FINAL REPORT

ACCIDENT DESCRIPTION

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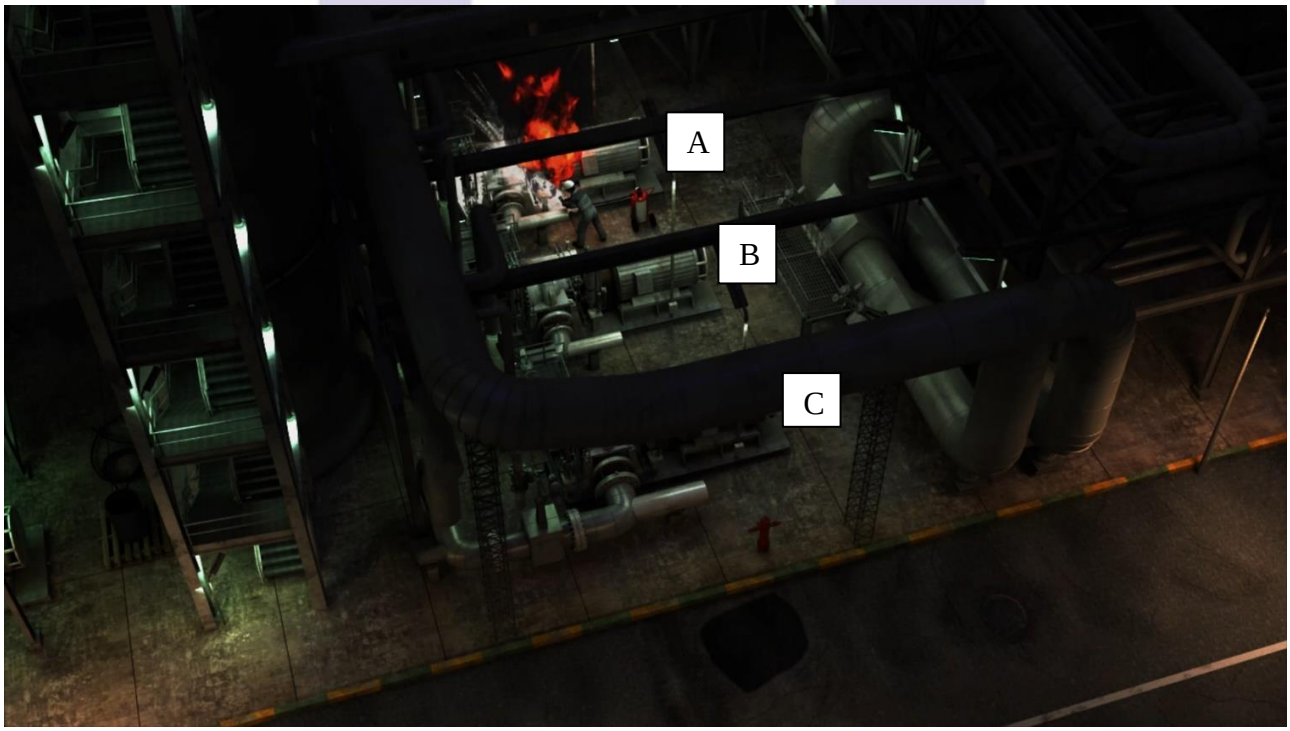
Root Causes
Causes of leakage
Causes of Fire Spread

ACCIDENT DESCRIPTION

In this petrochemical complex, 3 pumps 8001A/B/C are used to transfer the paraxylene liquid to the aromatic tower. The temperature of the paraxylene liquid after the pump is about 300 degrees Celsius and its pressure is 10 bar. The suction and discharge valves of these pumps are 32- and 20-inches manual, and for moving the thread up and down, the handwheel of the gearbox must be turned about 24 times. For this reason, a long time ago, it was decided to use an electric motor gearbox to open and close each valve. But the electric gearbox, while being more expensive, became defective after some time of use and was no longer able to close the valves completely. Therefore, to move the last threads, the operators removed the electric motor gearbox and installed a manual gearbox on each valve. In this way, four manual gearboxes and two electric motor gearboxes were installed on these pumps. For isolation each pump, at first the electric motor gearbox should be installed on the relevant valve and after closing the valve, the electric motor gearbox was removed and then the manual gearbox was installed to completely close the valve.



