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Nitrogen compression system explosion

Electrical failure initiated events leading to explosion. An oxygen analyzer, improved valving and alarm systems are new devices incorporated to increase operating safety.

Anhydrous ammonia is manufactured by Texaco, Inc., at the Lockport, Ill. refinery by the procedure illustrated on the flow diagram, Figure 1. Nitrogen is produced by air liquefaction and fractionation in a medium pressure air separation unit. Feed to this unit is atmospheric air which has been previously caustic washed and thoroughly dried in the warm purification unit. Hydrogen is supplied to the ammonia plant by two catalytic reforming units in the refinery. The reformer off-gas, which contains approximately 85 vol. % hydrogen with the balance being saturated light hydrocarbons, is successively scrubbed with solutions of monoethanolamine and caustic, then thoroughly dried prior to being introduced into the hydrogen purification unit. Hydrocarbon removal is accomplished in the latter unit by condensation at progressively lower temperature levels. Nitrogen is compressed, liquefied, and then used as a liquid wash to remove the last traces of methane from the hydrogen stream. A portion of the liquid nitrogen is flashed and leaves the HPU in the vapor state along with the hydrogen. More nitrogen is added to achieve the desired stoichiometric ratio of reactants prior to entering the synthesis unit. Anhydrous ammonia produced at conditions of high temperature and pressure in the synthesis unit is routed to pressure storage.

Reciprocating compressors with synchronous motor drives are used throughout this section of the ammonia plant. In some cases, notably air and nitrogen, a single multi-service compressor pumps both streams with adjacent, but not interconnected, cylinders. Three such machines operate in parallel to supply the full requirement of compressed air and nitrogen to sustain the process. In the event of a machine failure, the operation of the two low temperature units as well as the synthesis unit must be rebalanced in order to maintain satisfactory performance.

Explosion and damage

At 7:40 P.M. on February 1, 1962, an electrical failure occurred, resulting in the simultaneous shutdown of two of the three air-nitrogen compressors. The third compressor, due to reduced loading, continued to operate but the

