DISCUSSION OF ENERGY RELEASE IN A LIQUID OXYGEN PUMP

W. Leonard Ball
Air Products & Chemicals, Inc.
Allentown, Pa.

Earlier this year we experienced an energy release in a liquid oxygen pump that resulted in considerable damage to the pump and a forced plant shutdown. As the pump and the service are not uncommon, a description of the incident should be of interest to this symposium.

At this plant a 10-stage vertical pump is utilized to take liquid oxygen from the reboiler overflow. The discharge at 450 lbs/sq. in. gauge is to the main air exchangers where the liquid is vaporized and discharged either to a storage bank or to the transmission line to the customer. For reliability the pump is spared and both pumps are installed in a single, insulated pump box. To minimize the time required to put the spare pump on stream in the event of failure of the pump in operation, the practice was to keep the spare pump in a state of cold stand-by. For the rest of this discussion, I shall refer to these pumps as "A" and "B" with the energy release occurring in "A".

Loss of pressure

The "A" pump had been in continuous operation for over two months until two days prior to the incident, when it was necessary to shut the main air compressor down for maintenance purposes. At that time the "A" pump developed a packing leak and when the plant went back on stream the "B" pump was put into operation. The day prior to the incident the "A" pump was defrosted and repacked. At about 1700 hours, the next day, it was put on cooldown which was completed at about 1900 hours. At that time the inlet valve was left open, the outlet valve was closed, the drain line from the bottom of the barrel closed, and a return line from the pump discharge line to the column was open. This was the condition of cold stand-by that would have been maintained until it was necessary to start the pump and put it on stream in place of the companion pump.

This condition was interrupted, however, less than five hours later at 2340 hours when the operator heard a noise similar to a heavy door being slammed. On approaching the pump box, the only outward sign of difficulty was the gradual loss of pressure on the "B" pump and the beginning of a frost spot on the jacket. On closing the inlet valve to the "A" pump, the pressure of the "B" pump returned to normal. The "B" pump and the plant continued to operate normally until the plant was shutdown a few hours later.

Combustion reactions damaging

Upon removal and disassembly of the "A" pump, damage was found to be internal to the pump with the exception of the bursting of the pipe and the body of the drain valve in the drain line from the bottom of the pump barrel. Combustion reactions had occurred between the flanges holding the barrel to the suction head, and around the bolts holding the two halves of the volute case together, the bolts holding the bottom bearing housing to the case, and the bolts holding the case to the bottom flange of the suction head.

The largest reaction had occurred between the flanges of the barrel and the suction head. Here the metal clad asbestos gasket had been burned in two and gouges one-quarter to one-half inch deep had been flame cut into the faces of the flanges in two places. The burned areas covered about one-quarter of the face of the flanges.

Volute case damage

The burned areas around the bolts of the volute case were most interesting. These areas centered around the bolt holes and spread outward in a diminishing pattern. In two instances the reaction had reached the outer edge of the flange and had scorched the opposing inner surface of the barrel. This type of reaction had occurred at 12 of the volute case bolts and at the four bolts holding the bottom bearing housing to the volute case and none of them was interconnecting; each had been a separate and distinct reaction.

The unsupported halves of the case wear rings had been forced in all instances toward the next lower stage. The degree of distortion of the ring between the ninth and tenth stages was the greatest, and the degree diminished progressively counting back to the first stage. This gave a very definite indication that the highest pressure had occurred either in or downstream of the tenth stage. The fuel for the reactions was not hard to determine as free oil was found on all the flange surfaces mentioned as well as a light film on the outside of the case. As the pump had been thoroughly cleaned and inspected prior to original installation, this oil had accumulated during operation.

Reconstruction of events

From the facts noted above, we reconstructed what we believe to be the most likely sequence of events as follows:

1. The initial reaction occurred at the liquid-gas interface in the annular space between the pump barrel and the volute case. As the outlet from the barrel is eight to ten inches below the flange to the suc-

tion head and the pump had not been operated, the assumption that a gas pocket existed in this portion of the annular space is reasonable. There was motion here because of boiling liquid and possibly enough kinetic energy for the ignition of oil particles floating on the liquid surface. The only other part of the pump where there was possible kinetic energy was a leak between the flanges of the suction head and the barrel. The existence of this leak was evidenced by frozen insulation about 180° around the circumference of the flanges. As this flange interface connects into the annular space between the barrel and the case, original ignition here also fits into the general sequence of events discussed below.

