AIR HEATER EXPLOSION

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Feed air to the air separation plate is dried using activated alumina driers. Regeneration of these driers is effected by passing a side stream of the air feed over an electric heater and then through the alumina bed, heating it to a temperature of 450° F. After holding the bed at this temperature for 2 to 3 hr., it is then cooled to operating temperature. It was during the heating portion of a regeneration cycle that an air heater ruptured.

Accident description

On the morning of the accident, the foreman noticed smoke coming from the vicinity of the reactivation heaters and immediately opened the electrical heater breaker. A check of the reactivation flow rate, reactivation air and bed temperatures showed all three to be normal. In order to quickly cool the heater, the reactivation air was increased from 150 to 300 cu. ft./min. The foreman and an operator set up a step ladder to check the heater, and upon finding the insulation red hot, both men started to descend the ladder; it was then the heater ruptured burning both men with hot air and showering them with fine particles of insulation and hot metal. One man received first degree burns of the lower face plus second and third degree burns of the left hand; the other received a second degree burn of the arm. (The first man's hard hat probably saved his life as it took the brunt of the blast; the plastic was charred and the surface contained a multitude of embedded metal particles.) Approximately three minutes had elapsed from the time the heater-breaker was thrown and the rupture occurred.

System investigation

The reactivation heater consists of three pipe sections with each section containing a heater element. Reactivation air flows in series through the three sections.

To prevent overheating, the heaters are shut down automatically whenever:

1. Air temperature exceeds 600° F.
2. Reactivation air flow drops below 120 cu. ft./min.
3. Current draw exceeds 70 amp. (53 kw.).

These three safety items were checked as were all pressure gauges and thermometers. All were found to be normally accurate except that the temperature control switch set to interrupt the heater current whenever the exit air exceeds 600° F did not actuate at 600° F. Since the exit air thermometer read 500° F just before, and immediately after, the rupture, the fact that the temperature control switch actuated above 600° F when tested is not considered a factor in this particular failure.

Failure theories

Although the failure had every appearance of an electrical fault, other possibilities were considered. One such possibility existed that perhaps compressor lubricating oil had condensed in a pool, ignited by some source and burned, causing the hot spot. No carbon film or deposits were found in the piping or on the fin tube. The air compressor is lubricated with Cellulube 220, a phosphate ester oil having much higher fire resistant properties than the petroleum oil formerly used. Typical flash and fire points for Cellulube 220 and petroleum oil are shown in Table 1.

TABLE 1. TYPICAL FLASH AND FIRE POINTS OF CELLULUBE 220 AND PETROLEUM OIL.

	Cellulube 220	Petroleum oil
Flash point, °F	500	450
Fire point, °F	700	525
Auto ignition point, °F	1,180	—
Hot manifold ignition temperature, °F	1,370	—

Since no evidence of combustion was found, this theory was discarded. Another theory, which readily presented itself, was that perhaps the fins had become plugged with a foreign material (although the air feed is a clean stream) causing localized overheating of the heating element. Upon removal of the heating element, the fins in the vicinity of the hot spot were found to be filled with a material having the appearance of metal sinter. However, this material was determined to be deposits from the melted fins. No evidence was found to support the supposition that poor air distribution caused the hot spot.

Heating element failure

About one month prior to the accident, the heating element in the top tube (nearest the exit) failed. Since a spare heater was not immediately available, the bottom element was interchanged with the top unit and the system was operated using only two elements. It was not recognized at the time that the 70 amp. heater in the breaker, designed for three heater elements, was now oversized when using only two elements. (The system had been operated on two previous occasions without incident using only two elements.) The heating elements normally draw 8 kw. each, and thus, it would be possible for one heater to draw 45 kw. before the breaker heater would actuate. This item has been considered a probable contributing factor to the heater failure.

The heater element which failed had been fabricated by Westinghouse, who have since ceased to build this particular style of heater. Replacement heaters are now being built by the Edwin L. Wiegand Co., and it was to them we turned for assistance to determine the cause of the accident.

Heating element design

The Westinghouse heating element consisted of three Inconel tubes each containing a resistor coil surrounded by magnesium oxide. These three tubes were then in turn encased in a fin tube, separated from the tube wall and each other by magnesium oxide insulation. Upon examining the individual components in the vicinity of the failure, the Wiegand representative pointed out the following:

1. The resistor coil had melted and the insulation had fused both inside and outside the Inconel tube.
2. Pinholes were found in the Inconel tubes in the vicinity of the failure.
3. The Inconel tube had changed color indicating its being subjected to a high internal temperature.

56,000 hr. estimated service

This condition was stated to be typical of an electrical failure resulting from old age and fatigue. The heating element had been in service an estimated 56,000 hr., whereas the rated service (by Wiegand) for this type is 10,000 hr. Intermittent service, such as experienced in drier regeneration, is particularly hard on heaters. The alternate heating and cooling pulls moist air in and through the conduit, and also results in the various components working inside the insulation due to different coefficients of expansion. Another factor affecting the life of this type heater is the high temperature at which the resistor coil must be operated to get sufficient heat through the two layers of insulation to obtain the desired air temperature. The maximum temperature rating of the resistor coil is 2000° F, and to obtain an air temperature of 500° F to 550° F, requires the wire to be operated at approximately 1900° F.

The replacement heater consists of a single metal sheath containing the resistor coil packed in insulation. It is, therefore, possible to maintain a high skin temperature with a much lower resistance coil temperature. Expansion and contraction problems are also reduced from the reduction in the layers of metal and insulation.

A safer system

To provide a safer system, the following measures have been or will be taken:

1. Thermocouples were attached to each of the three shells and the temperatures monitored.
2. The replacement heaters will be equipped with thermocouples attached to the Inconel tube with a controller to interrupt the current on high temperature.
3. The heaters will also be individually protected by contact breakers wired in series to furnish better overload protection.
4. A 1/4-in. steel plate was erected on open side of the heater.

DISCUSSION

JONES—Canadian Industries Ltd.: I have a question on the regeneration cycle of the driers. Are they changed once a day, twice a day, or how frequently are they changed?

MESLOH: We change our driers anywhere from 8 to 12 hours. We are currently using 8-hour cycles; that is, we heat the bed for 4 to 5 hours and cool for 2 to 3.

JONES: Well, I believe if the period is 56,000 hours life, this is about 7 years, isn't it, this would put it at about six or seven thousand cycles. In the course of each cycle, apart from the thermal cycle, wouldn't there be a pressure cycle involved—would there be a depressurization or would the driers always be at your operating pressure, whatever it may be?

MESLOH: Each bed is reactivated at the same pressure, so we would always have a constant pressure on the heater at that point.

JONES: Did you do any testing on the residue of the steel pipe, or did you look for fatigue cracks or evidence of any seams or defects? As I mentioned on an earlier occasion, I would have expected a hot failure to exhibit a considerable degree of reduction at the fractured edge. There does not seem to be that feature here.

MESLOH: No, we did not metallurgically inspect the pipe.