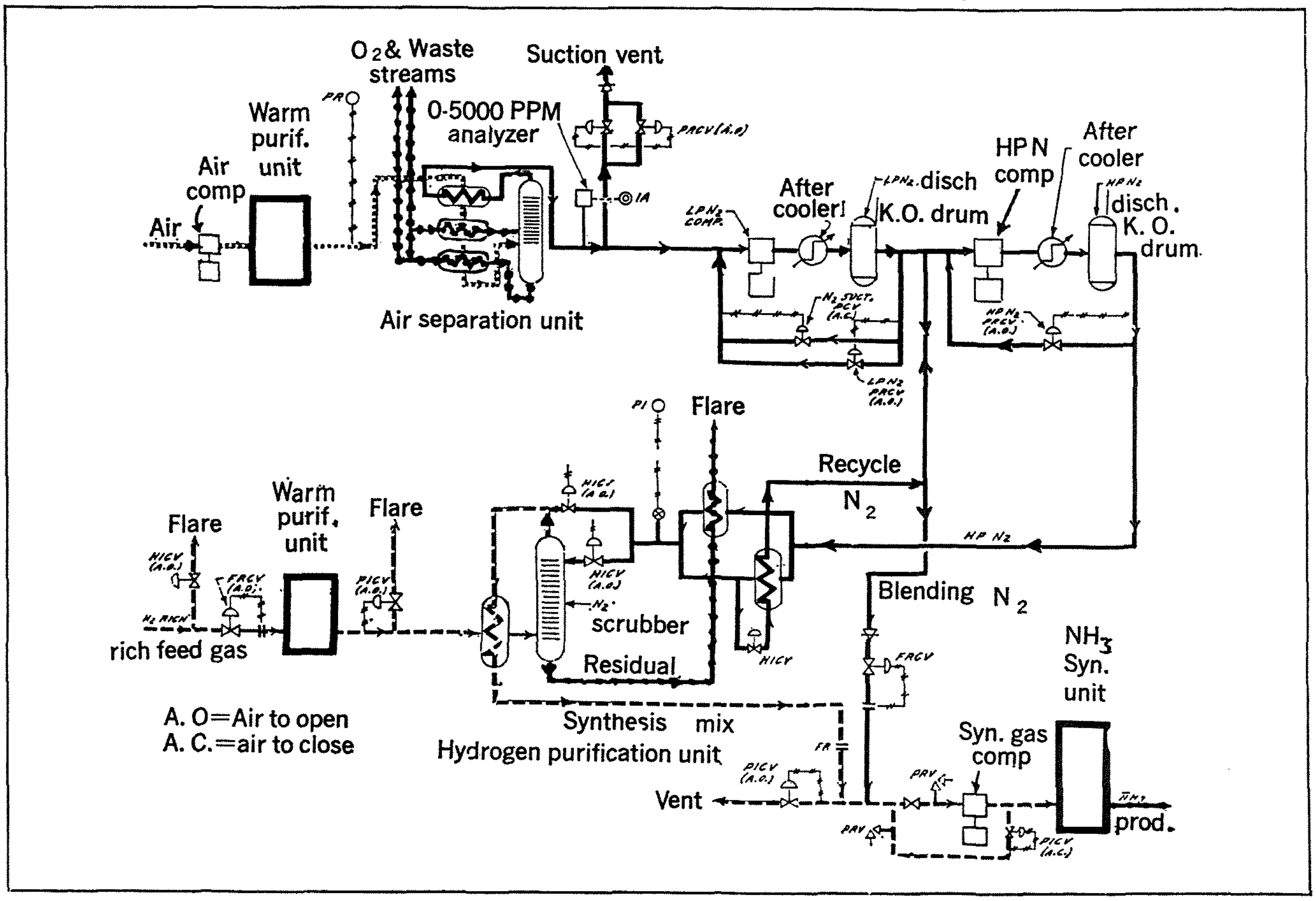

Figure 1. Process flowsheet for the anhydrous ammonia plant located at the Lockport, Illinois, refinery of Texaco, Inc.

supply of air and nitrogen to the process was sharply reduced. The synthesis unit and related compressors were immediately shut down when it became apparent that insufficient nitrogen was available to maintain the correct stoichiometric quantities of reactants to the converter. Operation of the two low temperature purification units was continued while an unsuccessful attempt was made to restart the failed machines. However, the operation of these units became unstable due to the sudden decline in air and nitrogen pressure and flow.

Under these conditions, the product nitrogen became contaminated with oxygen to a concentration greater than 1000 ppm which is full range on the low scale of the recording analyzer. This contaminated nitrogen was compressed by the single air-nitrogen machine remaining in service. However, the intermediate and high pressure stages of nitrogen compression were far below the normal operating pressures. This would permit hydrogen from the scrubbing tower in the hydrogen purification unit to backflow through the liquid nitrogen refrigeration system and a free expansion valve into the intermediate nitrogen compression system, which by this time was contaminated with oxygen. It appears that hydrogen ignition occurred in this system because the pressure was observed to rise suddenly. The compressor operator was starting to open a manual vent valve to relieve the pressure (which had not yet exceeded relief valve set pressure) when a detonation took place in the inter-

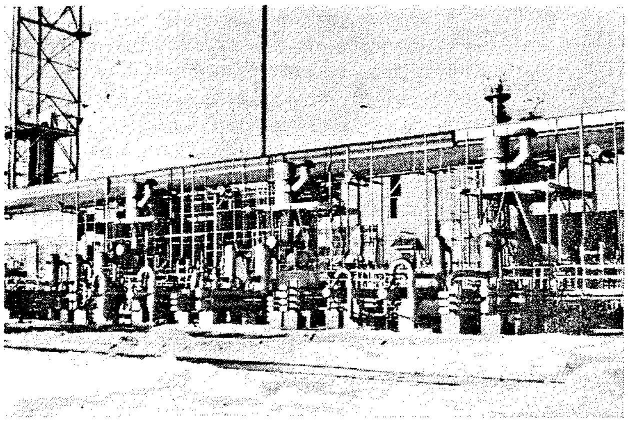

Figure 2. A broad view of the blast area, it being centered between and below the left two of the three air filters along the roof-line. Note the window and building siding blast damage extending clear to the end of the building at the right side of the photograph.

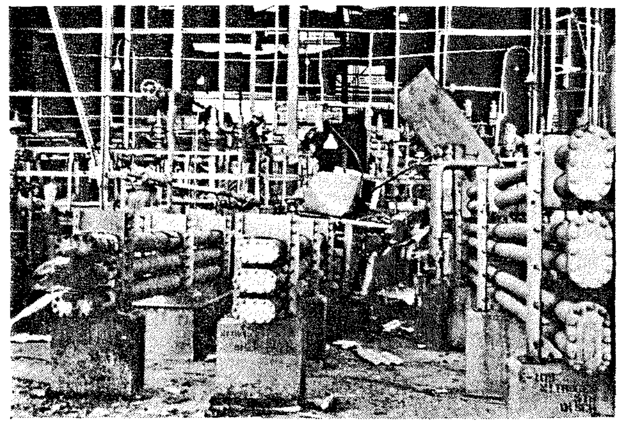

Figure 3. A closer view of the blast area, its center being just beyond the end of the exchanger in the center. Note the building siding and roof damage visible at the upper center, also the bent-upward steel plate beyond the exchangers on the right, such being part of an elevated walkway along the side of the building above the destroyed piping.

