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Subject: Red Alert: Air Compressor Explodes during Startup

Title: Red Alert - Air Compressor Explodes during Startup
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Executive Summary: Oil-flooded rotary screw air compressors are prone to fires and explosions during some operating conditions.

Lessons Learned Statement: It is essential to perform a risk assessment on new equipment. The assessment can be scaled to meet specific needs, and would not require the same depth on all projects. The amount of time and cost required to perform such an assessment is minimal compared to other costs associated with acquiring the equipment. For a risk to be assumed, it must be identified and quantified as to the probability and the potential consequence. If this is not done, the risk is no longer an assumed risk, it is an unknown risk. In this case, the compressor operators were not aware of the potential risks.

Constant vigilance is necessary around high energy equipment. Be attentive for unexplained changes in operating parameters, and document the changes noted. Notify supervision, and continue to investigate until a reasonable explanation is determined.

Discussion: An Operator was in the process of starting the facility air compressor in support of routine facility operations. During the startup, the compressor failed catastrophically, with explosive force, propelling parts, debris, and oil into the compressor room. The room immediately filled with atomized lubricating oil and smoke. The Operator, exited the air compressor room, dazed and covered with dark oil spray. He was still clutching an oil-soaked copy of the operating procedure in his hand.

Analysis: The investigation team determined the explosive failure was initiated by some form of ignition event within the air compressor's internal oil separator. The compressor involved in the event is a Sullair, oil- flooded rotary screw compressor, model number 20-150H ACAC 24 KT, Industrial.

In an oil-flooded, rotary screw compressor, the three elements necessary to support combustion (fuel, oxygen, and heat) are often present. The reason that more fires and explosions do not occur in this type of compressor is the oil/air mixture is too rich in oil and the upper flammability limit is exceeded. The Sullair 24 KT oil, which was confirmed to be in use in the compressor, is a synthetic oil with a very high auto ignition temperature and flashpoint, and does not easily ignite.

The exact cause of the fire/explosion could not be determined. Examination of the evidence following the explosion could only lead to postulated scenarios.

The most likely initiation sequence for a strong deflagration within the receiver/sump and oil separator region begins with the back flow of air through the minimum pressure check valve into and through the separator elements. The failure of this valve could result from a number of causes. The valve could become worn due to its cyclic behavior when a compressor is used often under low flow conditions, or carbon deposition from previous combustion events could increase the friction between the closure piston and the side wall of the valve, or the valve may have been

damaged by abnormal surging or pressure transients from minor combustion events. As the air passes back through the separator elements the oil aerosols produce electrostatic charges as they contact, and separate from, the fiberglass filter media. These charges cannot discharge through the grounding staples of the two separator elements because they are moving into the receiver/sump, away from the grounded separator elements. Normally, these charges are of no consequence because they are discharged through the grounding staples of the separator elements, and potentially combustible cells of fuel and air are quickly swept away as they pass through the separator elements and the minimum pressure check valve, into the service line. The most likely initiation sequence for combustion of oil aerosols in and near the separator filters contained within the receiver/sump is described as follows:

After a combustible mixture of oil and air is achieved, the next factor to consider is that of an ignition source. With the movement of air and oil in the compressor system there is always an electrostatic charge being produced. To guard against this, there are grounding staples in place to discharge the energy. These would be very effective in discharging most electrostatic energy. In this case, the electrostatic charge is believed to have been produced within the oil-air mixture itself, and could have built up a significant charge that arced from the mixture to the grounding medium. The grounding staples would not be able to effectively bleed off this energy. This discharge may have been the ignition spark that resulted in the chain reaction leading to the propagation of combustion and the explosion. It is likely that this type of electrostatic discharge has occurred previously, but the propagation of the flame was not maintained due to a lack of optimum conditions. The large heat absorption capacity of the oil probably prevented the larger ignitions during abnormal surging events in the past.
Once the explosion took place, the ASME vessel withstood the force but the air end discharge check valve, which weighs approximately 40 pounds, and a section of discharge piping, blew off of the compressor and struck the steel three-foot wide fire door with enough force to deform it about six inches.

CONTRIBUTING CAUSES - Maintenance Procedures Incomplete; Communications Ineffective
The facility personnel had been performing, and exceeding, the preventive maintenance requirements listed in the Sullair maintenance manual, however, based upon information acquired by the investigation team, this maintenance manual does not contain all of the needed maintenance requirements. The maintenance requirements which were not listed in the manual, or provided by the vendor, may have resulted in the malfunctioning of the compressor control system, resulting in abnormal surging, which contributed to establishing the conditions necessary for this event to occur.

ROOT CAUSES - Defective Compressor Design; Lack of Risk Assessment
Literature searches were conducted, other companies using the same type of compressor were contacted, and a thorough analysis of the event was conducted. It was concluded that oil-flooded rotary screw compressors are, by their very design, prone to fires and catastrophic explosions. The investigation team found that it is not uncommon to have minor explosions or fires with oil flooded rotary screw compressors. Installation of the Sullair compressor was completed in 1990. No known requirements existed to perform a risk assessment. Since off-the-shelf, high-energy systems may have a high consequence associated with failure, a risk assessment may have been

justified. An actuarial risk assessment, or even a search of the literature, may have furnished valuable information on the hazards involved with this type of compressor, if it had been required or accomplished.

Recommended Actions:

DOE facilities, with oil-flooded rotary screw compressors, should evaluate the need for physical barriers and/or engineering or administrative controls for the protection of personnel near these compressors during operation. All DOE facilities should evaluate the need for performing risk assessments on high energy off-the-shelf industrial equipment prior to procurement. Establish and maintain open communication with equipment vendors, and other facilities with similar equipment. Use the information gained in these exchanges to assist in your efforts to verify that your preventive maintenance program is complete.

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Reference: ORPS Report: ID--LITC-WERF-1998-0008; Accident Investigation Report for the Waste Experimental Reduction Facility Plant/Breathing Air Compressor Failure on November 4,1998 (INEEL/EXT-99-00281)