G. T. Wright
Dominion Foundries and Steel Ltd. (Canada)

Oxygen plant vaporizer explosion

An analysis of the causes led to plant changes for improving safe operation.

High purity oxygen supplied by three units with a total capacity of 350 tons/day is required by the Dominion Foundries and Steel, Ltd. for producing steel. At 8:10 P.M., September 30, 1959, the vaporizer in No. 2 unit exploded, wrecking the vaporizer and surrounding parts of the cold box, Figures 1 and 2. No one was injured and production loss was minimized because the No. 3 spare 150 ton unit had gone on stream three weeks earlier.

Plant description

The No. 2 plant is a 100 ton/day split cycle-type. The intake air is filtered through a 10-ply paper filter and then compressed to 75 lb./sq. in. gauge in a turbo compressor. It is water scrubbed to remove soluble impurities. Two thirds of this air passes through aluminum-filled regenerators, then into the high pressure column. The rest of the air is compressed to 350-550 lb./sq. in. gauge, goes through caustic scrubbers, heat exchangers, then through an expansion engine, and into the high pressure column. Rich liquid, produced in the high pressure column, then passes through silica-gel filters into the low

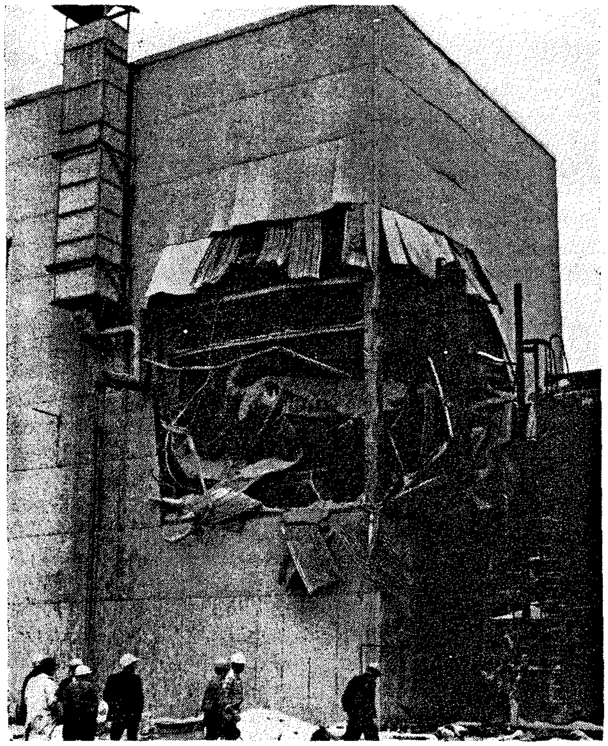

Figure 1. Damage to plant before any repair work was started. Vaporizer displaced from normal position can be seen in foreground.

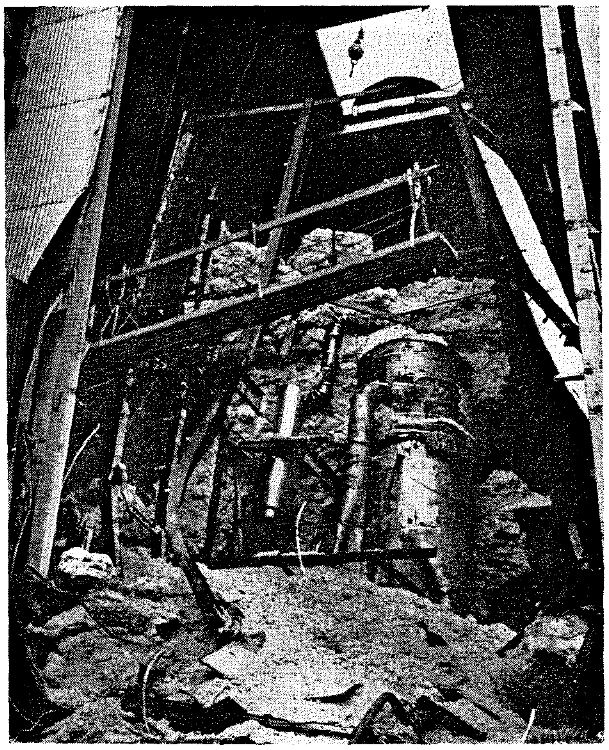

Figure 2. View of plant after cleanup commenced shows the low pressure vessel (dented) in the foreground.

pressure column where further rectification takes place. Liquid O_2 is then pumped to the main vaporizer which is flanged on top of the high pressure column. Gaseous O_2 is withdrawn from the vaporizer through heat exchangers to reciprocating compressors.

