Anatomy of a Waste Water Tank Explosion

An Online Continuing Education Course for Engineers

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Anatomy of a Waste Water Tank Explosion

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Introduction – This Is What I Am Going To Tell You

The waste-water tank explosion that I am going to tell you about happened at a sugar refinery in the late 1990s. The tank explosion was actually the last in a series of four explosions. An expansion of the sugar refinery's treatment facilities for process waste water was underway at the time the explosions occurred. Although construction was still going on, some of the new equipment was already in use. In particular, the process waste water was draining into a new underground sump and was being pumped from there up into a new aboveground aeration tank.

A sump is a relatively low place that collects water or other liquids by gravity flow. A pump, naturally referred to as a sump pump, is used to pump the water out of the sump for treatment or disposal or some other disposition. It is not uncommon for a house with a basement to have a sump in it. The sump collects any unwanted water that might enter the house due to rain or plumbing leaks or whatever. A sump pump is used to pump the water out of the house. Typically, the pump turns on automatically whenever water in the sump rises to a certain specified upper limit. The pump turns off when the sump is empty or the water level falls to a certain specified lower limit.

At the sugar refinery in this account, a rented submersible pump was being used to pump the waste water up out of the new underground sump and into a new aboveground aeration tank. The purpose of aerating the sugar refinery's process waste water was to strip out volatile hydrocarbon gases that were dissolved in the water. At that time, however, the new aeration equipment had not yet been commissioned. Consequently, the would-be aeration tank was temporarily being used as merely a holding tank. The waste water, which would be cleaner in the future after aeration had begun, flowed out of the tank by gravity through an outlet standpipe located inside the tank, like in a toilet tank. The water flowed into the open top of the standpipe and down its interior wall to intersect with the underground sump overflow pipe, which connected into the city storm sewer system.

According to three eyewitnesses, at about 4:30 in the afternoon of May 27, an explosion inside the sump blew the sump cover open, crashing it into a nearby control panel. Then the eyewitnesses heard rumbling and felt ground vibrations. Next, the roof of the tank ballooned, and the tank wall partially collapsed into a scalloped pattern around its circumference, at the seam between the tank wall and the tank roof. Ultimately, the tank split open along the seam

between the roof and the wall. These events occurred over a period of about three to five seconds.

Shown below is a photograph of the aeration tank after the explosion:

Two other men and I teamed up and determined the cause and origin of the explosions. One of the men was an industrial engineer, and the other was an electrical engineer. I am a chemical engineer. In the course of our investigation, we met with refinery management and technical staff. We inspected and photographed the explosion site and all the equipment involved; that is to say, the tank, the sump pump, the piping, and so forth. We interviewed the three eyewitnesses. We reviewed process flow diagrams and construction drawings. We obtained samples of the refinery's process waste water for subsequent laboratory qualitative analysis, and we analyzed the results of the laboratory tests. We also disassembled the rented sump pump and inspected it for any evidence that might point to the pump as having been the source of ignition.

We ultimately determined that water had leaked into the sump pump motor housing and caused an electrical short circuit. It resulted in an electrical explosion inside the motor wiring compartment. The arc associated with the electrical explosion blew through the motor lead epoxy seal and ignited flammable gases occupying the vapor space of the sump. The resulting

sump gas explosion blew the sump cover open. This explosion was the first of three gas explosions that resulted from the electrical explosion in the sump pump motor wiring.

The rumbling was the second gas explosion, which occurred inside the piping. The flame front of this explosion originated in the sump and traveled through the sump overflow pipe. This pipe made an underground upside-down T intersection with the tank outflow standpipe on its way to the city storm sewer. When the flame front of the second gas explosion reached this intersection, it branched and traveled up through the tank standpipe, as the standpipe also contained an explosive concentration of gases. The third gas explosion was the one that occurred in the overhead vapor space of the tank. Of the three gas explosions, this one caused the most damage.

