Explosion and Fire in an Acrylic Acid Tank at Japan on 29 September, 2012

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Basic Chemical Products
• Acrylic Acid, Acrylic Esters
Special Products
• Super Absorbent Polymers, Resins
Catalysts

... since 1973
In news

**The Sydney Morning Herald**

**World**

Migrant Crisis | Search for MH370 | Race to the White House | Gallipoli: 100 years | Environment

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**Factory blast to hit supply of nappies**

October 2, 2012

**World Of Chemicals**

Media

**Nippon Shokubai chemical plant explosion threatens diaper supply**

11:05 AM, 1st October 2012

TOKYO, JAPAN: An explosion at a large Japanese chemical plant has sparked fears of a global shortage of disposable diapers, said a report on Sunday. A tank at chemical producer Nippon Shokubai's factory in Himeji city, Hyogo Prefecture, exploded Saturday, killing a firefighter and injuring 35 other emergency service workers who responded to a callout, said the fire service.

The company has a 20 per cent global share of superabsorbent polymer, which is used

**abc NEWS**

**Uh-Oh. Diaper Shortage Possible After Plant Explosion**

October 1, 2012

By AKKO FUJITA via GOOD MORNING AMERICA

**ADAMS INSURANCE SERVICE**

Example #367 Of Supply Chain Risk: Chemical Plant Explosion In Japan Could Affect Global Supply Of Diapers
Outline

- Overview of process and facility
- Operations of intermediate storage tank
- Accidents chronology
- Consequences
- Causes and contributing factors
- Safety Culture
- OSHA/PSM and RBPS
- Lessons learned
• Stored at temperature controlled and oxygen (<5%) controlled tank with added inhibitors.

Acrylic Acid

- MP: 14°C
- BP: 141°C
- FP: 51°C
- Ig. P: 428°C

Di-Acrylic Acid

- Heat of dimerization: 145.3 kJ/kg

Polymer

- Heat of polymerization: 1076 kJ/kg
1 – Tank yard
2 – Basic chemical production yard (Acrylic Acid and Acrylates)
3 – Functional chemical production yard (SAP)

Area = 900,000 m²

Source: maps.google.com
Intermediate Storage Tank


Maintenance

Rectifying Column → Vent → Recovery Column

M-Gas → Rectifying Column

Recycle to Top

Tank Full

V-3138

70 m³

7% O₂

Liquid Stored < 25 m³

Insulated tank

Cooling Water (In) → Cooling Water (Out)

Recycle to Level Gauge

P-3138C (Transfer Pump)

LI
Intermediate Storage Tank

Modified Operating Principle (2000)

Rectifying Column → V-3138 (70 m³) Insulated tank → Recovery Column

- M-Gas
- Vent
- Recycle to Top
- Recycle to Level Gauge
- Cooling Water (Out)
- Cooling Water (In)
- Precipitation
- P-3138C (Transfer Pump)
Intermediate Storage Tank
21 – 25 Sep, 2012: **Start-up** after total shutdown maintenance work

- Units brought online
- Cooling loop initiated
- Inerting of expansion space underway
- Recirculation loop near the probe activated

**On September 24**

Stabilized tank volume ~ 10 m³
Accident chronology (2)

25 – 28 Sep, 2012: **Filling** of intermediate tank

- **9:30 AM, 25 Sep**: Shutdown to test tank capacity
- **2 pm, 28 Sep**: Max operating volume (60 m$^3$) was not activated. Dimerization caused T increase to 60°C from 40°C
- **9:30 AM, 25 Sep**: Shutdown to test tank capacity
28 – 29 Sep, 2012: **thermal runaway reaction**

2 pm, 28 Sep: Tank filled, recovery column fed directly

1: 17 pm, 29 Sep: liquid level high alarm

1: 20 pm, 29 Sep: white smoke emitted from the vent

1: 25 pm, 29 Sep: operator started spraying water using private fire hydrant

29 Sep: level exceeded instrument indication limit (85 m³)

plant-wide announcement, disaster prevention team

2:02 pm, 29 Sep: Fire brigade of 30 men arrived on scene and resumed tank sprinkler
2:20 pm 29 Sep, 2012: **the accident**

- Leak formed due to cracking which lowered the internal pressure causing the mix to boil.
- 2:35 pm: **BLEVE explosion**
  - $P_{\text{max}} = 6\ \text{bar}$
  - Force = 3 kg TNT eqv
- Content spreads in the vicinity causing fire spread around the vicinity
- 10:36 pm: Fire brought under control
Consequences of this accident (1)
Consequences of this accident (2)

- Complete destruction of intermediate tank
- 1 died, 37 were injured
- €15 M production loss,
- 9 month shutdown total €450 M

