Additional Incidents from a Survey of the Industry

The following brief items were developed under the guidance of J.D. Stafford, Occidental International Engineering Co., London, England. As part of his efforts in this undertaking, he read papers where the author was unable to be present at the actual symposium.

Swaying of a CO_2 Stripper

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In one of our plants we experienced severe vibrations in the pipework from the let-down turbine to the flash tower and swaying of the flash tower. When operating on the bypass valve everything was stable, but when operating the let-down turbine the top of the flash tower swayed with an amplitude of 4 inches and a frequency of about 1 cycle/sec. By accident it was found that the swaying was influenced by the addition of anti-foam.

A series of trials were then carried out to establish which changes influenced the vibrations.

Trial A

1. Addition of 2 pints of anti-foaming agent (Union Carbide S.A.G. 470), caused immediate and severe vibration of pipework and subsequent rocking of the flash tower.
2. The pressure on the downstream side of the let-down turbine increased from about 25 lb./sq.in. gauge (stable) to around 35 lb./sq.in. gauge (unstable).
3. The level in the flash tower dropped immediately from 42% to 36%. The level in the absorber increased more slowly from 35% to 41%.
4. After a period of about 1½ days the system became steady again, and the let-down turbine downstream pressure fell back to about 25 lb./sq.in. gauge.

Trial B

1. The addition of 1 pint of anti-foaming agent caused similar severe vibrations of pipework and subsequent rocking of the flash tower.
2. The pressure downstream of the let-down turbine increased from 25 lb./sq.in. gauge (stable) to around 32 lb./sq.in. gauge (unstable).
3. The level in the flash tower dropped from 46% to 43%, and the level in the absorber increased from 36% to 39%.
4. After a period of about 18 hours the system steadied out.

Trial C

1. The addition of 1/3 pint of anti-foaming agent caused no vibration of pipework or swaying of the flash tower.
2. The pressure downstream of the let-down turbine increased from about 23 lb./sq.in. gauge (stable) to about 27 lb./sq.in. gauge (just stable).
3. The level in the flash tower dropped slightly and the absorber level increased slightly.
4. To initiate vibrations a further 1/3 pint of anti-foaming agent was added (about 20 minutes after the first addition).
5. The pipework started to vibrate, and the flash tower

started swaying slightly.

6. The let-down turbine discharge pressure increased from about 27 lb./sq.in. gauge (just stable) to 29 lb./sq.in. gauge (unstable).
7. Within 6 hours the system had become steady again.

Each trial was repeated with the slip-stream filter both in commission and shut off, to check whether the filter affected the time period for the system to re-stabilize after having once started vibrating. There was no noticeable difference with the filter in or out, so it would appear that the adverse effect of the anti-foaming agent was just time-dependent.

We now add sufficient anti-foam to avoid foaming problems, but not too much to avoid vibrator and swaying problems.

It is considered that if too much anti-foam is added, there is slug flow in the line up the stripper whereas with just sufficient anti-foam there is a continuous flow of liquid and vapor. #

Explosion in vent stack of ammonia plant

An explosion occurred on one of our ammonia plants on 18th October last year in the main process vent system. This caused the rupture of a 24-in. bellows-piece in the section of line from the vent silencer up to the main vent. The operators did an excellent job by, after having closed all main vent valves tight shut, bringing down the plant to about 25% of capacity by controlling the speed of the syn-gas machine and then venting the gas through a small separate vent downstream of the LT shifter. The explosion happened about half an hour after that, for the first time since the startup of the plant, all main vent valves were shut tight and the main vent flame was extinguished. A smaller vent close to the main vent was still burning.

The most likely reason for this explosion was that the burning vent gas flame travelled back down the vent pipe and ignited a gas/air mixture at the silencer. Air had somehow leaked into the vent system.

The following actions were taken:

- the 24-in. bellows piece was replaced
- all drain lines from the vent silencer were provided with water seals with continuous water supply to prevent ingress of air
- all flanges and valves on the vent system were checked for tightness
- a nitrogen purge with a flow of about one ton/day was installed. Velocity in vent stack about 0.1 ft./sec. based on paper in *Hydrocarbon Processing and Petroleum Refiner*, May 1964. #

Environmental problems in an ammonia plant

After starting up one of our ammonia plants we found we had environmental problems. The plant was designed with a TEA- MEA CO_2-removal system without overhead condensors giving two brilliant white plumes and without process condensate stripper, the untreated condensate was run into a canal and with cooling towers converted from natural draft to forced draft by means of installing fans at the base of the towers; brackish water was used as make-up water.

