Recent Safety Experiences

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ABSTRACT

During the past few years, several oilseed solvent extraction plants have had severe explosions and fires causing death, injury and property damage. One city had part of its sewer system destroyed by a hexane explosion resulting from a solvent spill from an extraction plant into the sewer. This paper discusses a few of these incidents and how to prevent future disasters by new plant process designs, operation and safety procedures.

I received a call from Quincy Soybean Company, September 1966, that they just had an ignition of hexane vapors in their soybean solvent extraction plant. They had summoned the fire department and while a fireman was pouring water into the Rotocel extractor, there was a second flash, one hour after the first one. This flash was an explosion from inside the extractor. Quincy Soybean Company then made an excellent decision to abandon the solvent plant. They called me to come to Quincy as fast as possible. However, 12 hours after the call, and before I arrived, there was a third tremendous explosion, destroying the Rotocel and the building housing it. Fortunately, there were no fatalities or injuries since orders were given to evacuate the plant.

Briefly, this is what occurred causing this incident. The plant was stopped and emptied for maintenance but the extractor and plant had not been purged of hexane. The large door used to enter the extractor was removed and the elevator taking extracted flakes from the extractor was being repaired. New conveying flights were installed using an open electric motor impact wrench instead of an air motor driven wrench to remove and replace the bolts. The electric motor driven wrench caused the first ignition and this fire started a smoldering fire of the dust and flakes that had built up over years of operation on the walls and top of the extractor. The smoldering fire continued to burn, and when the concentration of hexane and air inside the extractor exceeded the lower explosive limit of 1.2% hexane by volume, the second explosion occurred. The hexane fuel was consumed by this explosion but soon the hexane concentration built up again to the explosive range of 1.2-6.9% hexane in air and was ignited by the smoldering fire still burning inside the unit. This final explosion had enough force to raise the extractor top 4 m, rupture the bottom and sides of the unit and blow the building siding 200 m to a nearby highway. I inspected the plant the next day and while climbing through the twisted rubble, noticed that the outlet valve from a large elevated solvent tank feeding the extractor had been left open. This explained how hexane vapors kept entering the extractor after the first flash to feed the second and third explosions.

I was assigned by Blaw-Knox to rebuild the plant. At that time, I thought that if steam could have been sent to the extractor after the first fire ignition, the second and third explosions could have been prevented. I therefore installed three 2-in. steam lines equally spaced, 1 m above the bottom of the extractor and also steam lines at the discharge hopper and the top of the extracted flake elevator taking solvent wet flakes from the extractor to the desolventizer. These five lines were connected to a single pipe header and this pipe was extended outside the controlled area. A box was constructed around this pipe along with two block valves, and a bleeder valve was placed between these valves. A sign was placed on the door of the box stating "emergency smothering steam." Now if there was a smoldering fire inside the extractor, all personnel could quickly and safely leave the plant, go to the smothering steam box, turn on steam and quickly snuff out the fire.

At 09.30 on March 26, 1982, I received a call from Delta Cotton Oil Company in Jackson, MS. They had a fire in the extraction plant the previous day, and a second explosion just 30 minutes later. Finally at 08.30, the morning of March 26, there was a third explosion, killing one man, very seriously injuring a second, and hurting four others. I was told there was confusion, there was concern about the possibility of more explosions and could I come immediately. Does not this scenario of three explosions at Jackson sound similar to the three explosions of the Quincy incident in 1966?

I was able to make a good plane connection, arrived in Jackson at 12.30, taken very quickly to the plant by a police car and was then informed of what had happened. The Rotocel extractor had failed under load at 02.00 the previous day and the large entry door on the bottom side of the unit had been removed. They found a cell door hinge pin had worked loose, coming partially out, which caused the extractor to stop. The extractor, still full of cottonseed cake and flammable hexane, could not be turned by its drive motor. The motor wire leads were reversed, the extractor run backwards until the door with the problem was over the discharge hopper and then the motor was stopped. The hinge pin and door were removed from the extractor at 05.00 and preparations were made to install a new door. I might add that this entire procedure is a very dangerous one since hexane solvent vapors are continuously pouring out of the extractor, mixing with air, and if there is a source of ignition, a fire, explosion or both could result. At 08.30, without any warning, there was ignition of hexane and a fire resulted. No one was hurt and the sprinkler system put out the fire. But then at 09.00, there was an explosion which injured two, destroyed the building roof and damaged the extractor and other equipment. The Jackson Fire Department arrived, ordered that the large entry door be reinstalled on the extractor and proceeded to add water to the top of the unit. They planned to fill this 5-m high vessel full of water, but could only fill it to a level of ½ m, since the extractor is not a pressure vessel and the sides would have burst. The next morning, thinking the fire was out, Delta employees slowly started to remove the large extractor entry door, 0.6 m wide and 1.2 m high. As soon as it was removed far enough to let in some air, there was a third terrible explosion. This blast formed the door in a large "C". The center of the "C" smashed the head of the worker who was removing the door, killing him instantly. A supervisor was also burned over 75% of his body and he died a painful death 16 days later in a nearby burn center. Two other workers were injured and the plant was again damaged. The fire department and the emergency team assigned to the disaster panicked, since they thought the fire had been put out and they did not know what to do next.

