Lessons Learned from an Unusual Hydrogen Reformer Furnace Failure

T. M. Rogers
Syncrude Canada Limited
QUICK FACTS

- Syncrude Canada Ltd is a joint venture partnership which converts Athabasca Oilsands into a Light Sweet Blend Crude Oil.

- The facility is an integrated mining, extraction and upgrading operation supported by a common power utility.

- Current capacity is 250,000 barrels/day of final product which is shipped via pipeline to southern markets.

- The Upgrading plant is similar to an oil refinery with two separate operating trains each including a crude unit, fluid coker and hydrotreaters.
QUICK FACTS

- Within the Upgrading plant 300 MSCFD of hydrogen in three steam/methane reformers is produced
- The incident occurred in the reformer furnace of unit 3

Furnace Facts

- Hydrogen output 81 MSCFD built in 1987 and operational in 1988
- The radiant section of the furnace contains eight (8) parallel rows of. Each row contains forty-six (46) tubes for a total of 368 tubes composed of spun cast HP-45 Niobium Modified Alloy with a design wall tube temperature of 935°C.
  - Each tube has a 4” ID by 39’10”
  - 108 burners arranged in 9 rows
General Furnace Arrangement

- SG-1A
- Convection Box 1
- Aux Burners
- SG-1B
- FPH
- SSH
- MFPH
- SG-2
- SG-3
- BFW
- Convection Box 2
- Flue Gas
General Tube Arrangement
SUMMARY

THE INCIDENT

- At 22:39 Sunday January 30, 2005 a rapid sudden high energy pressure impulse occurred within several radiant tubes in the unit 3 reformer furnace
- The furnace was in a startup mode on steam without hydrocarbon feed
- This impulse caused the simultaneous rupture of 5 tubes with sufficient force to eject portions of the tubes out through the roof of the furnace
SUMMARY…

- 41 more tubes were destroyed as a result of impacts by tube segments and the subsequent shock wave
- All of the flue gas tunnels suffered extensive damage
- Fire box sustained impact damage from shrapnel hits
- One Operator sustained serious injuries when he was hit by one of the ejected tube assemblies
- The entire reformer section was condemned necessitating replacement
Pre Incident General Radiant Tube External Arrangement

Post Incident External Damage
Tube 161 lifted approximately 16 ft (view looking up)

Internal condition of radiant section
FAILURE MECHANISM

- Prior to start-up water was present in the feed system upstream of the radiant tube section.

- As the Process Steam flow was ramped up per the startup procedure (increased mass and velocity) it picked up water and carried it into the radiant tubes.

- Water introduced into tubes underwent an rapid phase change generating an extreme local pressure impulse and shock wave. The wave initiated longitudinal cracking:
  - Entrained water impinged on hot (350°C) catalyst and possibly the pipe wall, “instantly flashing”
ROOT CAUSE

- Accumulated water was not removed upstream of the radiant section prior to introducing steam
- The Mixed Feed Preheat Coil is the most probable location where water was pooled prior to the event because:
  - Steam could have collapsed into water in the system after shutting down or from passing valves
  - Inlet header is not self draining
  - The outlet header is the low point
LESSONS LEARNED

- **Inadequate Safeguards:**
  - Insufficient size and location of drains to ensure all remnant water is removed

- **Inadequate Procedure:**
  - The startup procedure did not account for a startup of a cold furnace with no hold points
  - Insufficient information for operators to detect a wet system

- **Lack of MOC**
  - The startup procedure has two hold points for refractory dry out and new catalyst reduction, during the heat up phase prior to introducing the 600psig startup steam.
  - These hold points were not utilized since the neither was required
LESSONS LEARNED...

- Non-essential Personnel
  
  - At the time of the incident seven people were on the furnace structure
  
  Only the operations personnel were essential