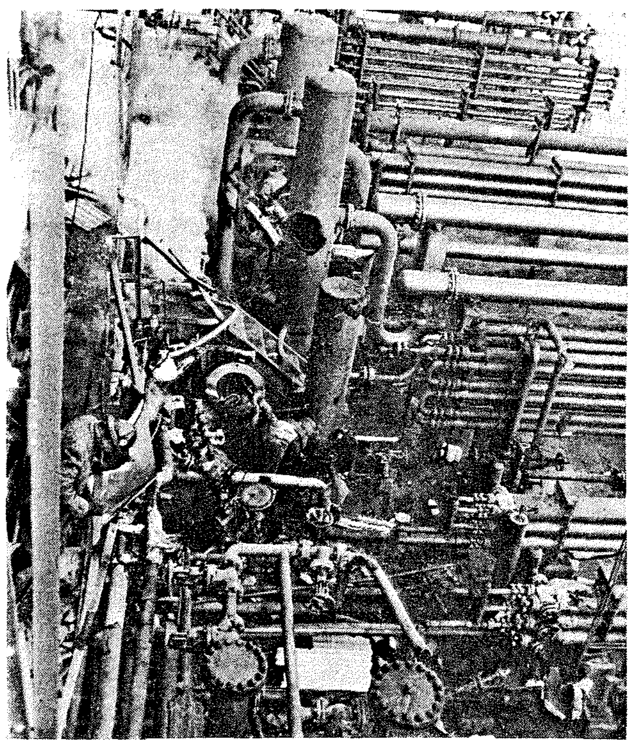

Figure 4. Overhead view of the blast area, the up-ended base of the destroyed drum is visible to the left of center. Most of the piping damage was from shock wave or concussion, with some shrapnel effects on it and on adjacent vessels, e.g. the punctured drum in the upper center.

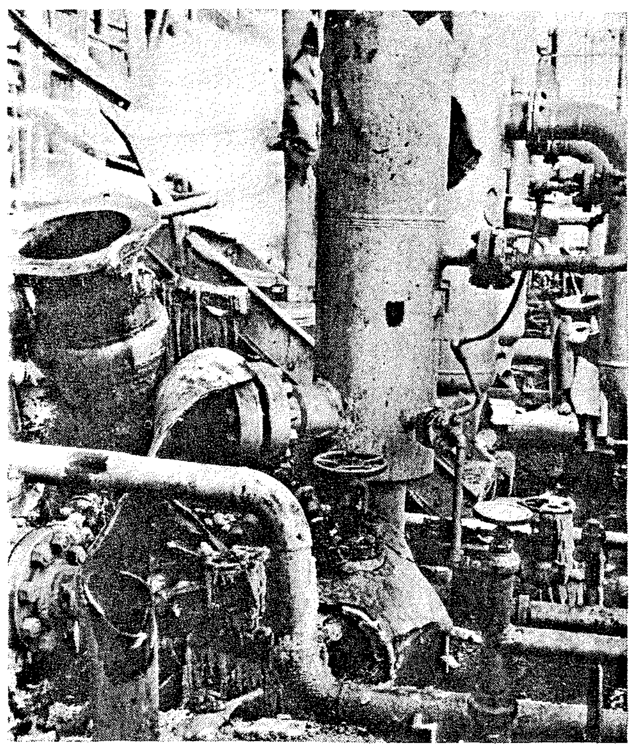

Figure 5. A close-up of the position of the up-ended base of the destroyed drum, seen in Figure 4. Its foundation had been the raised concrete section to the left of center at the bottom of the view, from which anchor bolts had been sheared.