The vaporizer is a vertical shell and tube unit about 5 ft. in diameter and 25-ft. high. It is a falling-film type and has 1600 ¾-in. copper tubes in a stainless steel shell. These tubes project 6 in. through the top tube sheet and are slotted to distribute the liquid O_2 around the inside periphery of the tube. N_2 at 65 lb./sq. in. condenses on the outside of the tube and boils the O_2 inside.

The plant started in August, 1956, and was derimed in November, 1956, because of mechanical trouble with the main blower. It operated continuously until April 23, 1958, when a minor explosion occurred. At this time the booster compressor stopped momentarily, and after start-up, the O_2 purity was very low. Subsequent examinations showed one vaporizer tube had ruptured.

Explosion at 8:10

On the day of the explosion, the wind had blown 5 to 15 mi./hr. from the direction of our coke oven battery and rain had fallen in the afternoon. At about 5 P.M. the flexotimers, which control the reversal of the regenerators, stuck, and one regenerator warmed up at the mid point from

Figure 3. Close-up of tubes in vaporizer and bottom tube sheet at right. The line of detonation can be seen to be approx. 6-8 in. above the tube sheet.

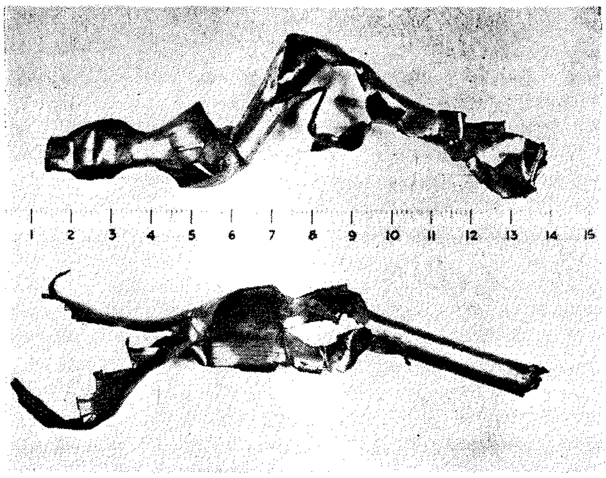

Figure 4. A close-up of an individual tube shows a fracture characteristic of acetylene explosions.

−150° to +60°. This also lowered the liquid levels in the low pressure column. After 28-33 min., the regenerators began reversing and the liquid levels began building up. At 7:30 the plant was operating more or less normally until 8:10, when the explosion occurred.

Approximately 30 tubes in the vaporizer burst 6 to 8 in. above the bottom tube sheet, Figure 3. The force of the explosion ruptured the stainless steel outer shell and blew out the side of the cold box and building closest to the vaporizer.

An independent research organization, The Ontario Research Foundation of Toronto, was given the job of studying the data to try and determine the causes of this explosion and the previous tube detonation in 1958.

Judging from the appearance of the fracture of the tubes, Figure 4, the explosion was apparently caused by an accumulation of hydrocarbons in the vaporizer, probably C_2H_2, which was triggered by the warm up of the plant.