Under normal operating conditions, two pumps were in service and one pump was in standby mode. On June 22, 2016 pump A had a leak which leading to a fire, but fortunately this fire was extinguished by the operators and firefighting team.

12 days later, this pump leaked again, and it was decided to send it to the workshop for repairs. But when the maintenance team was installing the blind flange, a leakage occurred from the discharge valve. Two repairmen wore special clothes and breathing apparatus and then installed the blind flange and fixed the leak with great effort.

In the morning of July 6, 2016, which was holyday, an operator noticed the leakage from pump C and reported it. As a result, the pump was turned off to be sent to the repair workshop. To prevent leakage, it was necessary to isolate the pump and close the suction and discharge valves completely. Therefore, the valves were first closed with the electric gearbox. Then they waited for the repairman to remove the electric gearbox and replace the manual gearbox. Because of the lack of a manual gearbox, he had to use the manual gearbox of pump A.

At first, he turned the handwheel of the valve in the direction of opening, so that it came out of the locked state, then by opening the related nuts and hitting the valve a few times, he removed the gearbox. Then the repairman removed the electric motor gearbox from the discharge of pump C and replaced the manual gearbox, after that he installed the electric motor gearbox on the discharge of pump A. Then he was going to remove the manual gearbox of suction of pump A and install that on suction of pump C. Suddenly, the discharge valve of pump A opened and its stem rose, but there was no leakage and the blind flange stopped the fluid to pass through. In other words, with the missing of the process isolation, the mechanical isolation worked properly. The repairman turned the handwheel of the gearbox motor installed on suction valve of pump A, but suddenly, a strong leak was detected on blind flange. In other words, in this valve, the isolation process was working correctly and the mechanical isolation

was incomplete, and when a small amount of the valve was opened, the process isolation was lost and the fluid leaked out.

By ejecting the paraxylene liquid with a temperature of 300 degrees Celsius and a pressure of 10 bar from the suction flange of the pump 8001 A, a cloud of toxic and explosive gas quickly covered the unit area. The intensity of the leak was so great that it was not possible to approach the defective valve without a mask. For this reason, the repairmen couldn't breathe and had to escape. The operators present at the place also tried to prevent the cloud of gas from reaching the heating furnaces by creating a water curtain and dilution before the arrival of the firefighters. But low water pressure prevented this operation. After about 5 minutes the explosive mixture reached a spark source such as furnace burners or perhaps the exhaust of a crane located on the site and exploded. The flames spread on the ground and around the pumps and shot out from the flange of the pump's suction pipe in the form of jet fire.

The operators present at the site informed the control room and they quickly started reducing the production capacity. Firefighters deployed a Tiger monitor and the only fire engine of the complex in two places far from the fire and started spraying water and cooling the equipment. A few minutes later, help was requested from the fire department of the special area and a fire engine was sent to the complex, deployed in a suitable place and started cooling the equipment. Unfortunately, due to the lack of water pressure in the first minutes and also the small number of fire engines, the cooling of the pipelines could not be done sufficiently, and therefore about 20 minutes after the first explosion and about at 17:35, another explosion occurred and half of the tower was on fire. The second explosion caused people near the place to be thrown around and the firemen decided to retreat. Unfortunately, at the first moments of the accident, the main pipe rack of the unit, which was located on top of these pumps, caught fire.

This caused the pipes to burst one by one every few minutes and the volume of the fire increased. After the second explosion at around 17:35, the operator emergency shut down the units and left the control room. At the same time as the feed was cut off and one of the XV valves of the aromatic unit was closed, a severe leak

occurred from its flange gasket and immediately caused another fire in this unit. This fire was located exactly below the power cable protecting the transformers of the complex; therefore, the fire caused the cable to burn and the power of the entire complex cut off. Fortunately, the pipes containing flammable liquids such as HTN, LPG and hydrogen, which were on this pipe rack, were not damaged, and before the rupture of these pipes and the spread of the accident, the fire was extinguished. At around 17:44, another explosion occurred and all 127 meters of the tower were on fire, and the flames reached a height of 170 meters.

Since the order to evacuate the complex was issued before this accident, upon hearing the sound of the explosion, everyone except few people left the complex. The fire caused instrument air pipeline rupture. When the power cut, some mechanical equipment and control system shutdown and also the boardmen left the control room. All these made the control of the unit difficult and almost impossible.