From a plant image point of view there were objections against the white plumes. We had to pay a penalty for polluting the water in the canal and the carry-over of brackish water from the cooling towers caused white spots on the wind screens of cars passing on the neighboring roads.

We tried to solve the problems as follows:

Plumes. We ran a 30-in. steel line from the CO_2 removal unit to the base of the 100-ft. high stack of the primary reformer and the mixture of flue gas and overhead product now only gives a minimal plume in wintertime.

Water pollution. At the same time we used the overhead product of the MEA stripper to strip off ammonia and methanol from the process condensate in a 3-m. high bed of Pall rings, in this way stripping off 60% of the ammonia and 80% of the methanol. The removal of the ammonia is influenced by the fact that process condensate is used as make-up water to the MEA system. The stripper was actually built to clean the MEA overhead product such that it could be used for the TEA stripper.

Cooling tower. The single layer louvres for entrainment separation were replaced by double layer louvres according to the excellent paper by H. Chilton in the Trans. Inst. Chem. Engrs. **30** 1952, 235-250, thereby eliminating the white spots on the windscreens. #

Air Steam Coil Failure

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The following is a summation of events that led to the failure of a primary furnace convection area air steam coil. It was a very cold night. At 2300 an extremely loud noise was heard coming from the steam plant. The steam plant operator called on the plant radio to report that the end had blown from the steam drum on one of two 900 pound boilers (designated for 165,000 lb./hr.). The operating foreman rushed to the steam plant and noted that it did appear to be a ruptured drum. However, due to the steam vapors and the very loud noise being emitted, it was impossible to verify positively.

The operator cut the fires off from the boiler. Shortly afterward the fires in the other boiler failed due to a lack of air for combustion. When the noise and water vapor had subsided, it was observed that the 650 lb. header relief valve was broken off. The pipe had broken in such a way that the steam discharging was directed in the direction of the boiler's steam drum. The 650 lb. header was blocked in and the one boiler was re-started. The other boiler could not be re-started since the draft fan was driven by a 650 lb. steam turbine.

During the problems at the steam plant the synthesis section of the ammonia plant was shut down, air was taken out of the combustor and process gas was taken out of the Foster Wheeler furnace tubes. Attempts were made to keep the furnace operating on 600 lb./sq.in. gauge steam produced on the unit. The convection zone temperatures were frequently checked. None appeared abnormally high. However, the furnace tube outlet temperatures increased from about 1460° to 1800°F. All furnace fires were killed. In a short time, steam was observed pouring from the convection area of the furnace.

The coils were checked

After cooling the furnace the HK-40 air steam coils were checked. One coil had failed. The repair was made by removing a section approximately six feet long and re-welding a new tube section in place. The furnace was again started and three more tubes failed. This time the metallurgical department microphotographed the tube samples taken from the failed sections. It was concluded that the tubes were as good as the new ones in stock.

The three failures were repaired and 90 welds were X-rayed. No bad welds were observed. Considerable damage was done to the refractory. Repair to it consumed almost as much time as the tube repair work.

Conclusions

The operating people feel that the relief valve did not lift. However, the relief valve had been seeping slightly. By reasonable deductions it is possible that the 900 lb./sq.in. gauge steam used to make up the 650 lb. header had frozen at the control station allowing the pressure to build. Had the steam seep caused ice blockage in the relief valve vent, the blowing of this ice plug could have caused much force on the header.

The installation design for the relief valve was poorly planned. The failure was in the 18-in. section of line to the relief valve about 6-in. above the header. All the piping involved was carbon steel schedule 40.

The relief was relocated far from the boilers. It is now properly designed and is braced.

The air steam coil welds should have been checked after the first repair was made. #

Secondary Reformer Air Inlet Nozzles Failure

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Chemicals and Phosphates, Ltd. manufactures ammonia by high pressure steam reforming of naphtha in a primary reformer, followed by a secondary reformer and the usual purification, compression and synthesis steps. The ammonia plant was in operation for two years when a routine check found several leaks in the welds of both air inlet nozzles to the secondary reformer.

