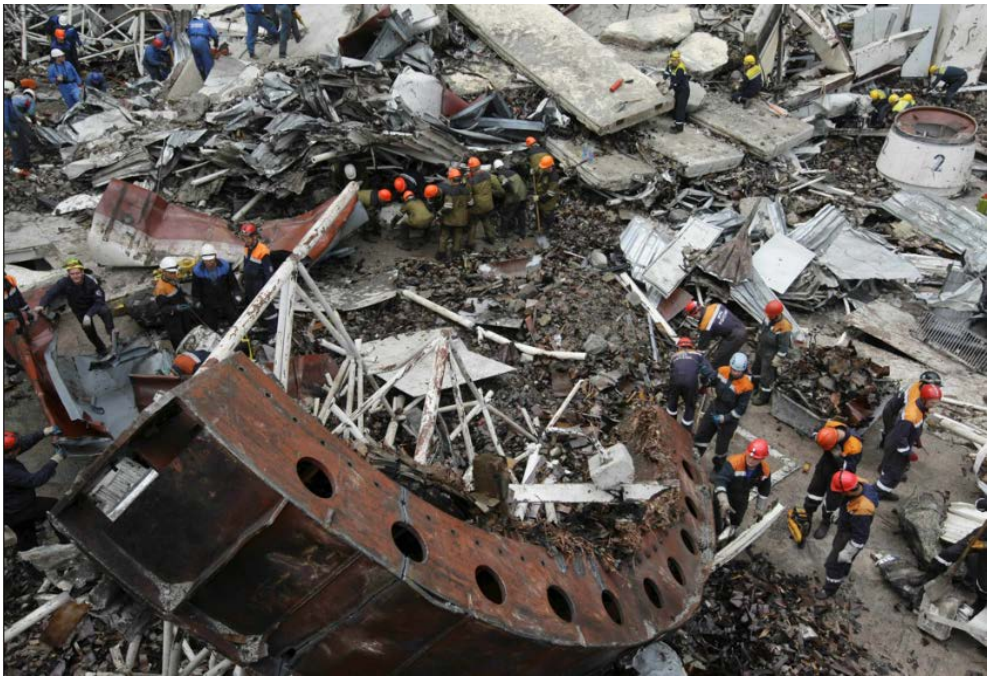
Sayano–Shushenskaya hydro power station accident – 2009

(extracted from Wikipedia and
http://archive.boston.com/bigpicture/2009/09/the_sayanoshushenskaya_dam_acc.html)

The 2009 Sayano–Shushenskaya hydroelectric power station accident occurred on 17 August 2009, when turbine 2 of the Sayano–Shushenskaya hydroelectric power station near Sayanogorsk in Khakassia, Russia, broke apart violently. The turbine hall and engine room were flooded, the ceiling of the turbine hall collapsed, 9 of 10 turbines were damaged or destroyed, and 75 people were killed. The entire plant output, totalling 6,400 MW and a significant portion of the supply to the local electric grid, was lost, leading to widespread power failure in the local area, and forcing major users such as aluminium smelters to switch to diesel generators. An official report on the accident was issued on 4 October 2009.

Before the accident:

After the accident:



Background:

Turbine 2 had experienced problems for a long time prior to the 2009 accident. The first of these appeared after its installation in 1979. Throughout 1980-1983, numerous problems with seals, turbine shaft vibrations and bearings surfaced. From the end of March to the end of November 2000, a complete reconditioning of turbine 2 was performed. Cavities up to 12 millimetres deep and cracks up to 130 millimetres long were found on the turbine runner and repaired as well as other defects. In 2005, further repairs were made to turbine 2. The problems found were similar in several aspects to the defects observed during the previous repair. 2009, turbine 2 was undergoing scheduled repairs and modernization. It was the first and only turbine in the station which was equipped with a new electro-hydraulic regulator of its rotational speed. The elevated vibration levels compared to other turbines were apparent for turbine 2l. The vibrations exceeded the allowed specification in the beginning of July and continued to increase with accelerated speed.

The Accident:

On the night of 16–17 August, the level of vibration increased substantially, and there were several attempts to stop the turbine. The load of turbine 2 was 600 MW, it was reduced to 100–200 MW. On 17 August 2009, the load was increased again to 600 MW, decreased to 200 MW and increased once again to 600 MW. During this time, the level of vibration was very high, as also registered by seismic instruments in the plant. During attempts to shut it down, the rotor inside the turbine was pushed up, which in turn created pressure pushing up on the turbine cover, which had been kept in place by 80 bolts, each 8 cm in diameter. Nine out of the ten turbines had been operating at the time, with a total output 4,400 MW. Turbine 6 was undergoing scheduled maintenance, but was ready for a restart.

There was a loud bang from turbine 2. The turbine cover shot up and the 920-tonne rotor then shot out of its seat. After this, water spouted from the cavity of the turbine into the machinery hall flooding the machinery hall and rooms below its level. At the same time, an alarm was received at the power station's main control panel, and the power output fell to zero, resulting in a local blackout. The steel gates to the water intake pipes of the turbines, weighing 150 tonnes each, were closed manually by opening the valves with hydraulic jacks keeping them up between 8:35 and 9:20 hours. The operation took 25 minutes, which is near the minimum time allowed for this operation (highest speed). The emergency diesel generator was started, the opening of 11 spillway gates of the dam was started and was finished 77 minutes later. 75 people were later found dead.

Cause discussed:

The official report states that the accident was primarily caused by the turbine vibrations, which led to the fatigue damage of the mountings of the turbine 2, including the cover of the turbine. It was also found that at the moment of accident at least six nuts were missing from the bolts securing the turbine cover. After the accident 49 recovered bolts were investigated, of which 41 had fatigue cracks. On 8 bolts, the fatigue damaged area exceeded 90% of the total cross-sectional area.

On 17 August 2009 at 8:12AM local time, turbine 2's output power was reduced by the turbine regulator and it entered into the non-recommended powerband II of 265–570 MW. Shortly after this, the bolts keeping the turbine cover in place broke, and under water pressure of about 20 bars, the spinning turbine with its cover, rotor, and upper parts started to move up, destroying machinery hall installations. At the same time, pressurized water flooded the rooms and damaged plant constructions.

Extent of Damage:

Overall, damage concerned all units and surrounding areas. Besides unit 2 also turbines 7 and 9 suffered from severe damage, while the turbine room roof fell on and damaged turbines 3, 4 and 5. Turbine 6, which was in scheduled repair at the time of accident, received only minor damage, as it was the only one of the station's 10 turbines that did not receive electrical damage due to shorting of transformers:

- Turbine 6: Flooded
- Turbine 5: Flooding and electrical damage
- Turbines 3 and 4: Moderate electrical and mechanical damage. Some damage to the concrete structures around them.
- Turbines 1, 8, and 10: Severe electrical and mechanical damage. Some damage to the concrete structures around them.
- Turbines 7 and 9:Completely destroyed, with extreme damage to the concrete structures around them.
- Turbine 2: Destroyed completely, including the concrete structures around it.