HYDROGEN COMPRESSOR CYLINDER EXPLOSION

BY

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On December 18, 1961, at approximately 3 o'clock in the afternoon, an explosion, closely followed by a second, occurred in the Compressor House of the Hydrogen-Urea Plant of the SunOlin Chemical Co. in Claymont, Delaware.

Before proceeding with the description of the effects of the explosion and an analysis of its cause, a little orientation may be in order.

One of the facilities at the plant is a Steam-Natural Gas reforming unit, designed to produce two products: Hydrogen, for sale to others; and Carbon Dioxide as a feed to our Urea Plant.

Compressor house

An integral part of this Reformer—Urea Plant is a Compressor House sheathed with light corrugated aluminum sheets over a steel frame, a floor four feet above grade, the wall on one side starting about 14 feet above grade. The other three walls begin at floor level. This Compressor House contains two Cooper-Bessemer "FM-6" horizontal balanced opposed reciprocating compressors, each driven by an open type 1250 Horse Power synchronous motor. The compressors are duplicates of each other and each has two stages of Hydrogen compression: the first stage from 100 pounds to 225 pounds; the second stage, from 215 pounds to 500 pounds. Each machine also has four stages of Carbon Dioxide compression.

Let me direct your attention to the second stage Hydrogen cylinder of the South compressor, since this is the cylinder which exploded.

The installation of this compressor was made approximately two years before the explosion and this cylinder—which is a double acting type—contained one suction valve and one discharge valve on the inboard end, and one suction valve and one discharge valve on the outboard end, with a fixed capacity clearance pocket on the outboard end.

During a major Shutdown in early December of 1961, modifications were made to this cylinder at which time a valve lifter was installed on the inboard suction valve, and a large variable capacity clearance pocket on the outboard end in place of the original fixed capacity clearance pocket.

Several hours before the explosion occurred, this (South) compressor was started up and placed on the line. It was taking suction from its normal source and discharging to its normal destination with the valve lifters and clearance pockets on all cylinders in an unloaded condition.

In particular, the suction valve on the inboard end of this second stage cylinder to which we are referring was lifted and the variable clearance pocket wide open.

Operating change

At approximately 3 o'clock on the day of the explosion, it was decided to decrease the flow to the Plant and four Operators went to the Compressor House: one to load up the South compressor which was running; the other three, to shut down the North compressor, which was running on the line.

The first Operator stepped in between the first and second stage Hydrogen cylinders of the South compressor and adjusted the valve lifter to place the inboard suction valve in service. He immediately heard a pronounced thumping noise and could see water spraying out the water jacket connection on the outboard end of the cylinder. He quickly ran around in front of this cylinder to the motor stop button, and by the time he reached it, a muffled explosion occurred. He immediately hit the stop button and headed for the door.

The other three Operators headed for other doors. They got out of the building, but the first Operator only reached the top of the stairway near the door to which he was heading, and a second explosion took place with the propagation of a sheet of flame.

This Operator had all his exposed skin singed in such a manner that the next day he appeared as though he had a deep sun tan. All exposed hair—eye lashes, eye brows—were burnt off. He rolled down the steps onto the ground and departed from the scene under his own power. His clothes were not set on fire.

Substantially all the corrugated roofing and siding of the Compressor House, Figure 1, was blown off and the roof on the large Urea Warehouse, about 75 feet away, was lifted and buckled in several locations. The duration of the fire was merely that of a flash, although flames continued to burn inside the second stage cylinder and could be observed through the open end, until they were put out with a Carbon Dioxide extinguisher.

