AIR SEPARATION PLANT FIRE

J. J. Rendos
Air Reduction Sales Co.
Jersey City, N. J.

On Wednesday, March 6, 1963, at 11:08 A.M. an explosion occurred in an oxygen circulating pump and connecting piping. The resulting fire involved refrigerating and associated equipment. This accident was caused by the ignition of combustible contaminants in the oxygen pump and connected piping. The source of ignition is unknown. The violent fragmentation of the cast-bronze pump body and associated equipment caused considerable damage and personal injury. The ruptured pump and associated pipe equipment were built according to code requirements. The violence of the explosion was such, that piping, pump parts, and cold box panels were ruptured.

Plant modifications

This plant manufactures liquid oxygen, nitrogen, and argon in addition to pipeline oxygen and nitrogen. Due to the increased argon demands, a modification was made to the primary air-separation column of one of the units. This consisted of adding more rectification plates between the argon attachment and the reboiler. This secondary column was so installed that it was necessary to take liquid oxygen from the present (low pressure) primary column and to pump the liquid to the newly installed column, Figure 1.

Oxygen reflux pump start-up

Four employees were engaged in starting up the liquid oxygen reflux pump on Unit No. 3 after an eight-day shutdown for maintenance and derime. The function of this reflux pump was to transfer liquid oxygen from the bottom of the primary oxygen column to the top of the secondary oxygen column.

The oxygen reboiler, reflux pump, and associated piping were last washed (using chlorothene) on March 20, 1962. Unit No. 3 was shut down on February 26, 1963, for maintenance work and derimed on March 5. After a complete derime, the column was cooled and had been running for 16 hr. when the procedures for starting up the secondary column by the use of the oxygen reflux pump began.

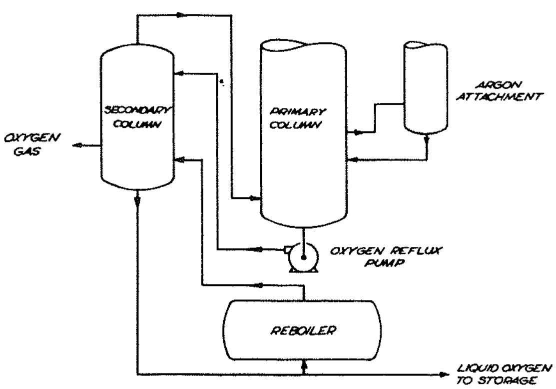

Figure 1. Simplified flow sheet.

The reflux pump shaft was free when the liquid oxygen inlet valve to the pump was first opened. However, the pump froze and could not be started. The inlet valve was closed and the pump bowl heated externally. This was accomplished by applying steam to the bowl of the pump. The steel panel and the insulation from the west side of the pump were removed for this procedure. When the pump shaft could be turned by hand, one of the men, who was standing on the west side of the pump housing, started to reopen the oxygen liquid inlet valve slowly. The oxygen gas vent valve and the outlet liquid oxygen valve were already open in preparation for starting the pump. Before the pump was started and when the inlet oxygen liquid valve was opened, an explosion occurred.

Explosion damage

The inlet, outlet, and vent lines within the insulated pump housing, as well as the 4-in. inlet line inside the cold box leading from the bottom of the primary oxygen column to the pump impeller casing, ruptured from an internal explosion. The impeller casing explosion blew several pieces through the end steel insulation panel. The violence of the detonation, Figures 2 to 7, forced the vertical pump shaft upwards with sufficient momentum to break loose the motor and

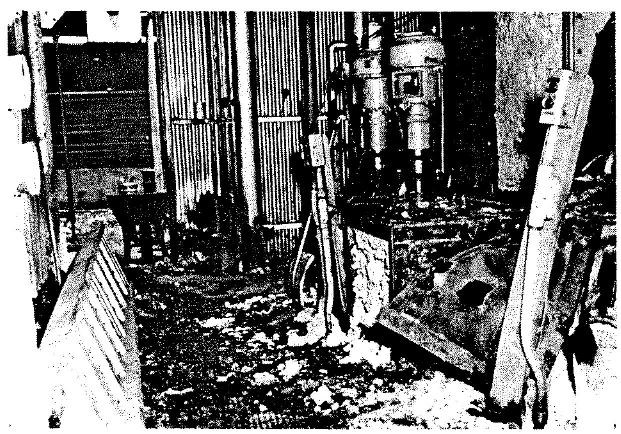

Figure 2. View from northwest corner of liquid oxygen reflux pump casing-floor level.

