory measures,
Henry Persson, Swedish Civil Contingencies Agency

Fires in silos: hazards, prevention and fire fighting,
Ulrich Krause, Wiley-VCH