Keynote Panel Discussion:
Cause & Effect - Hopper & Silo Failures and How They Could Have Been Prevented

Wednesday - May 4, 2016
9 – 10 am

Panelists:

Gary Chubb	President, Chubb Engineering
Richard Farnish	Wolfson Centre
Tim Hopper	Tank Connection
Karl Jacob	Dow Chemical Company

Moderator:

Eric Maynard	Jenike & Johanson

INTERNATIONAL POWDER & BULK SOLIDS CONFERENCE & EXHIBITION
Celebrate 40 Years of Powder • 1976-2016

Agenda

- Introductions
- Case studies
  - Causes of silo failures
  - 30 minutes
- Questions for panelists
  - 25 minutes

Panelist: Gary Chubb, SE & PE

- President, Chubb Engineering
- Responsibilities:
  - Owner/operator of engineering firm
  - Design of tanks for bulk solids and liquids
- Experience:
  - 30 years of review, inspection, recertification of tanks for all applications
  - Structural engineering of buildings, foundations, support systems

Panelist: Richard Farnish, CEng, MIMechE

- Senior Consulting Engineer, The Wolfson Centre for Bulk Solids Handling Technology, University of Greenwich, UK
- Responsibilities:
  - Teaching and supervisory support
  - Consultancy services to external clients
- Experience:
  - 20 years at Wolfson Centre
  - Silo design, pneu. conveying, segregation

Panelist: Tim Hopper, PE

- Senior Engineering - Advanced Design, Tank Connection
- Responsibilities:
  - Aluminum geodesic domes
  - Product development
- Experience:
  - 30 years of dome, tank design for dry bulk solids and liquids

Panelist: Karl Jacob, PhD

- Fellow and Founder of Solids Processing Lab, Engineering & Process Science, The Dow Chemical Company
- Responsibilities:
  - Development of particle-based processes and products
  - Troubleshooting and design of solids processing unit operations
- Experience:
  - Nearly 34 years of experience at Dow designing, troubleshooting and developing solids processing processes and products

Moderator: Eric Maynard

- Director & Senior Consultant, Jenike & Johanson (J&J)
- Responsibilities:
  - Director of education (internal/external)
  - Consulting engineer
- Experience:
  - 20 years at J&J designing, troubleshooting silos, bins, hoppers, feeders, chutes, and pneumatic conveying systems

Discussion – causes of silo failures

- Material & external loads
- Operational
- Fabrication & installation
- Maintenance
- End-user perspective

Material-induced loads

- Pebble-lime silos
- 32 ft (10 m) D, 133 ft (40 m) tall
- Cone to pant-leg hopper
- 8 ft dia. bin activators
- Operation of one-leg at a time for two weeks

Material-induced loads

- Eccentric loads resulted
- Poor operation sequence
- Repaired roof, panels
- Stiffened with circ. girders
- Cycle discharge frequency

External loads

- Starch silo
- 12 ft D (3.6 m), 47 ft (14 m) tall welded steel cylinder
- Silo filled by PD truck
- Explosion did not occur
- Ladder "retained" roof
- New roof installed with restraints

Operational issues

- Most storage silos are constructed using designs that assume free-flowing bulk behaviour (i.e. cohesionless and independent of time in storage effects)

- Most of the time such approaches are problem free, however if the properties of the bulk solid differ significantly from those for which the silo was constructed, major problems can develop

Operational issues

- Silo constructed to handle free-flowing prills
- Provision for displacement of humidity from silo using a forced introduction of air
- Silo loaded to ~ 30-40 t (80-100 t capacity)

- Following a weekend shut down the silo discharged material but flow stopped shortly after the work shift started
- Discharge aids were activated to clear the (perceived) blockage
- Unfortunately it was not realised that the 'blockage' actually took the form of a semi-stable arch formation above the cone of the silo – the resulting failure (and resulting vacuum) of which pulled in the top plate of the silo by approximately 4 ft (1.2 m)