Damage noted

An examination of the scene revealed the following:

The new variable capacity clearance pocket on the outboard end of the second stage cylinder had blown off, landing about 15 feet away, in between two cylinders of the North compressor and had been stopped by striking the concrete curb of the foundation. The piston from the second stage cylinder had come loose

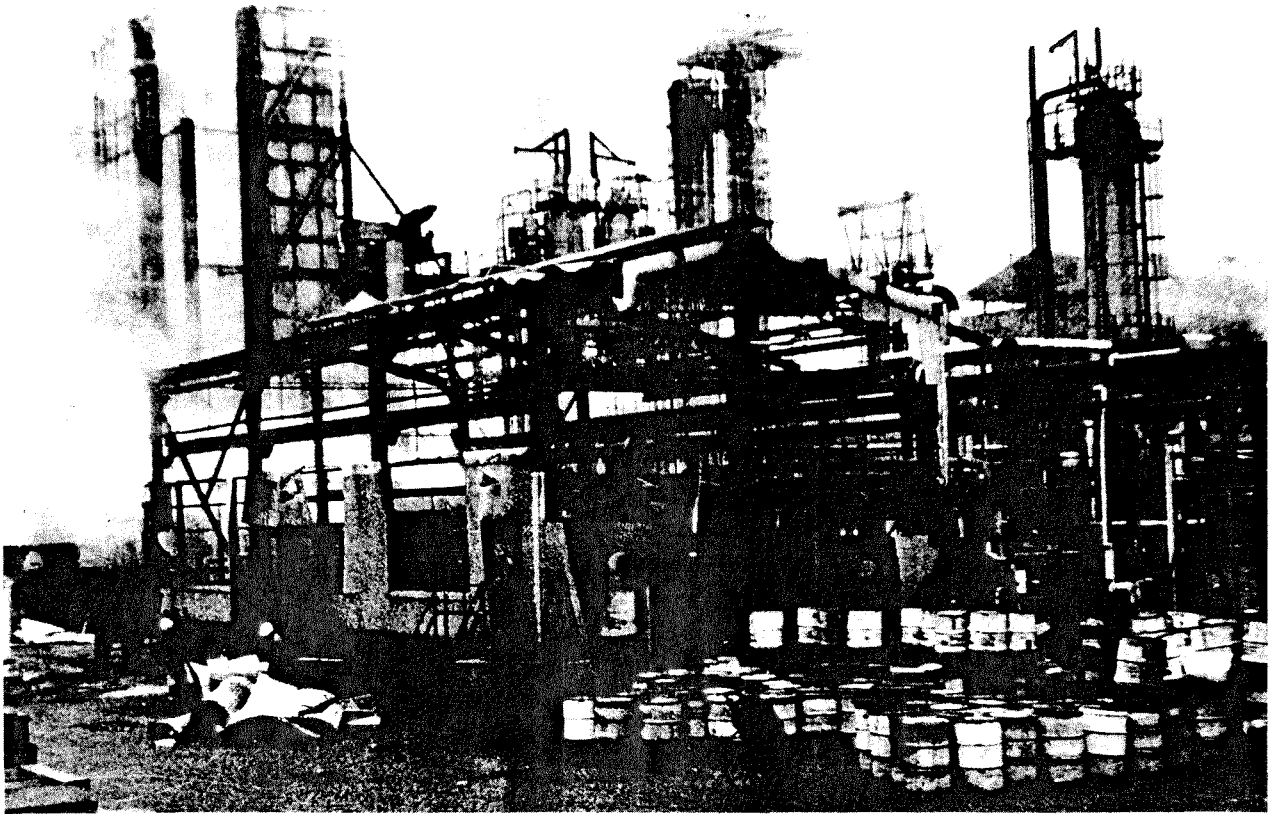

Figure 1. All the corrugated roofing and siding of the Compressor House was blown off.

from the piston rod and was lying on the Compressor House floor about six feet from the open end, Figure 2.

The cylinder from this compressor was then completely dismantled and the two suction and two discharge valves removed. These valves are standard compressor plate type valves consisting of a seat and guard with the valve plate and its spiral springs plus the large bolt and nut which fastens the valve plate assembly to the cage. The valve plate assembly is bolted to the cage with the guard against the cage when it is desired to assemble as a discharge valve, Figure 3; but if it is desired to assemble as a suction valve, this same valve assembly is turned upside down and the valve seat is against the cage, Figure 4. This has an advantage in reducing spare parts inventory, but does have other connotations as we will see.

Valve assembly analysis

Let us look at the pictures which were taken of the valve assemblies immediately after they were removed from the cylinders, Figures 3, 4, 5, 6.