European scale of industrial accidents
Direct causes

- Failure to commission of top recycle to top has caused AA to remain a high temperature for a significant long time in the upper portion of the tank.
- DAA formation created high temperature zones and overall temperature rise. It further started the polymerization and increased temperature further.
- Lack of thermometers and inadequate temperature monitoring has caused abnormal condition detection impossible until polymerization proceeded.
Organizational Issues

- The tank operating manual was not up-to-date
- Inadequate training for technicians working in nonstandard operating modes
- An insufficient risk analysis
- Poor oversight of plant modifications
- Inadequate supervision of maintenance operations
- Lack of emergency situation drills
## Contributing Factors

<table>
<thead>
<tr>
<th>Contributing factors</th>
<th>Management elements</th>
</tr>
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</table>
| 1. a) Excessive heating of feed liquid  
b) Recycle to top valve closed            | Design review, validation, design philosophies handover, PTW was not included in SOP |
| 2. Tank control procedure                                                           | Operation manual development and dissemination                                      |
| 3. Recovery column load up test                                                      | Risk assessment and safe work management for non-routine work                       |
| 4. c, d) Inadequate temperature control and detection                               | Operation condition setting and management                                          |
| 5. e, f, g) Unable to control temperature, avoid abnormal situation                 | Criteria for abnormal situations and its respective response procedure              |
| 7. h) Unable to avoid crisis situation                                               | Crisis management and disaster prevention activities                               |
**Absence of internal and external feedback mechanisms both inside the plant and throughout the group**

<table>
<thead>
<tr>
<th>Year</th>
<th>Location</th>
<th>Fire and explosion accidents in acrylic resin manufacturing plants</th>
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</thead>
<tbody>
<tr>
<td>1962</td>
<td>USA</td>
<td>Reactor overheat and runaway. Tank ruptured, fire and explosion. 10 Died, 46 injured</td>
</tr>
<tr>
<td>1973</td>
<td>Japan</td>
<td>Power failure caused cooling and stirring system down. Solvent vented to atmosphere, 101 injured</td>
</tr>
<tr>
<td>1983</td>
<td>USA</td>
<td>500 gallon Acrylic monomer tank exploded under external fire, 40 injured</td>
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<tr>
<td>1987</td>
<td>USA</td>
<td>Acrylic resin storage tank caused fire and smoke. 6 schools and near by town were evacuated</td>
</tr>
<tr>
<td>1992</td>
<td>USA</td>
<td>Fire and explosion in acrylic resin manufacturing plant</td>
</tr>
<tr>
<td>1997</td>
<td>USA</td>
<td>Reactor overheated and runaway. Tank exploded, formed vapor cloud, 1 injured</td>
</tr>
<tr>
<td>2001</td>
<td>Taiwan</td>
<td>Reactor overheated and runaway. 10 million USD loss</td>
</tr>
</tbody>
</table>
Attributives of Best-in-Class Safety Culture (Mannan et al, 2013)

- Leadership – “Safety takes precedence over production” but was that in practice?
- Culture and values – did not recognize the problems of complacency until too late, no rigorous hazard analysis, failure to learn from external experiences.
- Goals, policies & initiatives – safety goals were not effectively communicated down to the front line. The sign posted to use top bypass was placed out of technician’s line of sight.
- Organization and structures
- Employee engagement and behaviors – insufficient information whether vital employees were part of organization’s safety system, should have a better safety awareness to prevent the incident?
- Resource allocation and performance management – were there adequate resources to safety?
- Systems, standards and processes – breach of operational discipline, flawed MOC system
- Metrics and reporting – failure to capture the weak signal
- A continually learning organization - was not enough training of T-5108 and V-3138, didn’t understand the behavior of DAA and hazard of AA.
- Verification and audit – should have capture the problem?
OSHA PSM - should have prevent the incident?
Lesson Learnt

- Updating operational documentation must correspond to all process changes.
- A technical or procedural modification to a process, even minor in nature, can fundamentally alter the initial risk analysis and, with it, the design of safety barriers.
- Technician training and drills must also focus on the infrequent and extraordinary phases, such as equipment testing.
- For each product displaying risks of ignition, decomposition or runaway reaction, the control parameters deemed critical, e.g. the outcome of a HAZOP analysis, must be subject to continuous monitoring by technical staff throughout all process stages.
- Regular communication with follow-up is necessary between the design, maintenance and operations teams.
Acknowledgement

- Mr. Roy Sanders
- Dr. Hans Pasman
- Dr. Delphine Laboureur
- Dr. Sam Mannan
References


- French Ministry for Sustainable Development, *Explosion and fire on an acrylic acid tank at a chemical plant*, Himeji, Japan, Article No-42817.


Thank You !!!

Questions? Comments? Suggestions?

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