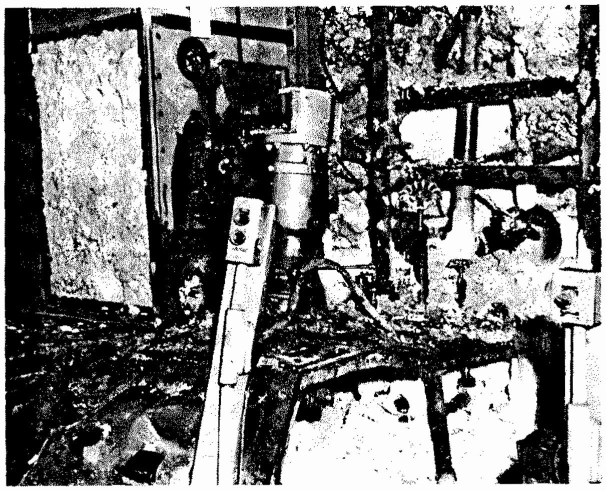

Figure 3. Close-up view of liquid oxygen pump installation.

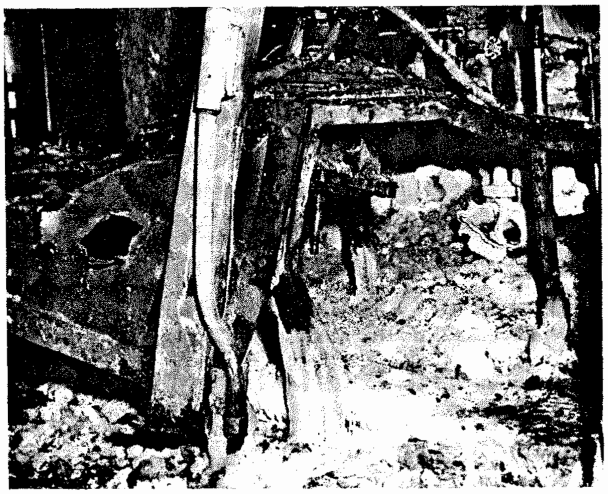

Figure 4. Close-up view of lower section of damaged pump area.

Figure 5. Overhead view taken from catwalk over Freon system of liquid oxygen pump area.

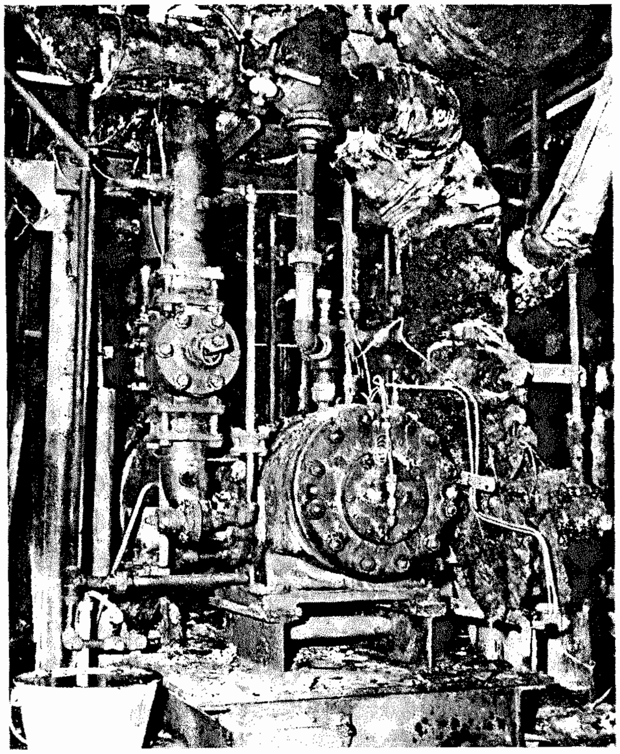

Figure 6. View from southeast corner of Freon system.