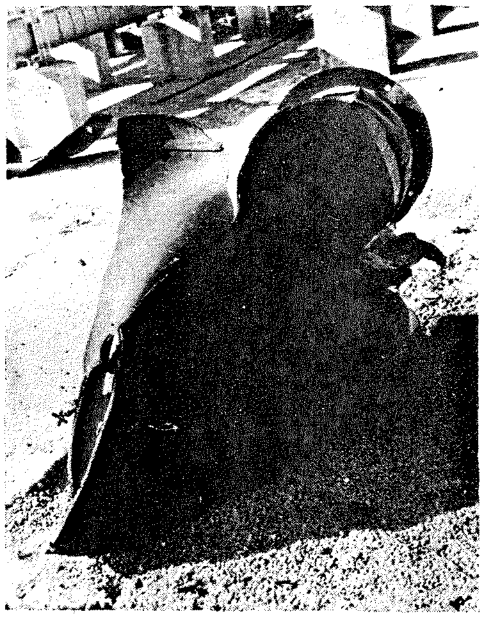

Figure 6. The base and part of the torn body of the destroyed drum, it having been removed to a clear area by this time. Its dimensions had been 20-in. O.D. by 8-ft. long, the wall thickness being 0.50 in. Although walls showed evidence of coked oil, there was still gummy oil in the base where the oily layer would have probably been thicker.

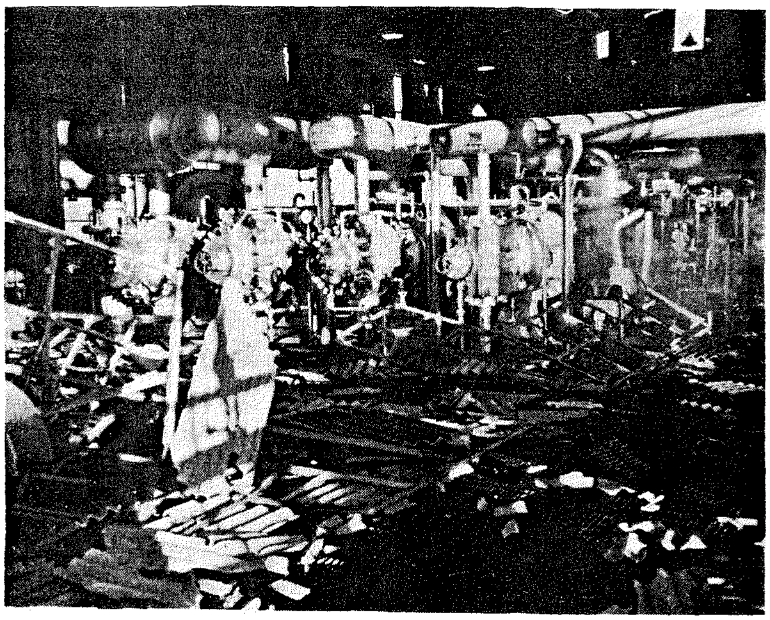

Figure 7. A view of the inside of the building, the center of the blast area having been just outside from the right side of the picture. Note the bent subway floor grating to the right of center, from the piping below the floor. Wire-glass windows immediately adjacent to the blast area were largely pulverized and as such were responsible for many of the face lacerations of the compressorman, who was standing just about at the right edge of the view, starting to open the compressor vent valve.

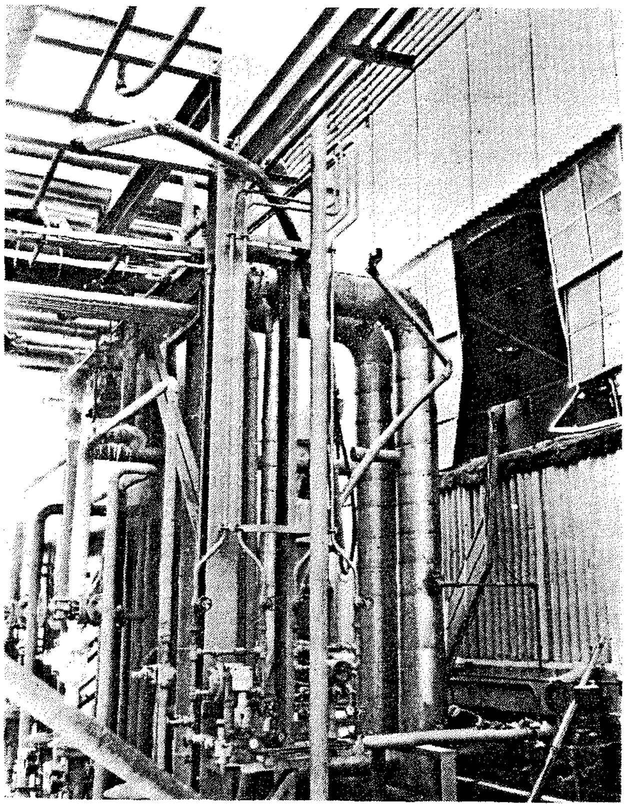

Figure 8. The typical damage in a 2 in., Schedule 40, carbon steel line from the destroyed drum, some 100 ft. away, the line damaged being the elbowed section in the right center. The upper end of the line had been connected by the ruptured 90° elbow to the horizontal run at the top which is bent backward over the I-beam support steel. The other bent, insulated, line is a steam line which got in the way of the other flailing piping.