The secondary reformer is a circular type vertical steel shell, containing a supported bed of catalyst. The inner side of the shell is protected by a heat resistant cast lining, about 15-in. thick and the whole vessel below the air nozzles is water jacketed.

The gas mixture from the primary reformer is entering the top of the secondary reformer at about 1400°F and 350-400 lb./sq.in. gauge. Hot compressed air at about 1100°F and 450 lb./sq.in. gauge is introduced through two 12-in. diametrically opposite situated nozzles below the top. Combustion and reaction then take place with an estimated temperature rise to 2300°F. The product gases leave at the bottom of the vessel.

The air inlet nozzles are lined with a 3-in. thick heat resistant cast lining. The outside surface temperature is about 300°F. The nozzles consist of an AISI 321 type s.s.pipe 11.6-in. I.D. and 0.6-in. wall thickness.

The nozzles are welded to the secondary reformer, which is a 17 Mn 4 (W.St. – Nr. 1.0844) carbon steel 1.41-in. (36 mm.) thick shell. (C = 0.14–0.20%; Si = 0.20–0.40%; Mn = 0.90–1.20%; P = 0.50 max.; S = 0.50 max.).

Weld preparation was a non-symmetric K, with 25°, 28 mm. deep level on the inner side and 40°, 8 mm. deep circumferential level on the external side.

Liquid penetrant test, which had been carried out during the shutdown, revealed a series of radial cracks on both welds.

Investigation of the failure

In order to find the cause of the failure, a chemical and metallographic examination of the weld deposit was carried out at the "Technion," Israel's Institute of Technology.

1. *The chemical* analysis was carried out on chips which were drilled from the weld area. The results showed that a 25 Cr – 20 Ni electrode was used (Cr = 24.8–26.0%; Mo = 0.45–0.48%; Mn = 3.5%; Ni = 19.6–20.5%; Fe = balance), for welding.
2. *The metallographic* examination. In order to locate the most promising areas for this examination, a sample was radiographed prior to the metallographic preparation. "Step-like" cracks were detected at this stage at two different areas of this specimen, but no preferred orientation of the cracks could be distinguished. The specimen was mounted in Bakelite, ground and polished, so that the examined surface was oriented at right angles to the weld's original surface (tangential to the flange).

A net of cracks could be seen through the whole length of this specimen, even with the naked eye. Microscopical examination at various magnifications revealed that the crack pattern was of an inter-crystalline type.

Apart from the main cracks, another network of fine voids could be seen. This network coincided with the grain boundaries of the deposited metal. Another proof for this void pattern is found in droplets pattern expelled at the grain boundaries. A change in color was noted close to the grain boundaries as compared with the matrix.

3. *Cause of failure.* As seen from the chemical and metallographic examinations the weld deposit was a 25-20 chrome-nickel austenitic type stainless steel and severe intergranular cracking occurred which caused the weld to leak. It is most probable that the attack mechanism could be related to a combination of the following three factors:
   a. Contact with hot gases at the inner wall of the vessel.
   b. Stresses induced through production and fabrication.
   c. Use of an inadequate welding electrode, vulnerable to the combination of ss 321, to carbon steel 17 Mn 4 (stress combined with high temperature).

Repair of the failure

It was decided to use the Arc-Air removal process for the removal of the failured weld deposit. The fear of carbon pickup through the above removal process was not a factor to be considered, as one of the welded parts of the vessel is, in itself, relatively high in carbon. However, care had been taken to grind the surface slightly before rewelding.

As liquid penetrant test was permanently used to see whether all original cracks were removed, this nondestructive technique served also to assure that no micro cracks, which might have been introduced by the removal method, exist.

The repair was very specific. It involved two different joints (carbon and austenitic stainless steels), at a pressure vessel which operates under relatively high pressure (450 lb./sq.in. gauge) and at high temperature.

The welds themselves are exposed to hot gas attack by gases which diffuse through the internal layer of the lining. A material high in ductility which withstands stress corrosion is thus needed. This material should overcome cracking due to the dissimilarity of properties and composition on both sides of the joint.