Rupture of instruments line caused all of the deluge valves, especially in the part of the tanks that was in auto state, came into service, and this caused the water pressure of the fire department to decrease and firefighter couldn't cool the tower completely.

By asking help from all the around complexes, many fire engines entered the complex, none of them could get close to the fire because of the fear of the tower falling. If the tower fell in any direction, there were other explosions and the shrapnel could damage people and other equipment. But fortunately, the base of the tower was resistant against the fire and prevent a tragedy.

After about half an hour when the tower was completely on fire, a loud whistle was heard from the tower and suddenly there was an explosion with a terrible sound. The tower ruptured from the middle part and fire was coming out from that place. This explosion caused flaming insulation, various metal pieces and even pieces of the tower tray to be thrown around and far away. These hot and flaming objects entered the naphtha floating roof storage tanks and caused tanks A and C to catch fire.

After some time, firefighters and a number of operators entered the complex and closed the deluge valves of the other tanks and then they extinguished the fire.

Fortunately, with the effective actions, chain explosions in other sensitive equipment such as reactors and absorption towers were prevented.

The fire of the tower was under control at around 2:00 AM and at 6:30 AM the fire of the tower and pumps was completely extinguished. Tank A, was extinguished after injecting foam into its rim seal area at 9:00 AM But unfortunately, tank C went out of control and finally tank roof sank and the entire tank was destroyed after burning for three days. Finally, after 60 hours, the fire was completely extinguished at 3:20 AM on Saturday.

This accident caused damage of over 100 million euros and fortunately did not have any loss of life.

CAUSES OF THE ACCIDENT

In this accident, there are three categories of causes:

- Root causes
- Causes of leakage
- Causes of fire spread

Root Causes

Ignoring accidents and near misses. The repetition of leakage from these three pumps caused the leakage be considered as a simple issue and insignificant event. So, the fire accident of pump A occurred on two weeks ago, was not enough motive and no effective action was taken to prevent the similar accident.

High-risk repair work turned into routine. Weaknesses in the pump design calculations, as well as the purchase of non-original mechanical seals, caused mechanical seals to be replaced five times a year instead every three years, therefore this high-risk repair work turned into routine.

Failure to follow the change management requirements. Since these valves were 32- and 20-inches manual, for moving the thread up and down, the handwheel must be turned about 24 times. This work took more than an hour for each valve and to simplify that, an electrical motor gearbox was used to open and close the valve without any standard instructions.

Lack of experienced worker and qualified equipment. The use of handmade blind flange in this complex had become quite common and also the electrical gearbox motor could not be adjusted to close the valve completely and there were not enough manual gearboxes for all valves. The use of inexperienced and unskilled repairmen for cost-saving is another example of this root cause.

Failure to follow the maintenance and repair requirements and permit to work system. For any repair work an instruction must be prepared. According to the risks involved, presence of the repair manager is required for inspection and safe operation. According to the mechanical insulation instructions, the standard blind flange should be fully bolted. Indeed, work permit had been issued for replacing the electric motor of pump C with manual gearbox, but at the time of the work, the gearbox of pump A was removed without any work permit.

Production oriented. Lack of attention to safety requirements, procurement of substandard materials, lack of maintenance and operational equipment, ignore the warnings of operators and production-oriented caused the complex staff didn't pay attention to a high-risk activity and think that if they stop a dangerous activity, they will be reprimanded instead of being encouraged.

Causes of Leakage Spread

On the day of the accident, which was holiday, experienced repairmen were not present in the complex, so it was decided to invite a person with little experience and salary to open the valve. Due to the lack of instructions, he was asked to remove the manual gearbox from the valve that isolated the line and replace the electric motor gearbox that was installed on the failed pump. In the past, this replacement did not cause leakage. Perhaps the reason was that when a manual gearbox was removed from a valve to install an electric motor gearbox, the corresponding pump was connected to the pipeline and as a result no leakage occurred. But on the day of the accident, opening and closing the manual gearbox, had not been investigated and the unskilled repairmen had not any information about the accident had occurred two days ago. So, he started to remove the

manual gearbox. In the incident had occurred two days ago, the mechanical repair men, had worn special clothes and breathing apparatus to install the blind flange.

On the day of the accident, although one of the operators warned about opening the manual gearbox, other people thought that the valve was leaking two days ago and the pressure before and after the valve was the same, so removing the manual gearbox was not dangerous.