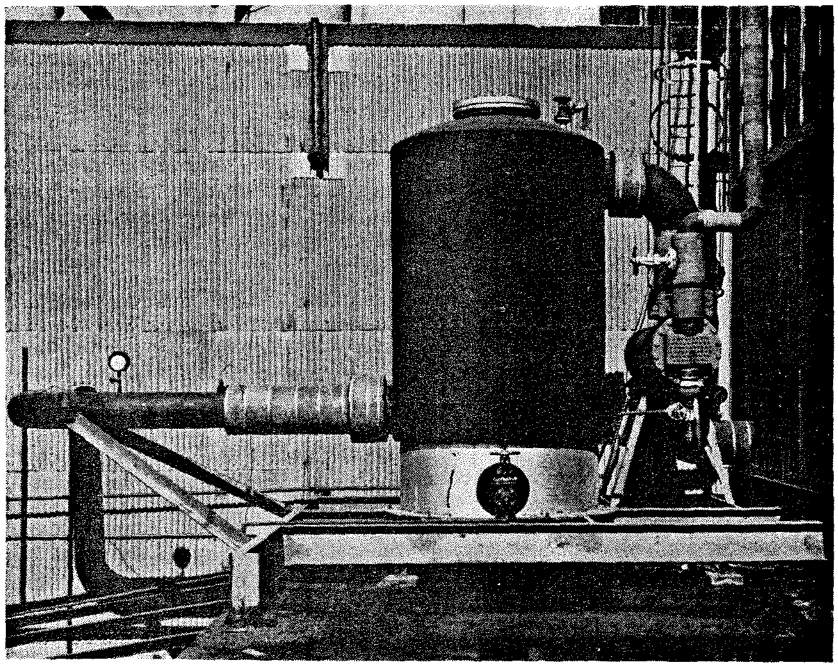

Figure 5. Catalytic filter installed on No. 2 plant. Air is heated 320° by the steam heat exchanger at the right.

Causes of the explosion

The following factors contributed to the explosion:

1. The warming up of the regenerator released hydrocarbons which would go into the high pressure column. A subsequent analysis of the derime exhausts from the regenerators of No. 1 plant showed that large volumes of CO_2 would also pass into the high pressure column. The warm up of the regenerator also caused the temperature of the vaporizer to fluctuate.

2. The foundation of the cold box had previously heaved from frost, and caused the vaporizer to be pitched away from the side where the explosion took place. It is possible this caused some tubes to be starved of liquid.

3. The wind was very gentle and from the direction of the coke ovens. It is probable that a higher than normal level of contamination existed.

4. A freshly regenerated rich-liquid filter had been put into service 12 hr. before the explosion. This Sovabead showed traces of C_2H_2 on the inlet side of the filter, but none on the exit side.

5. Because of production requirements, the plant had been on stream for 17 months which is longer than usual.

6. The contaminants after each unit in the plant in normal operation were checked, Table 1. Everything was normal and the silica-gel filter was removing all the C_2H_2 from the rich liquid.

7. An air pollution study indicated there were several sources of contamination in the district. The most critical was Dofasco's battery of 105 coke ovens.

8. In spite of the fact that some intake contamination was evident, no positive C_2H_2 test had ever been recorded after the rich-liquid filters. A test of the rich-liquid filters on the No. 2 and No. 3 plants after one month's operation showed less than 0.2 g., Table 2. This indicates the rich-liquid filters were operating at 99% efficiency.

Plant safety changes

The following changes were made to improve the operation of the plant and prevent any further explosions:

1. Alarms have been installed on the three plants to warn the operator should the regenerator temperature go above −50°. The plant will be shut down should this occur.

2. An auxiliary vaporizer has been installed in the No. 2 plant which can be derimed without shutting down the main plant.

continued on next page

G. T. Wright is Mechanical Superintendent of Dominion Foundries and Steel, Ltd., Hamilton, Ontario, where he has worked in maintenance and engineering since 1939. His department is responsible for the mechanical maintenance of the plant and generation of steam, compressed air, and oxygen. Wright received a B.Sc. in Mechanical Engineering from Queens Univ., Kingston, Ontario. He is a member of the Association of Professional Engineers of Ontario.

Table 1. Acetylene contaminant levels in plant operation.

Location	No. 1 Plant	No 3 Plant
After compressor	0.026 ppm	0.024 ppm
After catalytic filter	no filter	0.015 ppm
After water scrubber	0.032 ppm	0.013 ppm
After regenerator	0.028 ppm	0.015 ppm
After exchanger		0.055 ppm
Bottom of H.P. Col.	0.12 ppm	0.051 ppm
After rich-liquid filter	0	0
Bottom of L.P. Col.	0	0
After liquid O_2 filter	0	0
Vaporizer	0	0

Table 2. Contaminants on the rich-liquid and liquid oxygen filters in No. 2 and No. 3 plants.

