OIL SEPARATOR EXPLOSION IN AN AIR-SEPARATION PLANT

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On Friday, August 18, 1961, at 9:15 a.m., an explosion occurred in a high pressure 2,500 lbs./sq. in. abs. nitrogen system installed in the air-separation plant of the Air Reduction Sales Co. at Acton, Mass. The violent fragmentation of a cast steel oil separator vessel heavily damaged the adjacent operating equipment. Fortunately, there was no loss of life.

This ruptured vessel was built according to code requirements. Calculations for this cast steel separator indicated it could be expected to rupture at 10,700 lbs./sq. in. Before details are given to show the preventative steps taken to avoid a recurrence of such an accident, a few brief words on the function of this equipment are pertinent.

Plant description

Air Reduction Sales at Acton has a basic air-separation plant for the manufacture of 75 tons of liquid per day (oxygen and argon). This unit also is capable of making liquid nitrogen in place of the oxygen. The usual appurtenances for argon are included. The main air for separation is compressed to about 90 lbs./sq. in. abs. and the water and CO_2 are removed by reversing exchangers. The refrigeration is supplied by a 2,500 lbs./sq. in. abs. closed nitrogen loop with a high-pressure expander and the usual low level refrigeration. This is designated as Unit 1.

Due to the increased nitrogen demand at this location, an addition to the air-separation plant was made. The waste nitrogen from the basic air plant is compressed to 130 lbs./sq. in. abs; then, caustic scrubbed for CO_2 removal. It is then chilled and dried and mixed with recycle nitrogen before admission to the third stage where it is compressed to 2,950 lbs./sq. in. abs. and 260 F. This compression from ambient conditions to 2,950 is by the use of a six-stage reciprocating oil lubricated machine. The nitrogen from the compressor enters a surge tank, then on to an aftercooler and a prechiller operating at approximately +40°F. The prechilled nitrogen then enters the oil separator (approxmately three feet high and eighteen inches in diameter). Here the excess oil is separated by manual operation. The nitrogen then enters an alumina filter for the removal of oil vapors before its passage to an exchanger, where the nitrogen is cooled by the exhaust from an expander operating between the pressures of 2,600 and 130 lbs./sq. in. abs. This precooled high pressure nitrogen is then expanded through a valve, and the liquid formed is directed to the low-pressure column as reflux. The vapors formed during this expansion are recaptured and used for cooling the parent stream. The original high purity reflux that was used for the low-pressure column is removed as product nitrogen. This is known as Unit 2. In summary, the waste nitrogen from the basic air-separation plant is used as reflux for the low-pressure column, and the original reflux is removed as product.

Cause of accident

The present opinion is that ignition of the lubricating oil started in the sixth stage cylinder of the compressor while the compressor was handling a waste gas containing 18 to 19% oxygen. Ignition was caused either by excess friction in the cylinder (as indicated by the condition of the cylinder and moving parts) and in addition, possibly, unbalance in the last stages which led to high compression ratios and excessive heating. This ignition started a "fire" and a simultaneous "explosion wave."

The explosion wave then progressed through the discharge piping, the surge bottle, the aftercooler, the refrigerated chiller and to the separator. An inspection of the visible internal parts of the system indicated very little, if any, presence of oil. This is a very unusual condition as these lines should normally have an oil film. The fact that there was very little oil present would bear out the progressive combustion theory.

Downstream of the oil collection in the sixth stage aftercooler separator end, the nitrogen oil separator bottle was the first point in the discharge piping where appreciably large quantities of oil and vapor could collect. The explosion wave, upon reaching the separator, ignited the vapors with explosive violence and shattered the separator bottle into more than 25 pieces. Of the several pipes and vessels downstream of the compressor sixth stage, the separator had the lowest rupture strength. In the aftercooler and the chiller, the tubes were bulged and ruptured. Possibly, the "explosion wave" also caused local detonations at locations where there were lube oil collections. The internal damage to the high-pressure nitrogen system is attributed to the explosion in the separator. It should be noted that some difference of viewpoint exists on whether a pool of oil is needed as a fuel source. Some are of the opinion that an explosion can occur if only a film of oil or oil vapor is present.

Prior to this incident, trouble had developed in the No. 2 Unit expansion engine and No. 2 Unit was partially shut down in a routine manner. The compressor continued to run with the output vented to atmosphere. About 5:00 a.m. the trouble was corrected and No. 2

Unit was again put in operation. During the shut down period, one of the operators heard an unusual noise like a "thud" or "grunt" in the compressor, but before he could investigate, the noise stopped and the compressor operation appeared normal. Also during this period, the oxygen analyzer recorder showed that the oxygen content in the waste nitrogen increased one time to about 25%. Adjustments were made and the oxygen content dropped to about 7%. Later it increased again to about 21.5% and had dropped to 19% at the time of the explosion. Previously, these oxygen concentration fluctuations were not considered abnormal during change-over periods, as the source of reflux to the low-pressure column was being switched from Unit 2 to Unit 1.