Very little study is required to see that the

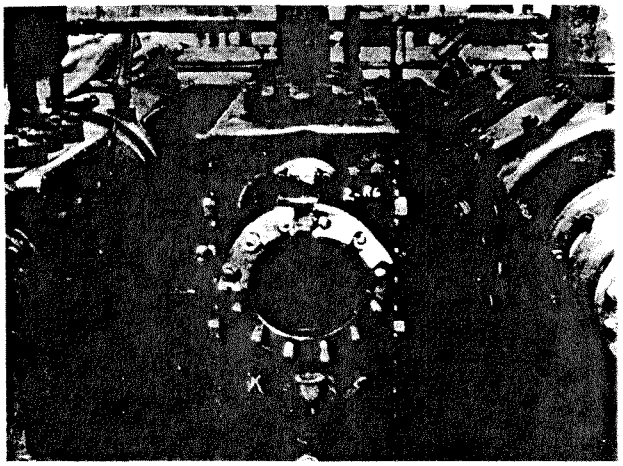

Figure 2. The piston from the second stage cylinder had come loose from the piston rod.

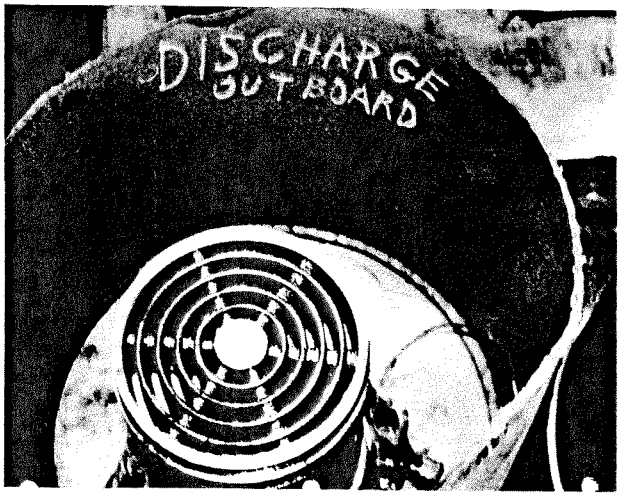

Figure 3. Discharge outboard valve.

valve assembly, which was installed in the location where the inboard discharge valve should be, was actually a suction valve assembly. Therefore, it appears that when the valve lifter on the actual suction valve was released, Figure 7, pressure quickly built up on the inboard side of the piston until it forced the piston off the rod and it in turn struck the large variable clearance pocket on the outboard end of this cylinder, bursting its flange and projecting it to the position as shown in the picture. We believe this was the first explosion that was heard.

Following this, of course, a considerable volume of hydrogen gas was released to the atmosphere and the second explosion occurred when this gas was ignited by an unknown cause.

There are a number of other interesting points which should be brought out in connection with this accident.

If the suction valve on the inboard end of this cylinder had not been equipped with a valve lifter and the valve lifted, it is probable that the compressor could not have been barred over by hand and also could never have been started from a dead stop, as the pressure built up in the inboard end of the cylinder during the starting of the motor would have probably kicked it off electrically before major damage occurred.

It should also be pointed out that there are other compressor manufacturers who make valve assemblies which can be inserted as either suction or discharge

Figure 4. Suction outboard valve.

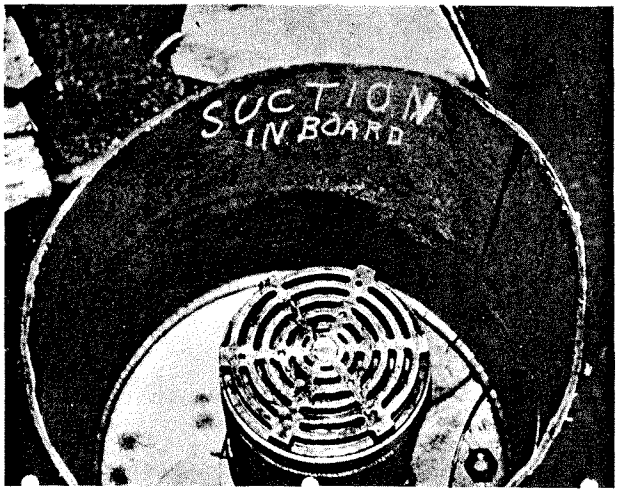

Figure 5. Suction inboard valve.