	Rich-liq. filter		Liquid O_2 filter	
	No. 2	No. 3	No. 2	No. 3
NO_2, g.	1.1	0.27	<0.015	<0.04
N_2O, g.	<200	700	700	900
CO_2, g.	1500	4500	130	600
C_2H_2, g.	52	0.46	<0.01	<0.18
Hydrocarbons, g.	<80	120	1000	600

3. The capacity of the liquid O_2 pumps has been increased 25% to give more liquid for flushing the vaporizer tubes.

4. The heaved foundation was replaced with a ventilated slab to prevent frost heaving.

5. M.S.A. catalytic filters have been installed on all three plants, Figure 5.

6. Activated alumina driers were installed in place of the lump caustic desiccator. This will give a lower dew point going into the warm-exchangers and act as an oil filter on the discharge of the booster compressor.

7. An additional silica gel filter has been installed on the discharge of the liquid O_2 pumps.

8. The cold box has been simplified with the removal of an argon column and the installation of stainless steel purge lines instead of carbon steel piping.

9. The cold box casing has been made air tight and continuously purged with N_2.

10. Level recorders have been installed on the separator after the auxiliary vaporizer and low pressure column. Warning lights indicate abnormal levels.

11. A deriming schedule of 9 months has been set for No. 1 and No. 2 plants, and 12 months for No. 3 plant. The No. 3 plant can operate longer safely because it has 100% product purge and has consistently operated at a lower hydrocarbon level.

#

Questions and answers

HEPP—Sun Oil Co., Marcus Hook, Pa.: I couldn't help but think of the similarity between this explosion and our own of four years ago. The damage to the reboiler is remarkably similar. We reached a little different conclusion, I believe, about these damaged tubes. We found a lot of tubes that were split open, and in our case where we had a long enough reboiler, there were a number of tubes which had more than one opening per tube. These were very equally spaced (about 14 in.) and it appeared to be a phenomenon of a pressure wave going through the tube which eventually exceeds the stress of the tube and opens it up at these points.

You perhaps might not have had enough length to observe this, but we found apparently the same mechanism that you noted. There was a minor explosion in the bottom of the reboiler under the tube sheet, which buckled the tube sheet. Then there was a progressive pressure wave going up the tubes, opening these holes along the tubes until they reached the interface level where, as you have indicated, there was no liquid washing. When it reached this point there was a large accumulation of hydrocarbons which erupted with the major force of the blast.

We were able to conclude to our satisfaction that there were two distinct explosions, a small triggering explosion followed by the main energy release, and they were at entirely separate places in the reboiler.

WRIGHT: We did notice one or two tubes which had been broken in more than one place.

KEITH—Hydrocarbon Research, N. Y., N. Y.: I do not recall whether you mentioned at what pressure this system was operating. Also, I want to know if there was any indication of any formation of acetylides of copper.

WRIGHT: There was no indication of any acetylides formation. The system operates at 65 to 75 lb. in the vaporizer. In the O_2 side there is a pressure of from 3 to 4 lb., outside the tubes N_2 is at 65 to 75 lb./sq. in.

N. H. WALTON—SunOlin Chem. Co., Claymont, Del.: I am not quite certain as to what your conclusion was on the initiator of the explosion. The reason I'm confused, perhaps, is because you said that you never got a positive test for C_2H_2 at that point, and yet it appears, that there was an initiator there. The wind from the coke oven battery makes me wonder whether oxides of nitrogen might be the initiator here.

WRIGHT: That might be possible. The reason for blaming C_2H_2 in spite of the fact that we had no positive test, was Ontario Research Foundation's statement that this fracture was definitely characteristic of C_2H_2. Certainly, we have no proof that there were not other contaminants in there —in fact, we are fairly certain that there were.

J. E. HART—Dow Chemical Co., Midland, Mich.: What is the frequency of your acetylene tests?

WRIGHT: The vaporizer and low pressure column are checked every 8 hr. by the B.O.C. method and the Ilosvay method.