The physical damage to the plant was contained in the No. 2 Unit only. Within twenty-four hours, No. 1 was in operation; but it was not until October 24, or ten weeks later, before No. 2 Unit was ready for operation. The reasons for the delay were:

1. Compressor 6th stage and aftercooler repaired.

2. High pressure nitrogen chiller replaced.

3. Freon refrigeration system rebuilt.

4. Building and associated structural members repaired.

5. Electrical equipment and instrumentation in blast area replaced.

6. Outdoor equipment hit by fragments repaired.

Preventive measures

1. Oxygen Analyzer Controller at Compressor. Since in all oil explosions there is the suspicion that oxygen is a factor, an oxygen analyzer controller was

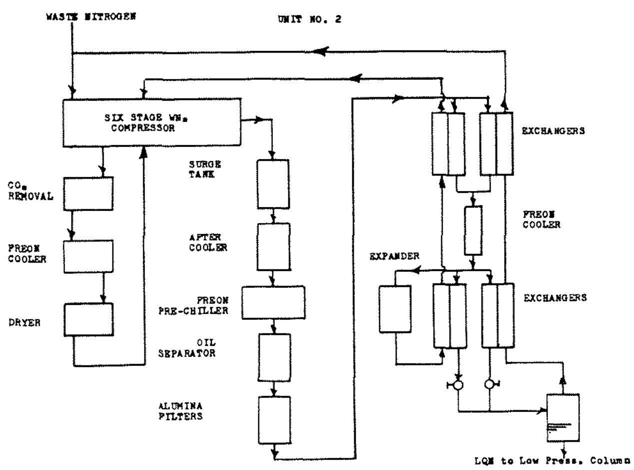

Figure 1. Simplified Flow Sheet.

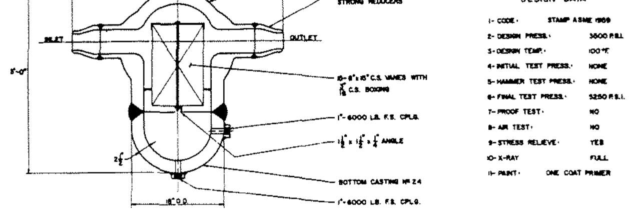

Figure 2. Drawing of Cast Steel Separator.

Figure 3. Remains of cast steel vessel, N-160 focal point of the explosion.

Figure 4. Remains of internal separator of vessel N-160.

installed at the inlet of the nitrogen compressor to monitor the oxygen. Automatic provisions were made to alarm at 2.5% oxygen and to shutdown the compressor if the oxygen content was above 3.0%.

2. Nitrogen Reflux Valve Modification in Unit No. 1. A high oxygen content in the waste gas may be due to malfunction in switching the reflux valves from Unit No. 2 to Unit No. 1 operations at the low-pressure (oxygen) column.

Instrument piping modification coupled with new operating procedures were made. When a switch-over from Unit 1 and/or Unit 2 operations is made, the nitrogen production is stopped. The product nitrogen is then used as reflux.

3. Analytical Testing—Reversing Exchanger Leakage. Strict control on periodic testing of reversing exchanger cores for core leakage. Leaks do occur and the high pressure air contaminates the waste stream with greater oxygen content.

4. Temperature Recorder—Compressor 6th Stage Discharge. For additional protection of the nitrogen compressor, a temperature recorder was installed at the sixth stage discharge. The alarm is set for 50 F above the normal operating temperature of about 260 F. Since there is the possibility of unbalancing the compression ratios in the different stages under certain operating conditions, an automatic control by-pass valve was installed between the sixth and third stages to keep the third stage inlet above 100 lbs./sq. in. abs. (During normal operations, recycle nitrogen

from the cold box is introduced at the suction of the third stage to maintain compressor balance.) In addition to the automatic bypass, a pressure alarm and a shutdown device were installed at the third stage suction.

5. Compressor Oil Blowdown Drains. Blowdown drains at all collection points for oil in the high-pressure nitrogen system were installed for periodic withdrawal.

6. Plate Weldment or Forged Steel Equipment. The cast steel separator was replaced by a plate weldment steel vessel. In all our plants, the cast steel vessels are being replaced. In the future, purchased equipment for this type of service and operation will be either plate weldment or forged steel. However, no inference should be drawn that tougher materials would have withstood this explosion without rupture.