Mines Safety Bulletin No. 172

Subject: High pressure compressor systems on drill rigs - fire and explosion hazard

Date: 10 March 2020

Background

Down-the-hole drill rigs that use reverse circulation (RC) techniques are commonly used for mineral exploration and for sampling purposes in open pit mining. These drill rigs use high pressure (HP) air compressor systems, either mounted on the rig or on a separate compressor truck.

The HP air compressor systems are typically based on oil-flooded rotary screw compressors (OFRSC) for the first stage compression, with a second stage booster compressor and associated intercooler, aftercooler, scrubbers, air-oil separator tank (incorporating a coalescing filter), air receivers and other ancillary equipment.

Numerous potentially serious explosions and fires on drill rigs reported to the Department in recent times have been attributed to issues with the HP compressor on RC drill rigs. Investigation of these incidents suggests that there may be systemic issues with the design, operation and maintenance of this class of equipment, as well as a lack of hazard awareness.

Summary of hazard

Other than general machinery hazards (such as noise, moving parts, hot surfaces, etc.), HP compressor systems on RC rigs have particular hazards and risks.

- Extremely high air pressures (350-500 psi).

  Any sudden depressurisation (e.g. air hose coupling failing, air pipe bursting) will be a very energetic and hazardous event (percusive shock wave, flying debris).

- External fires fueled by oil leak

  Parts of the air system (the wet side) are flooded with hot lubricating oil mist or liquid. Any loss of containment may result in an external fire, particulaly if leaked or sprayed over hot parts of the machinery (e.g. diesel motors). Most mineral-based lubricating oils have flash points of approximately 150-200 degrees Celcius at atmospheric pressure and are readily ignited by hot surfaces.

- Internal flash-overs

  Excessive carry-over of lubricating oil from the wet side to the dry side of the air system may form an explosive mixture with the compressed air, particularly if a second stage booster compressor is used and intercoolers or aftercoolers are not operating effectively.

The auto-ignition temperature of mineral based lubricating oils decreases with increasing pressure. Therefore, systems with second stage boosters are particularly vulnerable. The heat of compression, internal hot surfaces, and static electrical discharges can cause a sufficiently rich air/oil mixture (at sufficient pressure) to detonate. Such internal detonations, often referred to as "flash-overs" can develop large over-pressures within an enclosed system causing rupture or bursting of pressure equipment, as well as external fires.

Even if they do not cause rupture or bursting of pressure equipment, internal flash-overs can:

– damage air/oil separator elements causing further oil carry-over and a further, more energetic, flash-over

– vent to the outside through a safety relief valve causing a jet of flame and hot gases to be directed at combustible materials or personnel who may be in the line of fire.

Air/oil separator vessel The carbon deposits on outside of shell indicated the venting from the safety relief valve during internal flash-over.

Contributory factors

- High discharge air temperatures increase the risk of fires and explosions. HP compressor systems typically include a discharge air temperature switch that shuts down the machine when the discharge air temperature reaches 110 degrees Celcius, which suggests a problem exists with the compressor or its cooling systems. If the switch is faulty, then the compressor will continue to run and if the discharge air temperature reaches the auto-ignition temperature of the lubricating oil, an internal flash-over event may result.
- Other causes of high discharge air temperatures in a compressor system may include:

  – loss of lubricating oil to the compressor screws (e.g. clogging of oil lines, oil filters, valves) because the lubricating oil also cools the air end
  – fouled radiators (intercoolers and aftercoolers) not cooling effectively
  – radiator cooling fans not working
  – dirty or oxidised lubricating oil
  – low lubricant levels
  – malfunction of oil temperature control valve
  – high ambient temperature or lack of ventilation for compressor.

- Excessive oil carry-over past the air/oil separator and any booster inlet scrubbers may increase the risk of fires and explosions. Factors that may increase oil carry-over include:

  – using non-original equipment manufacturer (OEM) approved air/oil separator elements, as well as damaged or wrongly fitted elements
  – scubbers and scavenging systems that are not operating effectively
  – using the wrong oil grade for the ambient conditions
  – using an air/oil separator vessel that is not optimally sized for your air system (e.g. wrong wet side volume).

- Any undrained dead legs in the compressed air piping can become condensate traps and accumulate oily liquid over time. Such accumulations of oil may fuel an internal fire or contribute to a flash-over event.
- Compressed air systems on RC rigs are commonly fitted with spring type safety relief valves, usually mounted on the air/oil separator vessel. Such devices are not designed to relieve the sudden over-pressure produced by a flash-over event.

Actions required

The following actions are recommended.

- Ensure HP air systems for drill rigs are designed, manufactured, tested, inspected, operated and maintained by competent persons in accordance with OEM recommendations.
- Ensure operators and maintainers do not make modifications or use components or procedures that are not approved by the OEM, unless the change has been adequately assessed by a competent person to ensure there is no increased risk of exposure to a hazard.
- Implement systems of work to monitor the oil consumption of the compressor system. Excessive oil consumption may suggest excessive oil carry-over and an increased risk of a flash-over event.
- Ensure compressor systems for drill rigs are sized and selected for the foreseeable environmental conditions and a grade of lubricating oil is selected that is suitable for the expected ambient temperature range.
- Ensure air system monitoring and protection devices, including pressure and temperature sensors, are function tested for correct operation and adequately maintained.

Further information

Haul truck dash cam video of a blast hole drill rig fire at night caused by a flash-over in the compressed air system - operator in the drill rig cab during the event - https://vimeo.com/395399876/6fe2e36f5a

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