

<b>Incident Title</b>		<b>Multiple LPG Storage Tanks Rupture After Earthquake</b>	
<b>Incident Type</b>		Fire and Explosion	
<b>Date</b>		11 <sup>th</sup> March 2011	
<b>Country</b>		Japan	
<b>Location</b>		Chiba	
<b>Fatalities</b>		<b>Injuries</b>	<b>Cost</b>
0		6	Unknown
<b>Incident Description</b>		<p>On 11-Mar-11, a massive earthquake measuring magnitude 9.0 on the Richter scale occurred off the east coast of Japan, triggering a huge tsunami. Both the earthquake (known as the Tohoku earthquake) and the tsunami were of unexpected severity, leaving a trail of destruction affecting multiple high hazard installations (including the Fukushima Daiichi nuclear power plant). Ground motion from the earthquake damaged support braces on a Liquefied Petroleum Gas (LPG) storage sphere (Tk 364). The tank was undergoing regulatory inspection at the time and had been filled with water to exclude air and check for leakage. An aftershock 29 minutes later caused its support legs to buckle, and the tank collapsed onto a neighbouring pipe track. An uncontrolled LPG release followed which found an unknown ignition source, initiating a major fire. The fire quickly spread to neighbouring LPG tanks causing several consecutive boiling liquid expanding vapour explosions (BLEVEs), eventually destroying all 17 tanks in the LPG tank farm. Burning missiles from the explosions also damaged nearby asphalt tanks, causing a loss of containment and spillage into the sea. The sea wall prevented the tsunami inundating the site, but the flammable LPG vapour release started fires in 2 neighbouring chemical plants (domino escalation). It took 10 days to extinguish the fires and 2 years to restore the refinery to full production.</p>	
 <p>Credit: Newscom/Alamy Stock Photo</p>			
<b>Incident Analysis</b>		<p><b>Basic cause</b> was failure of the support legs of LPG storage sphere (Tk 364) to withstand the ground acceleration forces of a severe earthquake.</p> <p><b>Critical factors</b> included: 1) Sometime before the earthquake struck, an automatic emergency block valve (EBV) on an LPG pipe had been locked open pending repair to an air supply line to its actuator, 2) Tk 364 had been full of water for 12 days when the earthquake struck (increased vulnerability due to 1.8 times higher density of water versus LPG), 3) Tk 364 collapsed onto an adjacent pipe rack (causing a release of LPG and fire), 4) The locked open EBV was not manually closed in the 29 minutes between the earthquake and aftershock (allowed leaking LPG to continuously fuel the fire), 5) Initial firefighter response was delayed (poor communication and traffic chaos).</p> <p><b>Root causes</b> included: 1) Violation of regulations (EBV locked open), 2) Inadequate seismic design (failure to account for higher vulnerability to seismic damage when tank is filled with water), 3) Inadequate maintenance planning (tank water-full for 12 days versus expected 2 to 3 days), 4) Inadequate inspection, 5) Tight equipment spacing (LPG tank farm), 6) Poor land use planning (neighbouring chemical plants too close to refinery), 7) Creeping change (ageing plant, structural decay due to earlier seismic activity)</p>	
<b>Lessons Learned</b>		<p>1) Support legs and braces on pressurised gas storage tanks in earthquake zones should be reinforced to enable them to cope with seismic effects.</p> <p>2) Safety Management Systems should include emergency response plans to deal with natural hazard ("Natech") triggers (e.g. earthquake and tsunami).</p> <p>3) Regular exercises ("gun drills") should be carried out practising quickly extinguishing fires with telecommunications and access routes compromised.</p>	
<b>More Information</b>		<p>1) <a href="https://enatech.jrc.ec.europa.eu/download/attachment/24">https://enatech.jrc.ec.europa.eu/download/attachment/24</a></p> <p>2) <a href="https://enatech.jrc.ec.europa.eu/view/natech/14">https://enatech.jrc.ec.europa.eu/view/natech/14</a></p> <p>3) "Impact of 11 March 2011, Great East Japan Earthquake and Tsunami on the Chemical Industry", E. Krausmann &amp; A-M. Cruz, Nat Hazards 67, (2013).</p>	
<b>Industry Sector</b>		<b>Process Type</b>	<b>Incident Type</b>
Oil & Gas		Liquefied Gas Storage	Fire & Explosion
<b>Equipment Category</b>		<b>Equipment Class</b>	<b>Equipment Type</b>
Mechanical		Vessel	Storage Sphere