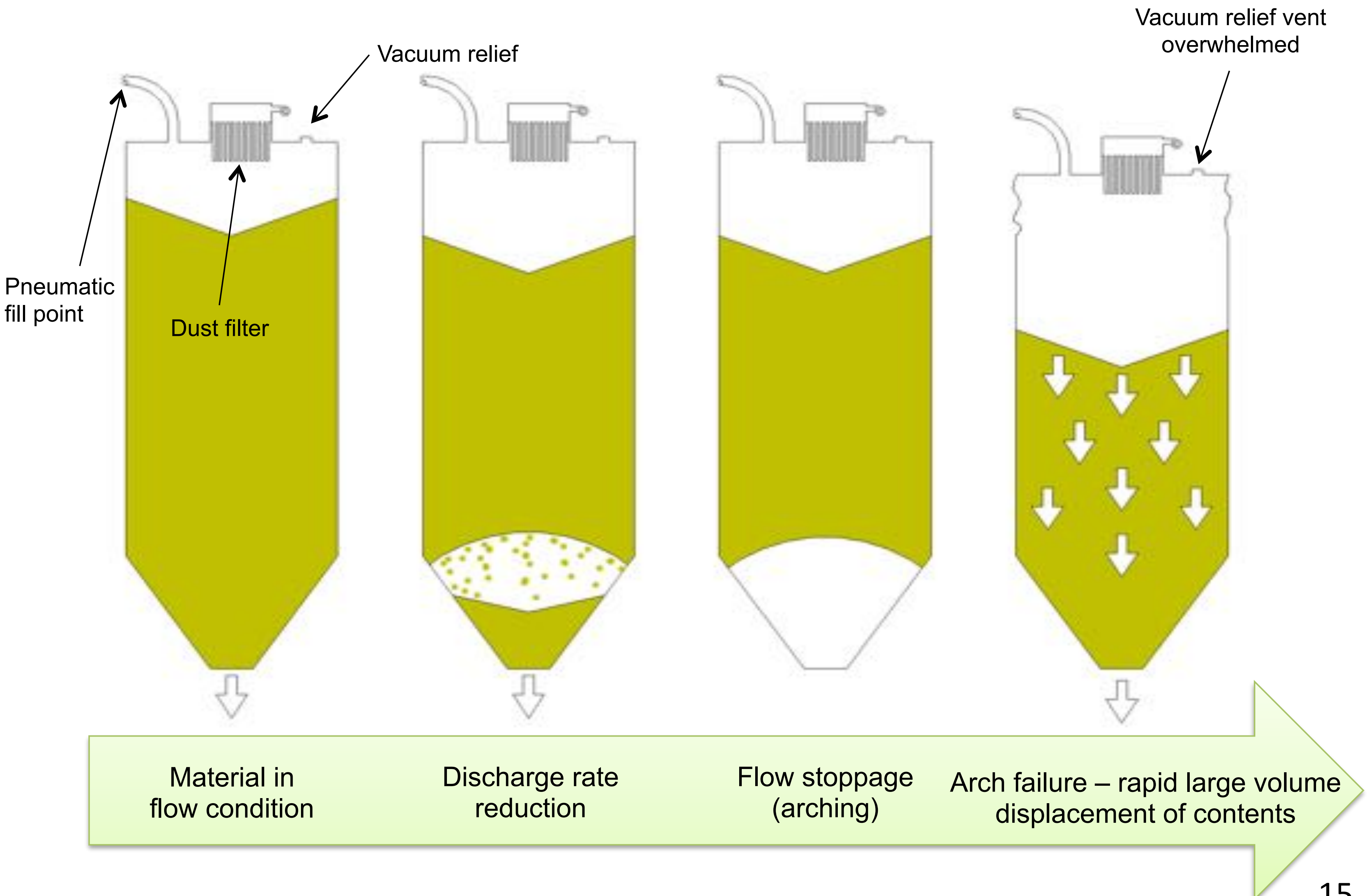
Operational issues

Deposits on
silo wall

Deposits viewed
through access point

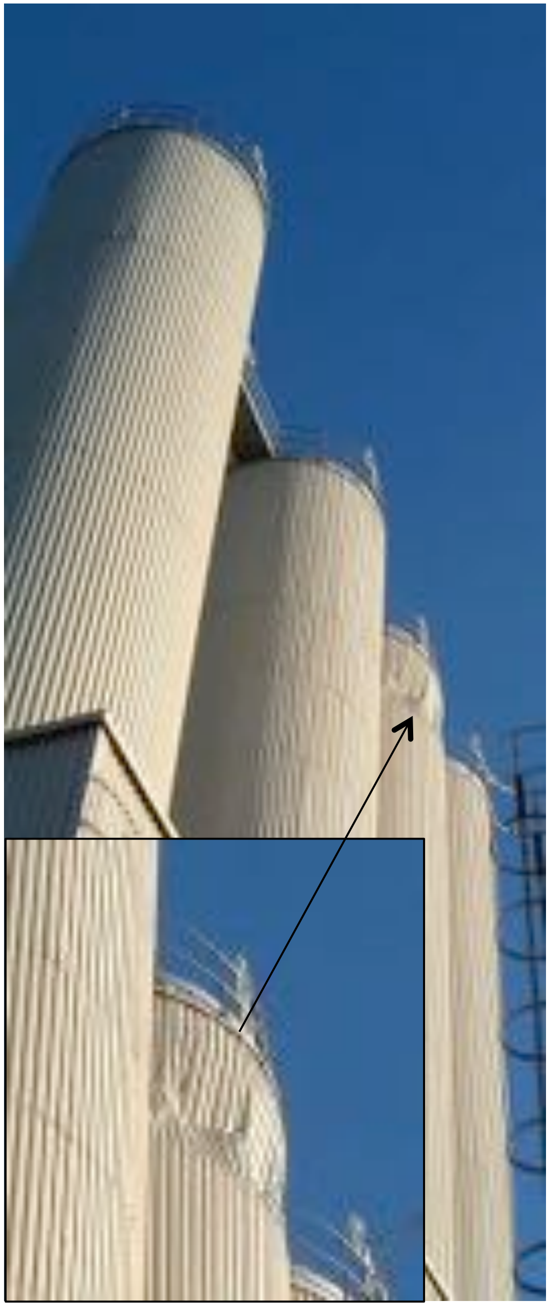
View of contracted
top plate

Operational issues



Operational issues

- Prilled bulk solid transferred into silo from ground level reception pit using a pneumatic conveyor – resulting in particle attrition
- Degraded prill consisted of whole particles, fractured particles, and dust
- Available moisture from prill absorbed by dust leading to major changes in bulk flow properties and cake formation
- Over weekend shut down supported the loss of moisture from the weak liquid bridges within the mass of material and allowed sufficient strength gain to arch above the convergence



Operational issues – lessons learnt

- Never use a ‘good’ (i.e. clean) sample as the basis for determination of vessel design – always consider what the condition of the bulk particulate will actually be at the equipment through which it will be handled (i.e. size distribution changes, moisture content, temperature effects, etc.)
- Always base equipment design on an understanding of the processes that lead into it – particularly so if the bulk material is friable
- Silos and storage systems are key elements in the process path and cannot be considered independently from the overall plant scheme or operating procedures

Fabrication

- PET (plastic pellets) silos
- 12 ft (3.6 m) D, 56 ft (17 m) tall
- Horizontal seam weld failure
- <50% external weld penetration
- Required weld repairs

Installation

- Sand silo (11 MM pounds)
- 38 ft (11.5 m) D, 120 ft (36 m) tall
- Improper column shimming
- Use of small blocks, washers