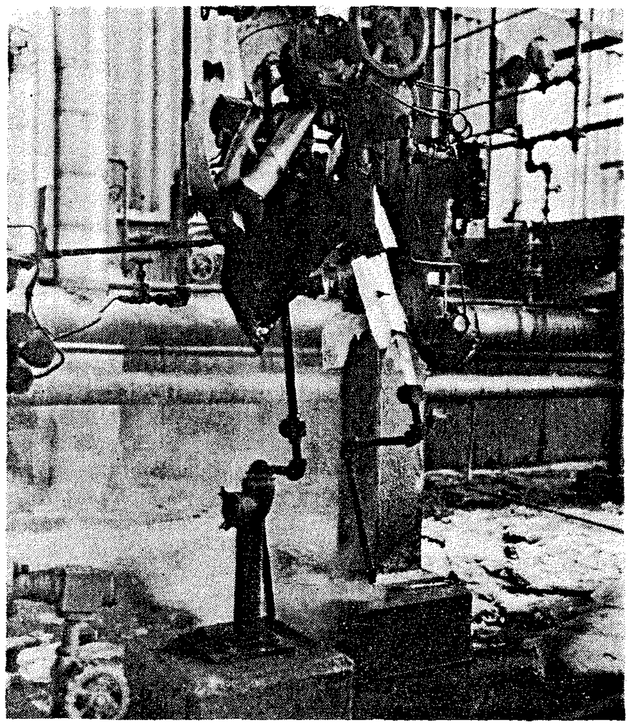

Figure 9. Another view of the damaged 2-in. line, some 80 ft. and the third elbow downstream. It was Schedule 40 stainless steel at this point, having been joined by a recycle nitrogen line from the low temperature unit. Note the flared, split, damage to the piping in the upper center, which had broken off the top of the elbow sitting on the pedestal below, as well as the line snapped off of the other side of the elbow. The furthest pipe breakage was a snapped-off nipple off the insulated 6 in. line in the right background, some 40 ft. still further downstream.

