

## **Refinery Damage and Emergency Response in the 1999 Izmit, Turkey Earthquake**

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In the early morning hours of August 17, 1999, an earthquake of magnitude 7.4 struck, within a few miles of major petrochemical facilities on Izmit Bay. The earthquake was a major catastrophe, with a death count of approximately 18,000 officially, and > 40,000 unofficially.

Turkey's largest refinery, designed and built by U.S. companies, experienced major structural collapses and oil spills. The refinery made international news because of fires that burned out of control for more than 3 days, forcing evacuation of areas where search and rescue missions were still taking place.

The author was a member of the U.S. investigative team, sponsored by FEMA and the NSF and spent 10 days in Turkey immediately after the earthquake. This paper presents damage observed as well as findings from follow-up visits. Detailed descriptions are presented of the emergency response to the fires. This earthquake is particularly important because it is probably the first time that a major earthquake has struck so close to large refineries and chemical plants.

### **Tupras Refinery**

The state owned oil company, Tupras, operates 4 refineries in Turkey, with the largest located in Korfez, about 80 km east of Istanbul. This is Turkey's largest refinery, and is responsible for about 1/3 of all of Turkey's oil production. This refinery produces about 220,000 barrels per day, which would be considered a "large" refinery by California standards. It also serves as the principal port for LPG import and distribution.

The refinery was initially built in 1961 and was owned and operated by Caltex for 10 years. Major expansions have taken place in the 70s and 80s. The refinery has largely been designed to international standards and with quality control typical of multinational industrial facilities. The enormous problems of construction quality evident in residential construction are not applicable to these types of facilities.

This refinery experienced perhaps the most widely publicized and spectacular damage to any industrial facility in any earthquake. Refinery fires were burning out of control for several days, forcing evacuation of a large area around the refinery. In addition, the refinery had to deal with oil spills and structural collapses.

The following sections summarize the performance in several areas of the facility.

### **Tank Farm Fires**

The refinery received international media attention because of tank farm fires that burned out of control for several days. The fire initially started at 4 floating roof naptha tanks. Naptha is a highly volatile material with a low flashpoint. Leakage occurred at the floating roofs when sloshing of the naptha in the tanks broke the seals. The fire was ignited from sparks from the metal to metal contact between the roof and tank wall. The fire spread through an open ditch to two additional naptha tanks the first evening. All six naptha tanks burned completely.

The fire spread to crude and product tanks, jet fuel tanks, and gasoline tanks. Most of the tanks in the storage area were heavily damaged. Some 30 of the 45 floating roof tanks in the crude and product area were heavily damaged and out of commission, primarily due to fire. Five tanks had their floating roofs completely "sink" in the tanks when the seals were damaged and contents sloshed onto the roof. Those tanks must be taken out of service and have the roofs repaired and decontaminated or replaced.

The refinery had 36,000 m<sup>3</sup> of fire water stored on site, which was all used up on the first day. The facility receives its main water supply through a dedicated pipeline from Lake Sapanca, some 45 km to the east. Due to multiple breaks in the pipeline, the refinery quickly lost all water and all fire-fighting capabilities. A total of 89 fire trucks were sent to the site in the next 3 days from neighboring municipalities and from Bulgaria and Germany. As the fire spread to additional tanks, aircraft attempted to douse the fires by dropping foam. After two days, the refinery used two diesel pumps to draw water directly from Izmit Bay to fight the fire, along with the aerial foam attack. Two more diesel pumps were added by a German response team. The fires were finally declared under control on Saturday, some 5 days after the earthquake.

There was some dispute regarding the usefulness of the aerial attack. A total of 24 sorties were performed, which we understood from Tupras were unsolicited. Some Tupras staff felt that the emulsion from the foam clogged drains and increased the oil spill problems.

While the fire was burning out of control, an area within 2 to 3 miles of the refinery was evacuated, including some areas where search and rescue operations were taking place in collapsed buildings. Train service was disrupted in the area because of the fire. The major concern was that the fire might spread to two 10,000 tonne ammonia tanks at the adjacent Igsas Fertilizer Plant. Personnel in neighboring facilities reported that in the first few days after the

immediate evacuation period, they were not allowed to leave their own facilities because authorities were not allowing anybody in or out of the area.

The tank farms were located just across a berm from some of the main processing units. One wood cooling tower located along that berm was burnt to a crisp by radiant heat. With the pipeways running into the units, it's not hard to imagine that the fire could have spread into the processing units and caused even more severe damage.

### **Crude Unit and Stack Collapse**

The other area of severe and spectacular damage in the refinery occurred in one of their three crude units, when a 115-meter high reinforced concrete heater stack collapsed. The break appeared to occur at about the height of the large diameter heater duct. The weakness at the duct opening appears to have been confirmed by further forensic research sponsored by the U.S. National Science Foundation.