After discussing the situation with them at the plant site, I was dressed in a fireman's suit and entered the plant with a fire chief. This was at 14.30, and no one had been in the plant for the past 6 hours. The sprinkler system was still in operation and its flow was so great it was hard to breathe and see. I was horrified upon entering to see a fire burning in the back of the plant which was about 1 m high and 2 m

long, even with the sprinkler system running. We walked to the fire and noticed it was coming from a pump packing gland. What was burning was miscella from a miscella tank full of hexane and cottonseed oil. I tried to close the valves to and from the pump but they could not be turned. The plant was 29 years old and the plug valves used in the plant were inoperable. We made many nervous trips into the building, getting more firemen to enter with us each time. We turned the sprinkler system off so we could see better, but the fire increased to a height of 2 m and a length of 4 m. I then asked the fire department to extinguish the fire with chemicals but they refused, stating it was safer to have the fire burning than to put it out. I disagreed and argued with them, but they still refused to put out the fire. I then climbed to the top of the extractor and walked to the miscella tank with the sprinkler system on and the fire still burning. I noticed a ½-in. water line to a water seal connected to the miscella tank and located above it. I reasoned that if water was turned on, it would flow to the bottom of the miscella tank, displace the hexane/oil miscella in the tank, feed water to the pump and thus put out the fire. The water flow was started at 16.00 and at 21.00 the miscella fire was out. But when I went to the top of the Rotocel to make a final inspection, I noticed there was still a smoldering fire inside, smoke exiting from the top and the extractor top was still hot.

The next day, arrangements were made to connect two hoses to steam lines in the plant. The boiler was fired, and steam was introduced into the bottom of the extractor through the two hoses. The extractor was throughly steam purged for 6 hours and at 17.00 on March 27, 1982, the fire was officially out.

I am sure you are interested in what caused these tragic explosions. The first ignition occured when no one was in the building, ruling out a spark made by operating personnel and eliminating the availability of an eye witness. An extractor stage pump, however, was located only 2 m from the extractor entry door opening that was in direct flow line of the hexane vapors coming continuously from the extractor. This pump motor was running at the time of the ignition. We noticed during an inspection of the plant a few days later that this pump motor was not of the explosion-proof type required in solvent plants but was an open-type motor. It is most probable that this motor was the initial source of ignition. The sources of ignition for the second and third explosions were the smoldering fires inside the top and sides of the extractor, caused by the first fire outside the unit. When the concentration of hexane and/or air reached the explosive limit, an explosion occurred.

Similar explosions such as at Quincy and Jackson must not happen again. These are preventable and I strongly urge that you install a smothering steam system to your extractor and solids discharge equipment from the extractor. The controls for the smothering steam should be located outside the controlled area so that steam can be turned into the plant without having personnel enter the plant, which would endanger their lives.

Steam is an excellent fire extinguisher and is readily available in a plant at all times. Make use of steam in your extraction operations. Provide smothering steam lines to critical points in your plant such as the desolventizer-toaster, drier and places where meal or cake could build up and begin to smolder. Purge the equipment with steam first before opening to extinguish possible smoldering fires. A smoldering fire can become a blazing fire when equipment is opened allowing air to reach it.

The Delta Cotton Oil plant in Jackson resumed operation on August 5, 1982. I was retained by the company to rebuild the plant. We incorporated all safety features specified by the Standard, National Fire Protection Association No. 36, Solvent Extraction Plants, 1978; we went far beyond that required by the NFPA Standard, adding new safety devices to ensure future safe plant operation.