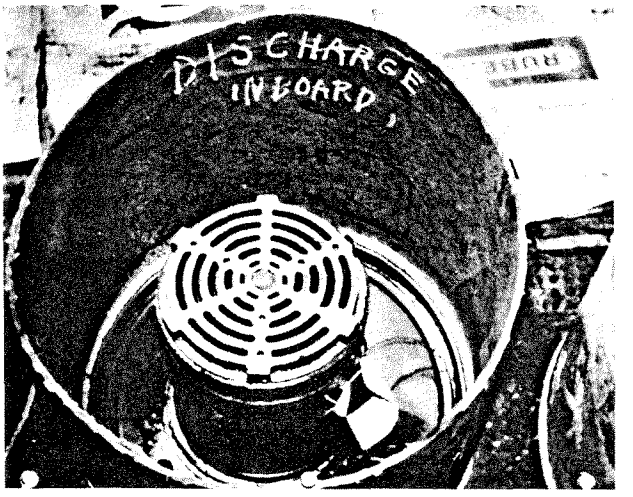

Figure 6. Discharge inboard valve.

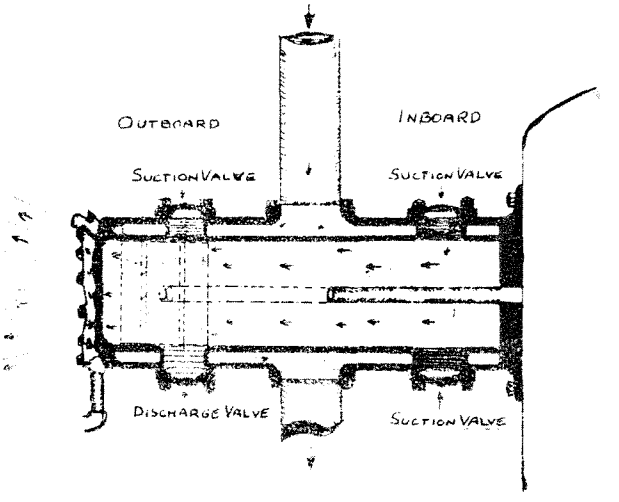

Figure 7. When valve lifter on inboard side of piston was released, pressure built up quickly.

valves in the same valve port. Thus, this is a type of accident which could occur to others and it is hoped that the lessons derived from this will arouse an interest in more careful inspection of the assembly of valves into compressor cylinders.

We were particularly fortunate in this accident in that no loss of life resulted and the operator who was burned lost only two working days.

Questions and answers

FLUDER—Calumet Nitrogen. We had a similar occurrence on a nitrogen machine when a discharge valve was installed backwards. It was a gas engine driven compressor and was started and ran for several minutes before the cylinder overheated and froze, stalling the engine. Fortunately, only the piston and cylinder liner were damaged. We have since made it mandatory that the chief operator personally check each valve as it is being installed, with a screw driver, and to make a report of the check.

WALTON—Well, this is a point I was going to mention, too. It's now the responsibility of our unit leader to personally check every valve that's installed. I think an-

other thing that I might mention here is this illustrates the importance of always turning a compressor over by hand before you start it. Now I find that some compressor manufacturers are selling compressors without providing devices for this. In my way of thinking this is a bad way to save money.

Q. I'm interested in your operation. You sent four men to the compressor house. Don't you have operators in there, or what?

WALTON—No, there's no operator in this compressor house normally. The operator who checks the compressors we call the "machinery technician" and he makes the rounds of the compressors and the pumps once an hour. But he's not present in the compressor house at all times.

Q. I'm also interested in the type of cylinder that this was. Was this forged steel or cast steel?

WALTON—This was a cast iron cylinder of the thrubolt type of design.