The top of the stack fell into the unit, destroying the heater, while the bottom portion fell into a pipeway running around the perimeter of the unit. The destroyed pipeway was heavily congested with piping from all over the refinery. Tupras reported that 63 product and utility lines were cut. It took more than a year to identify, isolate, and repair damaged piping in this area.

One of the pipes broken by the stack collapse was a naphtha line from one of the original burning naphtha tanks in the tank farm. A fire started when the collapse occurred, and although it was extinguished relatively quickly, it flared up several times because of the new fuel from the broken pipe. The supply could not be stopped because the two block valves were at the tank, inaccessible because of the fire, and downstream from the crude unit.

The crude unit was still out of service during a return visit some 13 months after the earthquake. The stack had just been replaced, and the pipeway had been rebuilt with new pipes that were yet to be connected.

### **Port Damage and Oil Spill**

The Tupras refinery has its own private port facility. Water depth is approximately 15 meters. The wharf structure reportedly had several sheared piles at the waterline. This was attributed to a combination of earthquake loads and existing heavy corrosion.

There was evidence of ground failure at the approach to the wharf. A steel frame pipeway on the wharf structure extending out from the shore partially collapsed, with broken frame connections and severely bent members. Damage was reported to supply and return lines due to this support damage.

It appears that multiple spills may have occurred at the port. Different investigators have received different stories about causes of the spills.

As the first outside visitors to the refinery after the earthquake, we were shown where a spill reportedly occurred during transfer operations. The vessel pilot apparently panicked and moved his vessel away from the dock, ripping the transfer hose before the manual valve could be shut down.

The refinery also reported LPG leakage due to a broken loading arm, as well as spills from other damaged piping on the wharf. The refinery also reported that the drainage system for the tank farm overflowed and contributed to the spill. This was reportedly made worse by emulsion from the fire fighting efforts.

Booms were laid down in the water to try to contain the spills. However, investigators from the State Lands Commission reported that a sheen from the spill from Tupras had extended around that end of Izmit Bay, and measured oil 3-6" thick at one marina. The skimmers arrived there one week after the earthquake.

Tupras reported that they recovered 600 m<sup>3</sup> of oil from their surge ponds and 300 m<sup>3</sup> from the sea.

### **Other Fires**

One other fire occurred in a warehouse. This fire was started in the chemical storage area, where chemicals fell from shelves and mixed on the floor, causing the fire. Because the firefighting capabilities of the refinery were already stretched to their limits, this fire was allowed to burn.

### **Deaths and Injuries**

Despite the heavy damage, there were no reported deaths or injuries at Tupras. It is interesting to note that of the approximately 18,000 official deaths in the earthquake (unofficially more than 40,000) very few occurred in industrial facilities, or at least in facilities of major multi-national companies. Those that did occur there were cases where buildings collapsed on workers. In addition, we learned of two truck drivers who were killed by driving through an LPG cloud, leaking from a facility next to Tupras, and igniting it.

### **Impact on Refinery Operations**

The refinery was completely shut down for more than 3 months. We understand that portions of the refinery were brought back on-line over time, but that the acute shortage of tank storage limited operations. During a return visit 13

months after the earthquake, we were told that most of the refinery was back in operation.

### **Lessons Learned**

It has been many years, if ever, since a major earthquake has struck so near to a concentrated area of petrochemical facilities. Numerous lessons were learned with respect to the types of things that might occur. Examples include:

- Structural collapse mechanisms for major process items (chimneys and cooling towers)
- Oil spills and response
- Safety effects from chemical releases
- Unpredictable human response
- Fire fighting limitations for major refineries

Had this earthquake occurred in a similar region of the United States, any one of these items could have been considered a major issue. In this earthquake, with the enormous loss of life, these issues were lost.

This paper and presentation have been developed to disseminate this information in hopes that the lessons learned from this and other earthquakes can be understood by owners and engineers and that this knowledge can be translated into continuously improved safety and performance for new and existing facilities.



Figure 1: Housing collapses led to thousands of fatalities



Figure 2: Tank farm fires – Tupras Refinery





Figure 3: Collapsed tanks in tank farm due to fire



Figure 4: Damaged seals in tanks from sloshing of liquids



Figure 5: Collapsed 115 m (350') high reinforced concrete stack





Figure 6: Collapse of stack inside crude unit damaged large heater



Figure 7: Lower part of collapsed stack fell into pipeway, destroying pipes and structure, causing fires



Figure 8: Oil spill cleanup on Izmit Bay