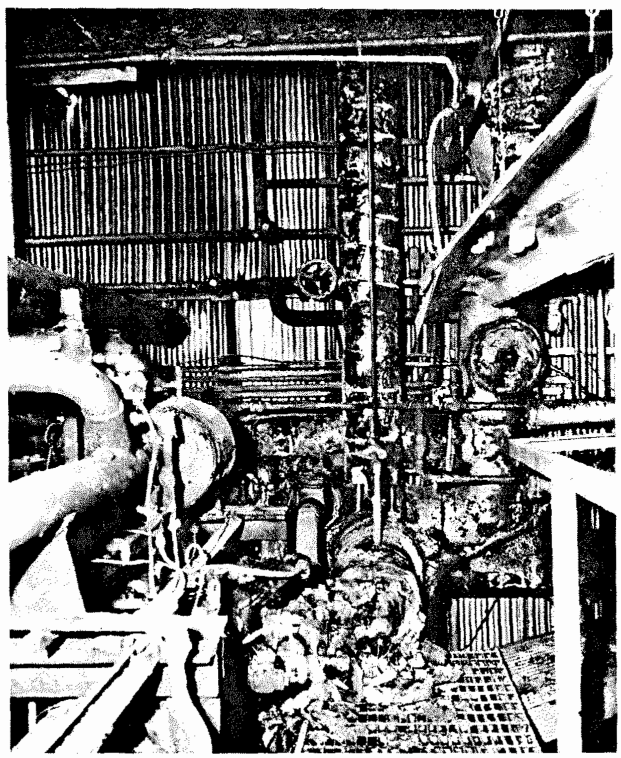

Figure 7. View from catwalk of fire damage to upper section over Freon unit.

casing on top of the shaft mount, throwing the motor 25 ft. to an overhead platform above the refrigerating equipment.

The pipeline explosion blew the panels from the east side of the pump housing and from the side of the cold box immediately in front of the pump. It also blew rock wool and fragments of the three pipelines around the area. This started an oxygen-fed fire at the refrigerating equipment several feet in front of the pump. The fuel was a mixture of Freon 12 (dichlorodifluoromethane) CCl_2F_2 and lubricating oil. Evidence of burning at the copper braid covering of the ruptured flexible hoses indicated that some combustibles were present in the hose lines.

Internal explosions

The damage was apparently caused by internal explosions:

1. in the 4-in. and 3-in. copper lines at the bottom of the primary column to the oxygen reflux pump,
2. in the pump impeller casing,
3. in the oxygen reflux pump line to the secondary oxygen column,
4. in the vent line branching from the inlet line, and
5. in the baffle-support pipe stiffener in the oxygen reboiler.

The series of coincidental ruptures in the pump and oxygen lines indicated that a detonation had occurred and that the pump and piping contained appreciable quantities of combustible in contact with the liquid oxygen. The combustible was probably lubricating oil which had accumulated in the system over an 11-month service period and that had been left, after the derime, in a plugged sump in the base of the pump impeller casing and in the crevices of the bellows-type flexible hoses which had been installed with their axes horizontal.

Source of ignition

The source of ignition could have been violent turbulence in the base of the pump caused by cold liquid meeting a warm heavy metal pump casing. Any liquid that reached the pump would boil violently because of the high heat capacity of the heavy metal parts. Although oil by itself would not be expected to ignite in liquid oxygen, even when violently agitated, the presence of solid acetylene could sensitize the oil to ignition by turbulence. The column had just been derimed. It would not be expected to show accumulations of acetylene above the solubility limit in the liquid so soon after a derime. The other three units, which were tested for acetylene before they were restarted after the explosion, showed no acetylene except for the usual trace in the scrubber.