Q. Was there enough energy involved to damage the crankshaft?

WALTON—No. The crankshaft wasn't damaged and, interestingly enough, too, none of the valve plates on the valves were broken.

PROCTOR—Linde Division. We are operating a large number of oxygen compressors as well as nitrogen and hydrogen machines and have been faced with the problem of having valves installed improperly. The possibility that it might occur always exists in a compressor. On our oxygen machines, we have devised methods by which valves installed improperly will meet with physical resistance. We have been able to do this while retaining the flexibility of being able to use a valve in either the suction or discharge ports. This avoids the necessity for maintaining a stock of both suction and discharge valves. In addition, we've suggested to compressor manufacturers that it would be worthwhile to have stamped on each valve guard and seat the identification of the valve, that is, whether it is a suction or discharge valve so that after it is installed in the compressor a supervisor can look in through the port and check for correct valve installation. Can you tell me if you have considered any of these steps?

WALTON—Yes. All this brings up another interesting point. We recently received some new plate valves for another make of compressor. These valves can be made suction or discharge valves by turning them over. On one side of the valve is stamped an S; on the other side of the valve is stamped a D. I think that you would probably conclude that if you would take this valve and place it in the valve port so that you can see the S, that this is proper for this to be a suction valve. Actually this is not so. The S has to be down where you can't see it.

So I don't think there's really any way that you can be real sure except by having the operator who is most closely involved here, look at the valve and poke it with a screw driver to be sure of its action and to be sure that he has been satisfactorily trained so that he understands how a valve works.

Q. I was interested in what other damage was done to the machine. Was the particular cylinder involved damaged so that it couldn't be reused?

WALTON—Well, this is interesting. The water jacket was damaged but the cylinder itself was not severely damaged. If it weren't for the water jacket damage it could probably have been reused. The fact that the crankshaft was not damaged—there was no deformation whatsoever—certainly speaks very well of the ruggedness of the crankshaft design on this machine. No. We were able fortunately to get another cylinder within a few days and this machine was back in service in one week.

MIDKIFF—Cooper Bessemer. I might add that we realize that this possibility does exist of installing the valves backwards. And so to help your own maintenance people in this, we have published what we call a Service News Bulletin that can be put in your valve shack or right where your maintenance people can look at it, which will help them in this training that you mention of understanding how the gas has to flow through the valve to amke it act either as a suction or a discharge valve. This can be helpful in the initial assembly of these valves to be sure that they are actually installed in the correct location.

Q. I wonder if it isn't possible if the compressor manufacturers are not aware of this and if they couldn't arrange so that you couldn't put a discharge valve in an inlet or an inlet valve as a discharge by making either the guard or the valve large enough so that you just couldn't get it in there the wrong way?

HUNTER—Cooper Bessemer. I think this last question here is one of those things where you're damned if you do and you're damned if you don't. On the one hand this interchangeability factor has always been considered to be a prime feature on reduction of inventory and on the other hand these problems crop up. We have furnished some machines that have had this feature of being impossible to get a suction valve into a discharge port and vice versa. But whether this should become a matter of standardization for the industry, I don't know. I think we'd have to have a little more expression of opinion in the form of written specifications from the purchasers of new compressors, or requests for conversion of existing units.

MASON—Dow Chemical. As Mr. Hunter points out, it is convenient and economical to have valves be interchangeable for use for either inlet or discharge service. But I believe that valves and ports could be designed to continue this interchangeability feature and, at the same time, eliminate the possibility of getting a valve installed wrong side up. For example, the 8 mm movie cameras are designed with 3 splines on the spindle for the reel for the unexposed film and 4 splines on the spindle for the take-up reel. This eliminates any danger of getting a reel in wrong. Some such similar design could be adopted that would prevent the installation of a valve incorrectly.

OWEN—I.C.I. It may be of interest if I tell you what ICI's practice is in this particular problem. As you know we run a considerable number of compressors in England and we've taken the decision that we make suction and discharge valves mechanically not interchangeable and carry the cost, which is quite a small one, of the extra inventory of spares. We think that the cost of this is small compared with the risk of the sort of incident that's just been described this morning.