# Atmospheric Tank Failures
## Mechanisms and an Unexpected Case

**12th Global Congress on Process Safety**
**Houston – April 2016**

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PROCESS SAFETY

# Mike Schmidt bio

- **Principal of Bluefield Process Safety since 2008**
- **Joined Union Carbide in 1977**
- **Began work in process safety following tragedy in Bhopal in 1984**
- **Joined faculty at Missouri S&T in Rolla in 2009, teaching on safety and risk**
- **Work includes**
  - **Facilitating PHAs, LOPAs, RTC establishment**
  - **SIS conceptual design, SIL verification calcs**
  - **PSM compliance and audits**

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# Presented by

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    **Bluefield Process Safety, LLC**
    **St. Louis, Missouri**
  - **Adjunct Professor,**
    **Missouri University of Science and Technology**
    **Rolla, Missouri**

# Atmospheric tanks

- **Not a consensus on definition, but consensus is not critical**
  - **Operate at < 1 psig (< 30 in $H_2O$)**
  - **Do not operate under vacuum**
- **Typical worries:**
  - **Flammable hazards**
  - **Overfilling**
  - **Leaks**

# Catastrophic atm. tank failures

- **Collapse**
- **Implosion**
- **Explosion**

# Collapse

- **Walls or joints fail locally, and then come "unzipped"**
- **Result from:**
  - **Inadequate design or construction**
  - **Converted to different service**
  - **Tank deteriorates over time**


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# Implosion

- **Do not produce shock waves or flying shrapnel**
- **May be breached, but loss typically not significant**
- **Result from exposure to vacuum**
  - **Vacuum pumps**
  - **Vacuum jets**
  - **Pump out**
  - **Gravity drain**
  - **Condensing vapor**

# Explosion

- **Internal pressure exceeds capability of tank to withstand**
- **Result from**
  - **Heating that causes increased vapor pressure**
  - **Connection to "high pressure" external sources (feed lines, utilities)**
- **Combined with inadequate venting**

# Exceeds capability to withstand

- **Atmospheric tanks are designed operate at ~ 1 psig**
- **Vapor pressure of water increases by 5 psi when heated from 80°F to 165°F**
- **Dead head pressure of pumps is typically well over 1 psig**
- **Utilities (city water, plant air) are typically in the range of 30 to 100 psig**

# A case study




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# The incident

- **Blowing out transfer line from caustic storage tank to day tank**
- **Caustic day tank failed**
- **Tank head flew ~125', coming down through nearby process building roof**
- **Employee fell during evacuation and received medical treatment**

# Caustic Day Tank head, after…

- **…coming down through roof of a nearby process building.**

# Process background - equipment

- **50% caustic solution**
- **3” stainless steel transfer line**
- **50% caustic entered tank through dip pipe from top of day tank**
- **Day tank equipped with 3” PVC goose neck vent**

# Process background - transfer

- **Transfer:**
  - **50% caustic transferred from storage tank to day tank**
  - **Transfer line blown clear with process air for 15 min**
- **Purge for maintenance, also:**
  - **Transfer line flushed with city water for 5 min**
  - **Water blown from transfer line with process air for 15 min**

# Incident time line

**Balmy, spring Friday morning**

- **~9:30 am - Prep for maintenance on leaking line by purging w/air**
- **~9:50 am – Line purged with city water**
- **~10:00 am – Disconnected water line; operator called away**
- **~10:30 am – Air purge reconnected and started**
- **11:10:19 – Day Tank explodes**

# Generic issues for caustic tanks

- **Sources of high pressure**
  - **Material incompatibilities → $H_2$**
  - **High pressure utilities**
  - **Pump deadhead**
  - **Heating frozen caustic**
- **Causes of blockage**
  - **Valves inadvertently closed**
  - **Frozen caustic**
  - **Vermin nesting**
- **Failure below design pressure**
  - **Exceeding design temp for MoC**
  - **Unsupported piping (esp. PVC)**