A Literature survey showed that Inconel 182 welding electrode (67% Ni and 14% Cr) is the most promising alloy. This filler metal showed excellent results when tested both at room and elevated temperatures. Thermal cycling of test specimens revealed no cracks, whereas welds performed with other ss electrodes, like 25 Cr – 20 Ni, did crack.

It was decided to use this type of electrode for repairs. The metal was preheated to 200°C during welding. No post heat treatment was used. The secondary reformer is now in operation for more than a year and no sign of cracks could be found in the weld. #

Waste Heat Boiler Failure

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A major failure, causing approximately 45 days down-time, occurred to a Waste Heat Boiler due to a minor operator mistake. A hazardous situation existed, but was considered safe by application of a specific operating procedure. The procedure could have succeeded, but a totally unexpected human action resulted in an accident.

Description of the installation

P.I.C.'s 1600 ton/day Ammonia Plant consists of two identical streams of 800 ton/day each. The waste heat boiler, in each stream, is a horizontal fire-tube type with natural circulation. It cools secondary reformer outlet gas, at a pressure of 35 kg/cm^2 g. from 960°C to 460°C approximately.

Downcomers from the steam drum are provided with drain connections at the lowest point. The drain lines join two high pressure collecting headers, that let-down into a low pressure line. The low pressure line leads to a flash drum, which collects hot water from several sources in the plant, and is used to generate 3 kg. steam.

The hazardous situation developed when a low pressure block valve was installed on the line going to the flash drum. The valve and a drain valve were added to permit isolation of the low pressure line for repairs. This became necessary when the line developed frequent leaks due to erosion caused by leaking let-down valves.

Description of the incident

Because of the possibility of accidentally rupturing the low pressure line, the low pressure valve was chain-locked in the open position during operation.

The line maintenance procedure called for a Process Foreman to close the high pressure let-down valves, and open the drain, before unlocking and closing the low pressure valve. The Foreman was to remain in attendance until the repairs were completed and the line was recommissioned. When repairs became necessary, the procedure was followed. Before commissioning the line however, the Foreman wanted to inform a Supervisor in the control room. He therefore instructed an operator to hold everything until his return.

Then the unexpected happened. The operator decided to "test" the low pressure line to make sure it had no weld leaks. He therefore closed the drain valve and cracked open one of the let-down valves!

The line ruptured, and the reaction swung the high pressure headers enough to cause failures on the down-comer drain connections. The hot water caused second degree burns to the operator, but he was able to leave the hospital in a few weeks.

Description of the damage

The waste heat boiler design, having tubes 12.5 meter long and a thin tube-sheet, was particularly susceptible to overheating due to loss of circulation. When water started flowing out at the bottom of the down-comers, circulation was reduced. Also a large amount of relatively cold Boiler Feed Water was introduced to the drum by automatic level control, and this caused a sharp drop in pressure, which in turn caused loss of circulation due to the formation of steam in the down-comers. The result was a failure of the hot-end tubesheet as well as the collapse of a large number of tubes. Repairs were quite costly, and resulted in a 45-day shutdown.

Conclusions

The procedure was deficient. It should have, at least, included chain-locking the let-down valves in the closed position, and the drain in the open position, while repairs were being done. The situation could also have been made intrinsically safe by adding a low pressure relief valve on the line.

What was even more surprising, was that the whole system was not really necessary. The high pressure drain valves should not be used during operation anyway because of the danger of losing circulation. A separate blowdown system, from the steam drum is in use. The drain valves are, therefore, only for completely draining the waste heat boiler after cooldown, to permit inspection and repairs. The correct course of action, instead of adding a low pressure valve, was to repair the let-down valves to prevent leaks during operation, and to discharge into an open sewer rather than the flash drum. This is what we eventually did, after the costly failure. #

Tube Crack and Vibrations in a CO_2 Removal Section

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A short report of two events in a 1400 ton/day steam reforming ammonia plant based on natural gas at Ludwigshafen, Germany. Both cases concern the CO_2-removal section, where MDEA (mono-methyl-di-ethanol-amine) is used as a solvent.