The repairman had to move up two threads of the valve to remove the manual gearbox. By opening the discharge valve and removing the manual gearbox, the valve suddenly opened completely due to the back pressure.

This incident indicated that the operator's perception was wrong. Because if the pressure on both sides of the valve was the same, the disc would not move upwards. Unfortunately, the observation of this incident did not cause to stop the operation and it was thought that the blind flange is reliable enough. After this, the repairman tried to open the manual gearbox of the suction valve. After turning the handwheel of the gearbox, the valve suddenly opened and the high-temperature and high-pressure liquid hit the non-standard blind flange and caused leakage. These blind flanges were handmade, and not only it was not possible to be fully bolted, but also it was not properly placed in the flange. No one could stand against toxic liquid with a temperature of 300 degrees Celsius and a pressure of 10 bar to close the valve.

Causes of Fire Spread

Isolation a part of the fire water network around the tower. A part of fire water network was previously isolated because of leakage and the valves of another part were not fully open for unknown reasons. So, within the first two minutes of the accident, it was not possible to dilute the leak out gas or create a water curtain. At the time of extinguishing the tank, the water pressure was low, but no effective action was taken to resolve it.

Absence of firefighters at the scene to monitor and operation. As it was thought cold work was not dangerous, fire department was not requested to send a

fire engine to be on standby at the scene, so when firefighters arrived, there was not enough time to respond.

Lack of readiness of the area's firefighting units. Lack of facilities, fire engines, training and unity of crisis management and also weakness of fire water resource management.

Occurrence of this accident on a holiday. Unfortunately, the day of accident was holiday so responsible, experienced and authorized managers were not present at the time.

After the emergency shutdown, the flow of fluid in the pipe rack was stopped and this caused an acceleration in their successive rupture. Also, a large amount of hydrocarbon materials in the equipment and pipelines were sent to the flare by the control system. Unfortunately, the flare line was also installed on the same pipe rack and finally when it ruptured, the volume of the fire was greatly increased, and the flame reached more than 170 meters.

According to the research published by ASME in 2016, if a standard designed tower with the specifications of this tower, is placed in full fire for 25 minutes it will collapse. This research is based on modeling, but it is consistent with the results of the tower of this complex, which collapsed after 25 and 30 minutes.

Now we want to investigate why the storage tanks caught fire and why one of them went out of control and was completely destroyed. In the floating roof storage tank rim seals fails due to various reasons after some time. If there is a fire in the rim space for any reason, by the foam chamber or foam pourer foam should be injected into the channel around the rim seal as soon as possible. Various experiences shows that this type of fire is completely extinguished after half an hour to a maximum of one hour. After injecting the foam and reducing the volume of the fire, the firemen should go to the top of the tank to control and extinguish possible rest fire from the wall of the tank.

The fire and explosion in the tower body caused flaming insulators and hot metal parts to fall around and inside these storage tanks. Since the mechanical seals had

problems, the leakage of hydrocarbon materials from the sealing space was extremely high. When hot or flaming objects fell into or near this space, the tank caught fire. However, since the volume of the tower fire was very large and on the other hand, the number of vehicles and fire fighters were very limited, these two storage tanks, didn't receive enough attention in the first minutes and even hours. The extent of the fire, weakness of the command and lack of familiarity with how to extinguish this type of storage tanks caused It took 14 hours to extinguish the fire. About 2 hours after using the correct extinguishing method, with injecting foam from foam risers of "tank A",fire was completely extinguished in at 8:30 AM on Thursday.

But "Tank C" had more liquid volume than "Tank A" and was almost full. The pictures taken from the extinguishing operation of "Tank C" before 9:00 AM shows that despite after 15 hours and destruction of the metal seals, the fire was controllable and it was only necessary that firemen went up to the top of the tank with water protection and extinguished the fires of breathing valves and part of the rim seal. But the lack of an experienced commander, experienced firefighting teams, suitable foam, sufficient facilities and especially the one-hour stoppage of foam injection caused the fire to increase and get out of control. As a result, the floating roof sank and it was no longer possible to extinguish it and it was necessary to allow all its hydrocarbons to burn. Of course, a number of brave operators of the unit, under the heat of the fire and possible dangers, were able to empty some of the materials of the storage tank from the bottom to another tank, although this action reduced the time of the fire, but unfortunately, it could not save the storage tank.