# Conditions at incident scene

- **Noted from video**
  - **Video shuddered, confirming explosion and shockwave**
  - **Cloud dispersed immediately-no BLEVE, no ignition, no boil-up**
  - **Head separated first on west side and then was propelled east**
- **Noted from field**
  - **Air at 90 psig, city water at 40 psig**

# Also noted from field

- **Though not visible from outside of tank, vent was encrusted with NaOH, choking off vent to less than ½”**

# Also noted from field

- **Separation was at weak seam weld**
- **Tank interior showed some staining, but no build-up like that in the vent nozzle**

# Contributing factors

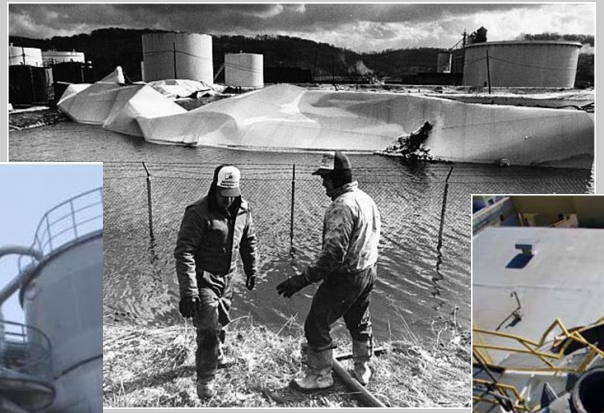
- **Direct cause – Source of high pressure was 90 psig process air used to blow down line**
- **Indirect cause – Plugged vent, (extended time allowed to blow did not help, but eventually would not have mattered)**
- **Basic causes – High pressure blow down, dip pipe that extended into liquid, inspection method**

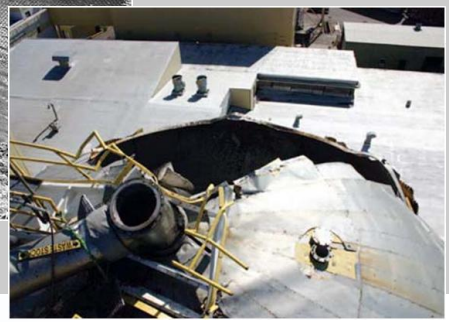
# Case recommendations

- **Assure vent is adequate**
  - **Dow recommends vent area be 4 times fill line area, and that vent extend to within 3’ of ground**
- **Vent inspection to catch build-up**
  - **Caustic mist generated by blowing line clear will plug vent**
  - **Consider boroscopes or inspection ports**
- **Remove dip pipe**
- **Regulate inlet pressures to as low as possible**

# General recommendations

- **Regarding catastrophic collapse**
- **Regarding catastrophic implosion**
- **Regarding catastrophic explosion**
- **Regarding use of dip pipes**





# Regarding catastrophic collapse

- **Apply rigorous MOC procedures when changing service, especially changes in density**
- **Act as though you know a tank is going to fail while being commissioned**
- **Pay attention to wall thinning, general *and* localized, during use. Pay special attention to potential points of erosion.**

# Regarding catastrophic implosion

- **Control sources of vacuum**
  - **Vacuum pumps**
  - **Steam vacuum jets**
  - **Pump out**
  - **Gravity draining**
  - **Condensing vapors**
- **Validate vacuum relief works**
  - **Atmospheric vents**
  - **Conservations vents**
  - **Inerting pads**
  - **Vacuum breakers**

# Regarding catastrophic explosion

**In addition to obvious concerns about flammability**

- **Control sources of pressure**
  - **High inlet gas pressure**
  - **High inlet liquid pressure**
  - **Heating**
- **Assure venting is adequate**
  - **Properly designed**
  - **Inspected, tested, and maintained**

# Regarding use of dip pipes

- **Use dip pipes for non-polar, flammable liquids, to avoid static discharge**
- **Avoid dip pipes for aqueous solutions of dissolved solids, which will lead to misting and deposits when blown out**

# General conclusions

- **Atmospheric tanks are relatively fragile**
- **Often overlooked as hazards**
- **Often neglected as a maintenance priority**

- **HazOp response to "pressure-too high" or "pressure-too low" cannot be, "That can't happen, we're open to atmosphere."**

# Questions?