At first, approximately two years after startup, a pipe bend in the process condensate drain of a heat exchanger burst. This exchanger is situated upstream of the process condensate separator. MDEA flowing through the tubes of this exchanger is heated up at a pressure of 20 lb./sq.in. gauge.

On the shell side, process gas is cooled whereby condensate is formed which is drawn off by a separate 6-in. pipe. After bursting of one of the bends in this pipe there was a heavy leakage of synthesis gas. Immediately the block valves down- and upstream of the damaged pipe were shut and a vent was opened. But gas streaming out in the meantime caused an explosion, followed by a fire. This fire lasted about 10 minutes until the gas pressure had dropped. Nobody was hurt. Material damage involved cable lines, electromotors, instrumentation as well as the windows and the cement asbestos wall of the compressor hall. The inspection of the cracked pipe bend—made of carbon steel—showed a strong erosion of the wall, Figure 1.

The velocity of the condensate flow through the bend is about 5 ft./sec. The condensate is saturated with gas, especially with CO_2, and the flow pattern, therefore, will be bubble flow.

Usually there is only a low corrosion rate of carbon steel by CO_2-saturated water, but in this case of a gas-liquid two-phase flow the corrosion is accompanied by strong erosion. The new pipe was made of austenitic stainless steel. Moreover, the wall thickness is measured from time to time.

Figure 1. Condensate pipe burst by erosion-corrosion.

A dangerous situation

The second instance in the same CO_2 section was no real accident, but all conditions present could have caused a very dangerous situation.

The CO_2-loaded MDEA from the absorber is first let down in an expansion turbine to the first desorber. From the bottom of the first desorber the solvent flows through a pipe with an original diameter of 28-in. and with a height of 120-ft. to the top of the second desorber. This pipe is made of stainless steel.

By the pressure drop there is a two-phase flow with a growing gas content within the pipe. This two-phase flow is pulsating and therefore it causes a strong vibration of the pipe. There were lots of cracks and leakages, and there was

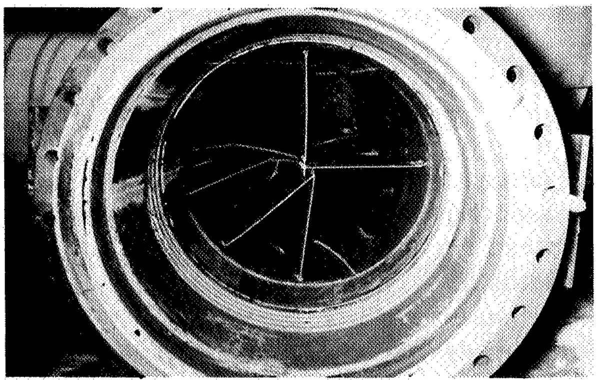

Figure 2. MDEA-pipe with damaged sheets.

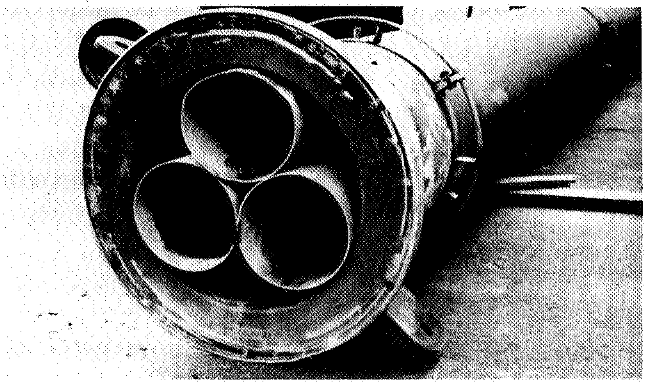

Figure 3. MDEA-pipe with three inserted tubes.

the danger of a complete breakdown. The first step to avoid vibration was to reduce the pipe diameter to 20-in. With the higher flow velocity there was a more uniform two-phase flow but there were still vibrations of the pipe. It was impossible to take a pipe diameter smaller than 20-in. because a pressure difference of 51 lb./sq.in. is necessary to have sufficient flow from the first to the second desorber. The second step was to fasten the pipe by a supporting frame, but this was also not successful.

The flow pattern of a gas-liquid flow depends on the ratio of the gas-liquid content, the flow velocity, and the diameter of the pipe. It was impossible to change the ratio of the gas-liquid content and the flow velocity, but it was possible to change the pipe diameter without increasing the pressure drop by parting the cross-section of the pipe.