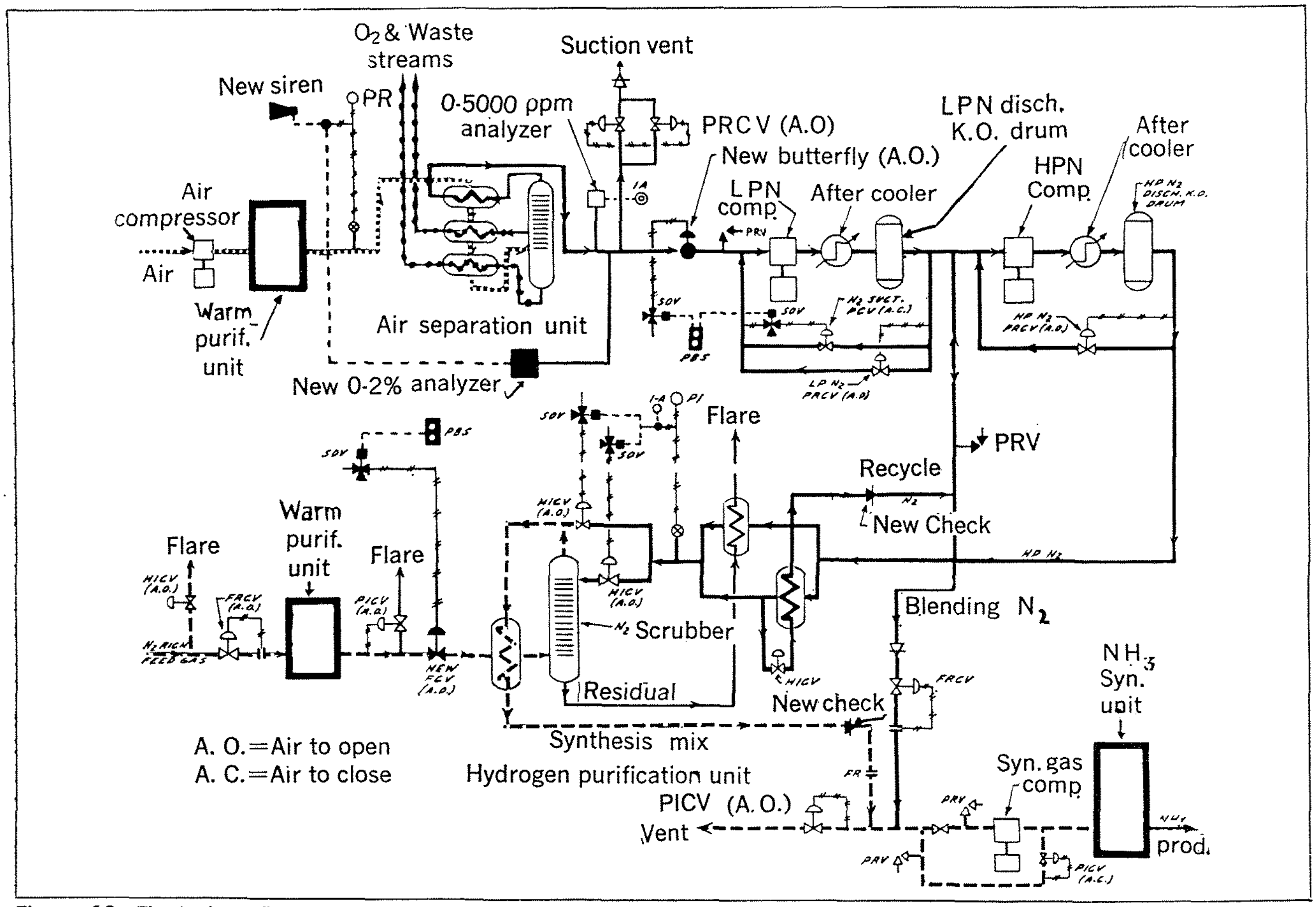

Figure 10. Final simplified-flow diagram of the anhydrous ammonia plant. The five new operating safety features added are indicated by the circled numbers which correspond to the description in the text.

mediate nitrogen oil separator drum and related piping. The time of the explosion has been fixed at 7:52 P.M.

Extensive damage was caused by the explosive burning and shock wave which had an estimated intensity of 2,000-3,000 lb./sq. in. There was also considerable damage due to concussion and shrapnel. Small fires were extinguished by plant personnel on the air-nitrogen compressor and an intercooler. The compressor operator suffered multiple face lacerations by flying glass; he has since recovered and returned to work.

Illustrative of conditions after the explosion are Figures 2 through 9.

Safety improvements to plant

Various additional safety devices have been incorporated into the process since the explosion. These have been added-in on the final flow diagram, Figure 10. The new safety devices incorporated are:

1. In the event that nitrogen pressure is lost, such as occurred prior to the explosion, the two air-operated valves which admit liquid nitrogen into the hydrogen system in the hydrogen purification unit would be closed. An alarm light would be activated to show the closing of these valves.

2. A new oxygen analyzer has been installed on the product nitrogen from the air separation unit. The original analyzer is a low range instrument normally used on the 0-1000 ppm scale although it also has a 0-5000 ppm high range. At an oxygen concentration of 2% the new analyzer will energize a new siren. The siren will also be sounded when the air pressure to the air separation unit drops below 100 lb./sq. in. gauge. Abnormally low air inlet pressure is a prelude to fractionation difficulties and oxygen contamination.

3. Upon hearing the siren or observing process instability, the controlman will close a new butterfly valve in the nitrogen suction line to the compressors, thereby diverting the air separation unit production to the vent. At the same time a kickback valve will open, permitting the intermediate nitrogen compression stages to recycle back to the suction. Installation of the butterfly valve isolated the compressor suction header from its normal relief valves and therefore new pressure relief valves were required between the butterfly valve and the compressors.

4. To provide a quick and positive shut-off of hydrogen feed gas in the event of a pipe or vessel rutpure in the hydrogen purification unit, an air-operated valve has been installed in the feed gas line to this unit. This valve is closed from a push-button station in the control room.

5. To minimize the effects of a compressor system explosion on the hydrogen purification unit internals, check valves were installed in the nitrogen recycle and synthesis mix lines from the unit. It is expected that these check valves would dissipate the shock wave caused by an external explosion. Since the check valve installation in the recycle line permitted its isolation from a protecting relief valve, a new pressure relief valve was installed on the intermediate pressure nitrogen system at the hydrogen purification unit. #

AUTHORS

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