There is a remote possibility of chlorothene, which is combustible in oxygen, being present but the probability is so low that the possibility is not worth considering. It seems reasonably certain that lubricating oil was the sole combustible. The pump casings on the oxygen transfer pumps showed lubricating oil when disconnected and inspected internally after the explosion and fire. Also, some unbrazed sections of lapped joints, in the silver brazed copper inlet line, showed evidence of explosion inside the lap joint where oil had probably collected. When the outer female copper joint bulged, the inner or male connection bulged inwards tearing open the silver brazed joint revealing unbrazed areas which had not been thought to exist. Some unconsumed oil was still noticeable in one area inside the ruptured pipe.

Probable cause of explosion

1. The internal explosion in the pump and associated piping was probably caused by the rapid combustion of lubricating oil that had collected since the last washing period, March 20, 1962, and that had not been removed by the deriming operations (March 5, 1963).
2. The oil accumulation was trapped in the convolutions of the bellows-type flexible hoses, mounted with axes horizontal and in the plugged sump in the pump bowl.
3. The cause of ignition is not known although it might have been turbulence in the hot pump when admitting liquid oxygen possibly sensitized by the presence of frozen acetylene.

Corrective action

1. (a) The cold box oxygen transfer pumps similar in construction and service to the oxygen reflux pump will be cooled and inerted with liquid nitrogen before using them in liquid oxygen service.
   (b) Before doing any maintenance work on the trasfer pumps, such as, thawing or repairing, the liquid oxygen pumps will be inerted with liquid nitrogen.
2. Drains will be provided in all oxygen transfer pump bowls in the boss at the center of the casing. This is the low point.
3. In the future, all flexible hoses in liquid oxygen service will be installed with axes vertical.
4. The combustibility hazard of Freon 12 refrigerating equipment will be examined to determine need for less exposed positions or for automatic sprinkler protection.
5. All plants will be equipped, in the engine rooms and need cold boxes, with large fire hoses connected to a suitable source of water. These hoses are to be equipped with fog nozzles. This accident proved once and for all the advisability of installing such equipment in the engine room. The damage would have been many times as great were it not for the hoses and fog nozzles supplied to this plant.
6. All air separation unit cold box equipment will be solvent washed so long as oil lubricated compressors are used.
7. In Unit No. 3, the following procedure was followed in the main cold box to eliminate the oxygen reflux pump:
   (a) Isolated secondary oxygen column.
   (b) Connected oxygen column reboiler to the primary oxygen column.
   (c) Blanked the derime valve to the primary oxygen column.

DISCUSSION

RENDOS: At the time that this facility was constructed, there were no centrifugal compressors being manufactured below the 8 to 10,000 std. cu. ft./min. range. Since this plant unit operates on 6,000 std. cu. ft./min. of air at 90 lb./sq. in. abs. provided by an oil lubricated compressor, provisions were made to scrub the incoming air with liquid air. The high pressure column has a scrubber built into it for this purpose. This unit removes the oil as well as the air contaminants. We are certain of the scrubber operation because of the considerable testing done in the field and also in our laboratory. The vapor from the top of the scrubber is clean with total contaminants in the low ppm range. It is during defrost that we have been putting oil into this separation unit.

BULKLEY—American Oil: I was interested in your comments on the aluminum valve that exploded when it was scratched during cleaning. Would you amplify a little on that?

RENDOS: The test facilities at an Eastern University were very clinical in preparing the equipment for missile component testing. One of the aluminum valves was being disassembled for cleaning with carbon tetrachloride. During this procedure—when the valve was being cleaned with a scraper and carbon tetrachloride—the valve "took off." I have no further information.

BULKLEY: I think this is a rather interesting point because this is at least the third or fourth incident that I'm aware of where explosions have occurred when the nascent metal is exposed by scratching. Cook, at the University of Utah, repeatedly initiated detonations in hydrogen-oxygen mixtures by opening a valve. He later found that it was necessary that the valve have a somewhat rough surface so the seat was scratched as it opened. He could do this reproducibly. At our Whiting refinery, we believe that one serious detonation accident was initiated by merely opening a valve.

RENDOS: The reason I brought this story of the aluminum valve to your attention is that you people operate plants with aluminum exchangers and other aluminum components.