In my opinion the pump should not have been used until the aeration system was commissioned. It is also my opinion that if aeration had been going on, the volatile gases would probably not have reached explosive concentrations in the tank vapor space. Moreover, we concluded that there was not any reason to have been running the sump pump in the first place, unless the refinery staff were running it to check out things like whether it turned on and off at the selected water levels in the sump.

Discussion – This Is What I Am Telling You

The Planned Facility

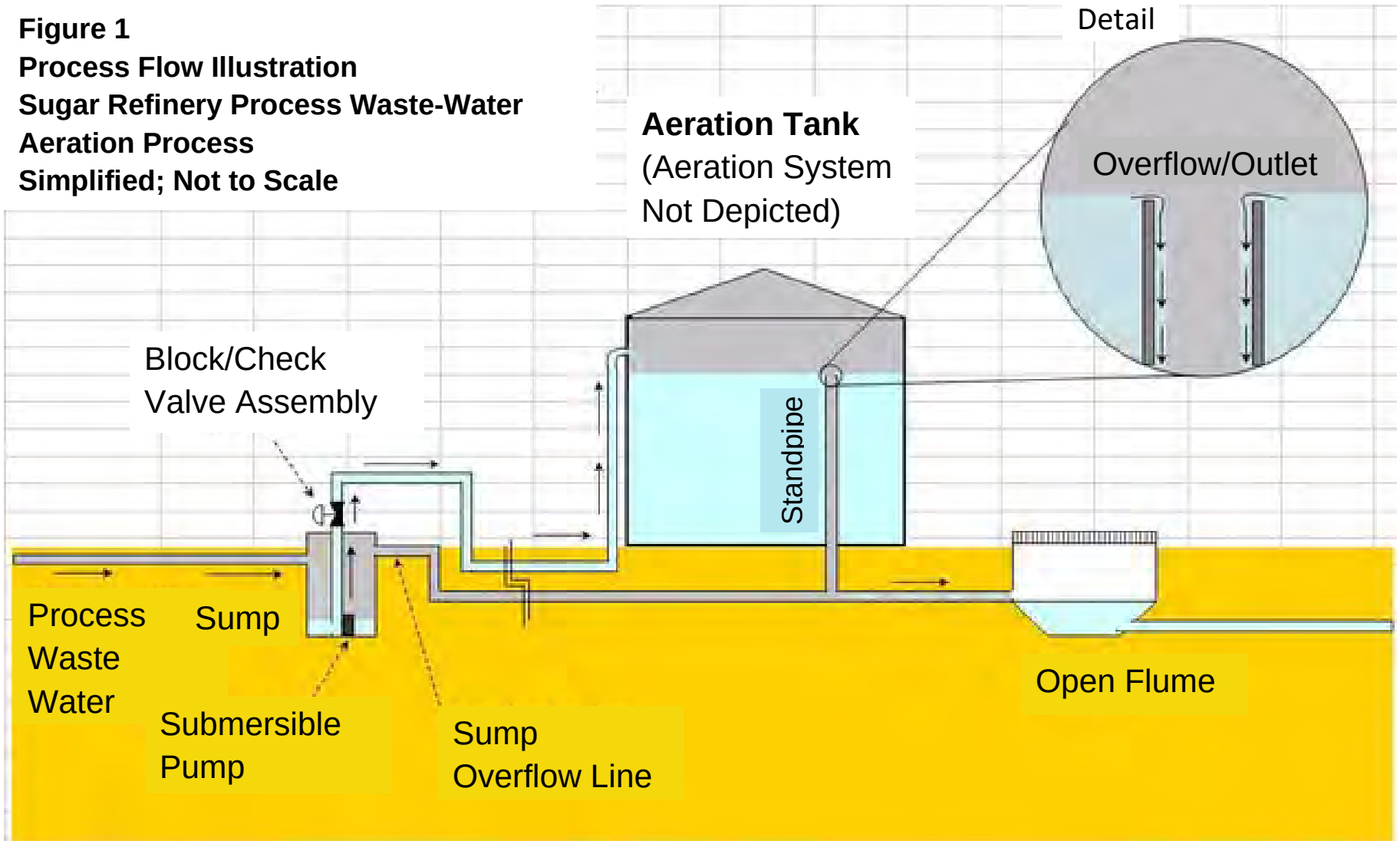
The sugar refinery in this account was constructing new treatment facilities for process waste water when the new waste-water-aeration tank blew up. The new facilities were to include:

- the new aeration tank referenced above and a new pH-neutralization tank, piped together in such a manner as to allow the two tanks to be used in series or in parallel, as desired;
- a new underground sump that would receive refinery process waste water;
- a new submersible sump pump;
- water-circulation pumps associated with the aeration tank; and,
- various other equipment and piping required to aerate the process waste water before routing it to the city storm sewer.

The Aeration Tank

The new aeration tank was a large aboveground tank with a cone-shaped roof. At the time it was functioning only as a temporary holding tank, because the aeration system had not yet been commissioned. Process waste water exited the tank by gravity overflow into the open top end of a 22-foot-tall standpipe that was located inside the tank, like in a toilet. The standpipe made an upside-down T intersection with the underground sump overflow pipe. This overflow pipe ran to a below-grade flume that was open to the atmosphere. The flume drained into piping that emptied into the city storm sewer. This configuration is simplistically illustrated in Figure 1 shown below.

Figure 1
Process Flow Illustration
Sugar Refinery Process Waste-Water
Aeration Process
Simplified; Not to Scale



Status of the Sugar Refinery's Treatment Facilities for Process Waste Water on the Day the Explosions Occurred

Immediately prior to the explosions, the new underground sump was receiving process waste water. The water was being pumped out of the sump and up into the new aboveground aeration tank. As said before, the aeration equipment had not yet been commissioned, and thus the tank was serving only as a holding tank. (In my opinion the pump should not have been used until the aeration system was commissioned. It is also my opinion that if aeration had been going on, the volatile gases would probably not have reached explosive concentrations in the tank vapor space.) The water was being pumped out of the sump with a rented submersible sump pump, which we later learned had not been inspected before being put into service. The new pH-neutralization tank was not in service and, process-wise, it was isolated from the aeration tank. Construction activities were focused on installing the water-circulation pumps. The torch-cutting that was associated with this work had ceased about one and a half hours prior to the explosions.

By design, and at the time of the incident, the new sump was receiving process waste water streams from the sugar refinery complex as identified below:

1. Waste water from the char house area of the refinery – bone char is the result of burning bones in the absence of oxygen. Intimate contact of sugar with bone char removes the color from sugar.
2. Waste water from other plant systems and areas:
    - rain;
    - water-cooling tower blow-down;
    - the automotive garage;
    - the machine shop; and,
    - the laboratory.

The Sequence of Events

Statements of the three eyewitnesses to the incident consistently support the following sequence of events:

1. The sump explosion occurred, blowing the sump cover open.
2. The eyewitnesses heard rumbling and felt ground vibration, and they saw pipes shaking.
3. The new tank blew up.

We ultimately determined that an electrical short circuit in the sump pump motor wiring had caused an electrical explosion. This was the source of ignition for the explosion of a mixture of air and flammable gases that occupied the vapor space of the sump. The electrical explosion and the sump gas explosion were apparently perceived as only one explosion by the eyewitnesses, probably because the explosions occurred so close together in time. The explosion of the sump gas was the first of three gas explosions. Based on our investigation, we concluded that:

- The rumbling was the [illegible] inside the piping. The flame fron[illegible]eled through the sump overflow p[illegible]ration tank outflow standpipe.[illegible]ough the standpipe, as it also contain[illegible] overhead vapor space of the tank.
- When the fla[illegible] tank, the gases there also exploded. T[illegible] the most damage of the three gas exp[illegible]

This triple-gas-explosi[illegible]