- Damage to silo skirt and foundation

Maintenance

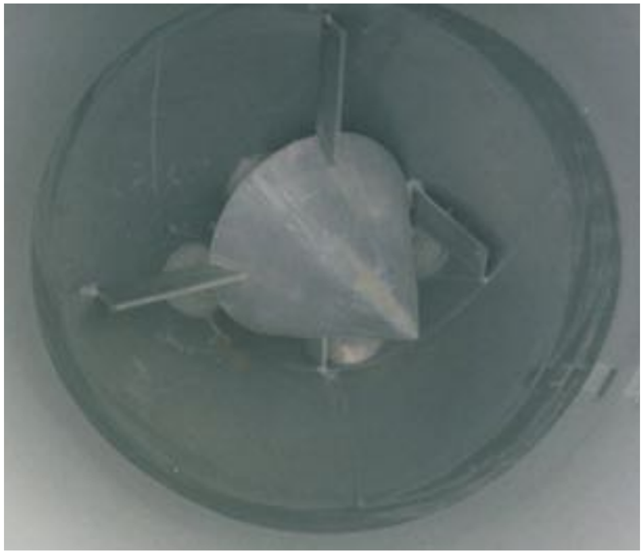
- Plastic pellets silo
- 12 ft (3.6 m) D, 60 ft (18 m) tall
- Long, cold winters
- Water drainage issues allowed freezing/thawing to damage silo foundation
- Corrosion of anchor plates, bolts, and skirts
- Repaired with proper grading




Owner responsibilities

- **Prior to design** – if you are doing flow property testing, did you send a "representative" sample for testing? This is crucial!!
- **Design** – Do you understand the implications of the design? (equipment size, first time product, ancillary equipment, product variability, etc.)
- **Fabrication** – Significant responsibility here – material of construction, fasteners, weld procedures and penetrations, steel work where the silo might be placed, appropriate relief design
- **Operation** – periodic inspection is very important – look for dents, creases, buckling, bulging of the silo. May not always occur at the most obvious points – sometimes it might be at the top of a silo. Get professional help to assess and remediate the problem.
- **Process/silo alteration** – many things can go wrong here – material changes that cause a change in mass flow or funnel flow, addition of outlets which cause a severely lopsided profile of the silo contents, fluidization of the silo contacts (remember you lose the frictional support of the silo walls!), repurposing of the silo, etc.

Questions ?



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Richard Farnish	Wolfson Centre	R.J.Farnish@greenwich.ac.uk
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Moderator:

Eric Maynard	Jenike & Johanson	epmaynard@jenike.com