2. A hydraulic ram effect caused by the original combustion resulted in the failure of the drain valve and piping. There was no visible evidence of ignition in this piping.

3. This hydraulic surge, as it entered the discharge of the case and passed through the volutes, caused the distortion of the case wear rings in a decreasing degree from the tenth stage backward toward the first stage.

4. The pressure wave created by the original combustion caused the flanged faces of the volute case (and also the flanges between the suction head and barrel if the original ignition was at the liquid surface) to separate slightly. Bolt tension brought the flanges back together again with sufficient force to ignite the oil accumulations between the flange faces. This is the only way we can explain the fact that the only evidence of burning was between flange faces and there were at least 17 distinct and separate areas where combustion had occurred.

Cold stand-by discontinued

In reviewing the incident and prior operating procedures, the cold stand-by procedure was immediately noted as a means of concentrating contaminants in the pump. The cold stand-by procedure described earlier was discontinued and several alternate methods are being studied.

1. The pump may be cooled down and left filled with liquid oxygen but a continual purge bled off from the bottom drain. This very evidently is expensive with respect to refrigeration and liquid oxygen, but requires no additional piping.

2. A system being installed for test purposes involves wrapping a coil around the pump barrel and refrigerating the unit using liquid nitrogen. We do not yet have data to indicate the effectiveness of this system.

3. A third system that has been proposed is to flow nitrogen gas through the pump. Cold waste nitrogen could be taken from the top of the low pressure column, for instance, and then vented to the atmosphere.

As the oil in the pump was identified as coming from the main air compressor, the solubility of oil in liquid oxygen appears to be the key to the migration of the oil through the plant. The lubricant, however, decomposes to some degree in the compressors. The lack of predictability in the composition and the molecular weight of the breakdown products greatly complicates this study. Another complication to the study is the analytical techniques required for a study of this type of contaminant. One part per million appears to be the lower limit of present techniques and this level appears to be the upper limit of the desired study.

In addition to the change of cold stand-by procedures and the study of solubility, we have also placed all of this type of liquid oxygen pump on a one year inspection and washing program. This frequency is lowered as necessary if the plant history warrants such a change.

Questions and answers

Q. Did you find a similar oil deposit in the other pump, the one that did not blow up?

BALL—Yes. There was a similar deposit in the other pump, not to the degree that we did find in the pump in which the reaction occurred.

KARWAT—Linde Co. (Germany). The explosion probability and the sensitivity to mechanical impact of oil deposits in liquid oxygen have proved the greater the thinner the oil film. However such impacts must be very strong ones. After ignition with a primer cup a very thin oil film on copper-wool or glass-wool explodes with the same, violence like acetylene. On the other side there must be remembered the fact that in former times (20 to 50 years ago) when air separators were fed from oil-lubricated compressors, nearly each separator was greatly contaminated with oil, whereas due to the absence of sufficiently strong impacts no oil explosions were observed but acetylene explosions accompanied by oil decomposition.

WALTON—Sun Olin. I'm not trying to second guess you on your analysis here, but how sure are you that the bolts and the threads on these items were thoroughly degreased? I mean, to me it seems rather strange that the oil had intruded with the oxygen, moved to the location of the bolts that hold the case together and the places on the piping where you did have joints there. I just wonder how sure are you that these were thoroughly degreased?

BALL—In this case we're quite sure that this was a clean pump because some time previous, 18 months to 2 years prior, we had had a reaction at the bolts on a different pump and at that time we felt that they were not degreased and cleaned before the unit was put into operation. We inspect and clean our own units before putting them into the plant itself. In this case we are quite sure that the pump was cleaned and that these particular areas were clean.

Q. Dr. Karwat suggests that oil is a common thing in liquid oxygen. I think we should clearly understand that there are many different cycles for producing the oxygen and I assume his remarks apply to these cycles which use high pressure air which are delivered to the air separation plant from a reciprocating compressor.

It is hard to imagine that oil could enter into the unit, the air separation box from a low pressure cycle which uses only a centrifugal compressor. And of course this is one of the advantages of that type of a cycle.

KARWAT—My remarks should be understood so that only small apparatuses of the classic systems are meant.

Q. What type of lubrication do you use on the primary compressors?

BALL—The oil that we found in this pump was positively identified as water soluble lubricants coming from the first stages of the compressor. We have found, that because of the breakdown of the lubricant in the compressor, decomposition products accumulate which do give us trouble in the water wash sections.