

## NEWS

# Quake shuts world's largest nuclear plant

No one died as a result of Japan's latest nuclear incident and environmental damage seems to have been mostly avoided. But is this testimony to successful plant design or a warning of impending disaster, asks **David Cyranoski** in Tokyo.

**A**fter the stunning revelation that the nuclear power plant damaged in an earthquake last week was built above an active fault line, Japan faces an uphill struggle to convince its citizens, and the rest of the world, that its commitment to nuclear power is safe.

Perched on top of four converging tectonic plates, Japan is one of the most earthquake-prone countries — geological instability causes around 1,000 tremors a year there. And yet, with 55 operating reactors, it has the third largest nuclear generation capacity in the world — behind France and the United States. With few indigenous energy resources, Japan relies on nuclear power for about a third of its needs, and aims to up this to 40% in an ambitious expansion programme that will see 11 new facilities built by 2017.

This tricky dichotomy was brought into stark relief on 16 July when a magnitude-6.8 earthquake caused a shut down of the Kashiwazaki-Kariwa plant, in Niigata prefecture on the west coast. The damage to the facility was relatively minor, no one died and the amount of radiation released was reportedly negligible — well within international safety limits. Nevertheless, the incident has sparked fears that neither Japan's nuclear facilities nor its

nuclear safety evaluation system can handle the seismic activity that plagues the country (see 'The big one').

The quake — which killed ten people and injured more than 1,000 in Niigata — sparked a fire in a transformer that supplies electricity to one of Kashiwazaki-Kariwa's seven reactors and leaked radioactive cooling water into the sea and gas into the atmosphere. The plant — the world's largest in terms of power output — has been shut indefinitely. International observers have described the handling of the incident by its owner, Tokyo Electric Power Company (TEPCO), as a public-relations disaster, especially in light of the country's history (see 'A shaky nuclear record').

## Catalogue of errors

Because the earthquake occurred on a national holiday, only four people were available to fight the transformer blaze, so it took around 90 minutes and the help of local firefighters to put it out. The public were not informed of the incident for seven hours, and the disclosures of leaks and malfunctions trickled out over several days. TEPCO initially said that 100 drums of solid nuclear waste had fallen over, but inspectors later said hundreds had been



Cracks in the ground next to Tokyo Electric Power Company's Kashiwazaki-Kariwa nuclear plant.

knocked over, and the lids of several dozen had opened, spilling their contents.

The list of malfunctions, damages and mistakes rose from an initial 50 to 63 in the ensuing days, and included an admission by the company that the 1,200 litres of contaminated water that poured into the ocean was 50% more radioactive than it had previously stated. Perhaps most worrying was the discovery, nearly three days after the quake, that radioactive iodine gas

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## A shaky nuclear record

A string of past accidents, safety lapses and cover-ups in Japan have shaken public confidence in the industry.

- July 2007: earthquake damage at the Kashiwazaki-Kariwa nuclear power station run by Tokyo Electric Power Company (TEPCO) results in radioactive leaks, burst pipes and a fire.
- February 2007: TEPCO admits 199 cases of falsifying inspection data at three nuclear power plants, including Kashiwazaki-Kariwa.
- August 2006: negligible

radiation released via radioactive heavy-water steam at TEPCO's Fukushima-Daiichi power plant.

- August 2004: five workers at the Mihama nuclear power station run by Kansai Electric Power Company killed and six injured by boiling water and steam when a corroded pipe bursts.
- February 2004: eight workers exposed to low-level radiation at the Japan Atomic Power Company's plant in Tsuruga when they are accidentally sprayed with radioactive water.

- September 2003: small leak of radioactive water from a reactor at Chubu Electric Power's plant in Hamaoka.

- September 2002: TEPCO ordered to close all its reactors after admitting it falsified data.
- November 2001: Hamaoka plant shut down after two radioactive leaks occurred within days of each other.
- July 2000: more than 100 litres of radioactive water leak from a reactor at the Fukushima plant after an earthquake.

- September 1999: high-level radiation leak at JCO Company's fuel-reprocessing plant in Tokaimura when uranium oxide being mixed went critical because of deviations from prescribed procedure. Two workers die later from radiation exposure.
- March 1997: workers exposed to low doses of radiation after a fire and explosion at another Tokaimura fuel-reprocessing plant (operated by the official Japanese fuel-reprocessing organization Donen).

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## The big one

'Genpatsu-shinsai', a term coined by seismologist Katsuhiko Ishibashi at Kobe University in Japan, is the media's post-quake buzzword. An amalgamation of the words for nuclear power and earthquake disaster, it describes a nuclear meltdown caused by a quake. Many fear that genpatsu-shinsai will be realized at the old Hamaoka plant in Shizuoka on the coast southwest of Tokyo, which has become the focus of anti-nuclear protest in the country.