At first we made an installation of four sheets (1.2-in. thick, stainless steel) cross-shaped and so we had four cross sections. After a running-time of roughly one year it was destroyed by vibration corrosion, Figure 2. Then three inserted tubes of diameter of 9-in. and a wall thickness of 1.3-in., Figure 3, were installed within the pipe.

By the final step the flow velocity is unchanged and the pressure drop within the seven cross sections is only a little larger because the wall friction area has grown. The parting of the cross-section of the pipe reduces the separation of the gas-liquid flow and gives also a more uniform flow. Since that time—nearly six months—no more vibrations were observed. #

Lubrication Failure on a 3500 HP Engine

Anonymous

The engine involved is part of a multi-service compressor in a smaller-sized ammonia plant.

Following a maintenance turnaround, the engine was started and allowed to run without oil lubrication. Needless to say, the length of run was not long; stoppage was due to the overheating and seizure of a main bearing.

Description of damage and repair

The No. 4 main bearing was severely damaged through overheating (later the temperatures were estimated to have reached 500° to 700°F.) The adjacent bearings were moderately damaged.

After replacing the eight main bearings, a second startup was terminated after three minutes when it became apparent that No. 4 main bearing was again overheated. The existence of a major problem was confirmed by dimensional checks: in addition to an ovality in the cap, a significant eccentricity in the shaft was indicated.

The possibility of an *in-situ* repair was rejected in favor of the safer course: return of the crankshaft to the manufacturer's shop. There the shaft was thoroughly inspected and straightened. Tensile stresses at No. 4 journal were reduced and beneficial compressive stresses introduced by peening. Because of the removal of severely stressed metal by grinding, an oversize bearing is now required.

After the shaft was removed, some distortion of the main bearing saddles was detected; this was remedied by in-line boring. In all, the machine was out of service for 82 days. Fortunately the repair appears to have been successful as the unit has now run well for several months since reassembly.

Circumstances leading to failure

The startup followed a maintenance turnaround in which considerable work had been performed on the engine. One job had been the replacement of filter cartridges in the main oil filter located in an out of the way spot beneath the floor gratings. Prior to the change out an operator had closed the block valves on either side of the filter to permit opening without oil spillage. The replacement was begun by one maintenance crew and finished later by another crew. The work was carried out on a general work order which covered several of the minor jobs on that engine.

Instructions were given the compressor operator, through the log book, to carry out a thorough pre-start check; about 4½ hours were available for these checks. In addition long standing instructions were to have the shift supervisor present during startup. In this case, both the operator and the shift supervisor were considered to be experienced since they had been operating this equipment for nearly four and seven years respectively.

However, during his pre-start inspections the operator failed to notice the oil filter was still blocked in. During the start he failed to notice the zero oil pressure reading. Also during this critical period, the Shift Supervisor left the scene for about a minute to get a mechanic to close some open pressure taps. The shutdown circuit didn't help either, as this was automatically bypassed during the starting sequence.

Major changes made

A written pre-start check list is now used. Before each start this form is completed and signed by both the operator and the shift supervisor.

A permissive start circuit was added. This instrumentation permits the engine to turn over only after sufficient prelube oil pressure has been detected.

Over-temperature sensors were installed in the caps of all new bearings. Excessive temperatures will result in an automatic shutdown.

The valves on either side of the main oil filter were chained and locked open.

The use of one work order to cover several jobs has been greatly restricted.

This incident, we believe, illustrates the fact that not all problems are due to material failures—human error still occurs. However, we look forward to no more lubrication failures. #

Explosion in an East Asian Urea Plant

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Urea processes using stainless steel as a construction material require introduction of oxygen or air in one of the feed streams to the synthesis section. Stamicarbon introduces air into the carbon dioxide feed stream. This carbon dioxide usually contains small amounts of hydrogen.

After conversion of the major part of the carbon dioxide into urea the off-gases from the reactor consist of ammonia, carbon dioxide and inerts (H_2, O_2 and N_2). Prior to venting this gas into the atmosphere, it is washed with a carbamate solution which has, under the prevailing conditions, a large capacity for absorption of the ammonia and carbon dioxide. This absorption is carried out in a high pressure scrubber, operating at a pressure of approx. 140 ats. The off-gas from this scrubber contains only traces of ammonia and/or carbon dioxide. This off-gas was of a composition which was within the upper and lower explosion limits.