Now I want to discuss how a water sprinkler fire protection system functions. German extraction plants do not use water sprinkler systems since German law states you are not to fight a petroleum fire with water. I feel this is wrong, and there is evidence that many German solvent extraction plants could have been saved from destruction if water sprinkler systems had been installed. Certainly the sprinkler system saved the Jackson plant from total destruction, not only from the three explosions but also controlling the miscella fire that burned for hours after the final explosion.

A sprinkler system accomplishes two important purposes: one, it cools the equipment containing solvent, reducing the amount of hexane vapors produced by the fire; and two, the water spray leaving the sprinkler heads is atomized so finely that it prevents the oxygen in the air from getting to the fire. This fine water spray thus blankets or smothers the fire.

I recommend that if you do not already have a water sprinkler system in your plant you should install one quickly. These devices are required in US solvent plants and they have saved many installations from complete destruction when there has been a fire in the system.

There occurred in Louisville, KY, probably the most violent and damaging hexane explosion on record. This happened at 05.16 on Friday, February 13, 1981. No one was killed and there were only four people hurt with only minor injuries. However, about 10 km of the Louisville sewer system was destroyed, as were highways, roads, homes and businesses. Some areas of Louisville did not have sewage services for a year. If the explosion had happened a few hours later during the morning rush hour, hundreds of people would have been killed and injured.

The explosion was in the sewer system 10 m below ground. Roads above the blasts were buckled, craters 8 m in diameter were formed, pavements were destroyed and pieces of concrete were thrust into the air causing a great deal of damage. The concrete sewers in some places that were 4 m wide, 3 m high and 1 m thick and with 7 m of earth on top were actually moved sideways ½ m. The top of the sewer was split apart about 20 cm, breaking the reinforcing steel like matchsticks. In some places, the top of the sewer was split into three longitudinal lengths. I walked the sewers for 7 km and was appalled by the extent of the damage in the sewer system.

I am not permitted to provide too many specific details about this explosion, since I have been retained by the City of Louisville and Sewer District as their expert. Basically, here is what happened. The Ralston Purina soybean plant shut down due to a mechanical breakdown of equipment. The outside temperature that day had dropped to -26 C and when they attempted to restart the plant on February 12, 1981, this frigid weather caused them numerous problems. During the start-up process, hexane began to exit from the plant to the city sewer system. Chemical Week magazine in its January 13, 1982 article reported that US federal attorneys stated they could prove that as much as 68,000 L (18,000 gal) was released into the sewer. The plant was stopped about 01.00, February 13, but the detonation of hexane in the sewers was about 2 km downstream from the solvent plant and was possibly caused by an automobile. The initial explosion set off about 15-20 additional ones. There was fear that the sewage treatment plant for Metropolitan Louisville might explode so all sewage from the city

was diverted directly to the Ohio River. Officials could not take the chance of losing the sewage plant to an explosion which would mean that over 1 million people would not have sewage treatment services for well over a year. I believe you can now understand the magnitude of the Louisville explosion and the health problems that could have resulted. What actually occurred was serious enough.

A US Federal Grand Jury was convened in Louisville on March 1, 1981 and was installed for a period of 10 months. Several Ralston Purina employees faced possible criminal indictments. On December 29, 1981, Ralston Purina was convicted under provisions of the US Comprehensive Environmental Response, Compensation and Liability Act of 1980. Ralston pleaded guilty in the US District Court in Louisville to four separate criminal counts which were: (a) discharging hexane into the Ohio River; (b) failing to report to federal officials the release of a hazardous material; (c) introducing a flammable substance into the Louisville sewers; and (d) introducing an explosive substance into the Louisville sewers. For these four counts, Ralston Purina was fined $62,500 and the US Government dropped their criminal indictments against the Ralston employees. Still pending are many civil suits totalling over $300 million.

Could a similar explosion happen again in a sewer system? Certainly. How could such a disaster be prevented? By installation of simple and inexpensive instrumentation to shut down the plant automatically in case of a plant upset. If plant personnel will not shut down a plant when it is out of equilibrium, then take this decision out of their control and shut the plant down for them.

Three serious plant incidents have been discussed. Many lessons can be learned from them so they will not be repeated. I have been personally involved in four other major solvent plant explosions. I hope I will have the opportunity to discuss and share these experiences with you at a future date.