Hamaoka is built directly on top of a major fault line. Just offshore, in the Pacific Ocean, three of the planet's main tectonic plates rub against each other. The

reactors at Hamaoka may be the strongest anywhere in the world — they are encased in massively reinforced concrete bunkers, supposedly able to withstand a quake of up to 8.5 in magnitude. The Tokyo authorities are now working to a disaster plan that assumes an 87% probability of a magnitude 8.0 quake within 30 years.

But the earthquake that triggered the 2004 Indian Ocean tsunami measured more than 9.0.

Kiyoo Mogi of Tokyo University, former chairman of Japan's top authority on earthquake prediction, the Coordinating Committee for Earthquake Prediction, said

the plant poses a serious safety risk and that atomic experts are calling for it to be shut down. Mogi said that it is "hard to say at this stage how many nuclear power plants should be stopped... but I can say Hamaoka power plant in Shizuoka should be stopped immediately".

Lawyer Mitsuei Murata of Tokai Gakuen University, a former diplomat and leading anti-nuclear campaigner told *Nature* that a quake at Hamaoka could smash the reactor. This, he says, could send a radiation cloud across Tokyo within 8 hours, killing hundreds of thousands of people immediately and millions thereafter.

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— or intentionally avoided — seeing fault lines," Nakata says.

Daisuke Suzuki, TEPCO spokesman for the Kashiwazaki-Kariwa plant, says of new guidelines to govern reactors and quake resistance, "The 2007 guidelines require us to look back 130,000 years, rather than the previous 50,000, so we might find evidence that it was active."

"The new guidelines also require geomorphological techniques to be used now, which may have revealed that the fault was longer if we had used them before," Suzuki says. He admits the earthquake was probably caused by movement of this fault. "If so, it must be longer than seven kilometres to have caused such a large earthquake."

### Blind thrusts

The new guidelines — under which all 55 reactors are being re-evaluated — are an improvement, says Katsuhiko Ishibashi, a seismologist at Kobe University's Research Centre for Urban Safety and Security and a member of a 2006 government subcommittee to revise them. For example, the method to estimate ground shaking is better. But his proposal to reconsider the survey standards for active faults in the guidelines was dismissed by the committee.

The guidelines also failed to factor in the effects of 'blind thrusts' — movements that cannot be seen by seismologists but can cause quakes with magnitudes of greater than 6.5. Ishibashi says that "the committee's misunderstanding leads to a strong underestimation

of powerful earthquakes". On the day of the last committee meeting, Ishibashi resigned in protest.

So is it safe to build a nuclear facility on such shaky ground? Scott Burnell, a spokesperson for the US Nuclear Regulatory Commission in Maryland, argues that they can endure floods, tornadoes, hurricanes, earthquakes and even a tsunami. "They are designed to withstand just about everything short of a meteor strike," he says.

**"This case is close to the worst scenario."**

The worldwide track record in nuclear versus nature has been good. In 1992, a 690-megawatt reactor at Turkey Point in Florida weathered the winds of Hurricane Andrew. And in 2004, the Kalpakkam reactor near Madras, India, emerged unscathed from a massive tsunami that engulfed the city in which it was located. Sensors detected the rising water level and shut down the reactor before the tsunami reached the shore.

Most observers agree that the Kashiwazaki-Kariwa reactor seems to have performed well. Despite being designed for a lower-magnitude quake, the reactor buildings are mostly intact. Mitsuru Uesaka, a nuclear engineer at the University of Tokyo, says that given the difference between the expected shaking and that experienced, "this case is close to the worst scenario. Even so, the leaked radiation was negligible," he says.

**David Cyranoski, with additional reporting from Geoff Brumfiel in Washington DC.**

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was still being vented from one of the reactors.

TEPCO built the facility to withstand a magnitude 6.5 quake — the Japanese safety standard for reactors located on sites not above an active fault line. But it has now emerged that the offshore epicentre of last week's quake is on an active fault line that probably extends directly under the Kashiwazaki-Kariwa plant. A preliminary investigation of the quake and its aftershocks has revealed a fault line of up to 30 kilometres long.

Akira Fukushima, of Japan's Nuclear and Industrial Safety Agency in Tokyo, says that four fault lines were identified at the site in 1980 before the facility was built, but that all were considered inactive. *Nature* has heard claims from Japan's seismologists that data indicating an active fault line was potentially under the site were ignored when the plant was enlarged.

Hiroaki Nakata, a seismologist at the Hiroshima Institute of Technology, says that TEPCO found a seven-kilometre-long fault line in 1996, during investigations as part of its application to install two new reactors on the plant, but failed to investigate it fully.

Nakata has produced a map showing where fault lines taken from TEPCO data should have extended. "When we find an active fault, we check features surrounding it. There's no reason for TEPCO to have stopped when they did. There are many places where they missed