Stamicarbon designed this high pressure scrubber in such a way, that if this off-gas would be ignited, the high pressure vessel would not be damaged. The only damages that could occur, would be rupture of the relatively cheap internals, which could be replaced easily.

The events which took place

The first explosion took place in February, 1974. The exact moment at which the explosion occurred could not be traced. The performance of the plant was hardly influenced by this explosion. After detection that there might have taken place an explosion in the high pressure scrubber, the plant was shut down, and the top cover of the scrubber was lifted. Within 4 days after plant shut down, the plant was back on stream again.

The internals had been damaged as can be seen in Figure 1.

A second explosion took place in the same plant in April 1974. The damages to the internals of the high pressure scrubber were basically similar to the damages caused by the first explosion.

Source of ignition

The most probable ignition source for the two cases has been the presence of oil traces in the absorption part of the scrubber. If the off-gas does not contain any ammonia and/or carbon dioxide, the partial pressure of oxygen in this off-gas would be between 300 and 350 lb./sq.in. gauge in case the anticorrosion oxygen is introduced in the carbon dioxide feed in the form of air.

Laboratory tests have demonstrated that the flame-point of oil will be lower if the partial oxygen pressure is increased. From this phenomenon we believe we might conclude that oil acted as the ignition source.

Explosion prevention measures

There were basically 3 methods for explosion prevention:

a. removal of hydrogen from the carbon dioxide feed stream.

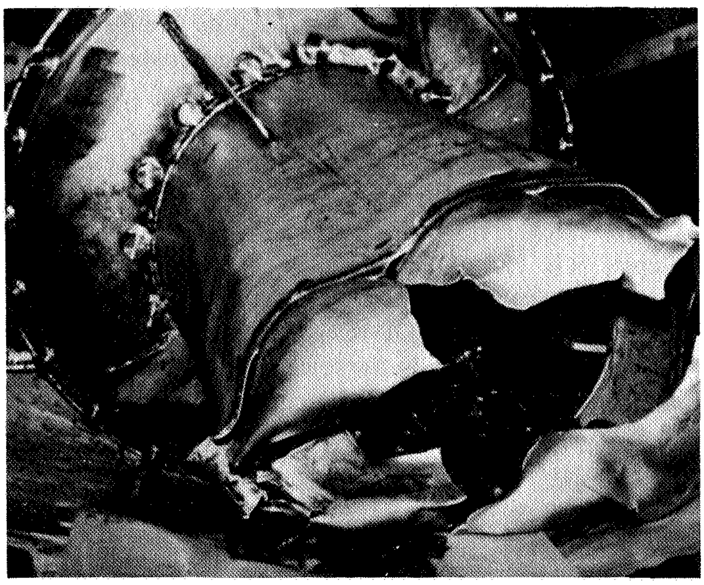

Figure 1. Damaged internals.

b. elimination of ignition sources.

c. avoiding explosive gas mixtures in presence of high partial oxygen pressures.

Removal of hydrogen from the carbon dioxide feed was expensive, as additional to the investment to be made for the catalytic hydrogen removal system, extra investments had to be made in the H.P. scrubber due to higher inert contents in the reactor off-gas (if air is used for combustion of the hydrogen, for every 1% by volume of hydrogen, 2% by volume of nitrogen are introduced).

Elimination of the possible presence of oil in the high pressure scrubber was unrealistic, especially where this plant was using a reciprocating carbon dioxide compressor.

Stamicarbon decided to change the operating conditions in the high pressure scrubber in such a way that the scrubber off-gas would not be within the explosive limits. This resulted in an off-gas containing ammonia and carbon dioxide. Further reduction of the ammonia and carbon dioxide content of this off-gas will be carried out in an absorption system operated at a pressure of only some atmospheres.

The partial oxygen pressure of the vent gas is therefore considerably reduced. Stamicarbon has ample experience of safe operation with hydrogen-air mixtures at pressures below 18 ats in many plants all over the world. #