# Kashiwazaki-Kariwa Nuclear Power Plant

**Seismic Design of the Kashiwazaki-Kariwa Nuclear Power Plant: a Historical Perspective**

**Why Kashiwazaki-Kariwa?**

Prior to establishment of the Kashiwazaki-Kariwa Nuclear Power Plant there were oil fields in the region. Studies related to these oil fields showed that the ground was unstable, so informed locals knew very well that it was an unsuitable place to construct a nuclear power plant. Why then was such a site chosen for a nuclear power plant? The answer is simple: Kakuei Tanaka of Lockheed bribery scandal fame. Kakuei Tanaka, either as Prime Minister, or as the man pulling the strings behind the scenes, was Japan's political strong man. He was from Nishiyama Town, which is now part of Kashiwazaki City. He had a sizable shareholding in real estate company Muromachi Sangyo and in practice controlled the company.[1] The site of the Kashiwazaki-Kariwa Nuclear Power Plant (KK) was bought up by Muromachi Sangyo and later sold to Tokyo Electric Power Company (TEPCO). Money changed hands several times in the process and it is said that Tanaka's profit from the land sale was 400 million yen ($11 million at the time).[2] Under these circumstances, it is not hard to imagine that concerns about seismic safety were never going to stand in the way of construction of the plant.

**Seismic Design of KK**

Japan's first seismic safety guidelines for nuclear power plants (*Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities*, hereafter referred to as the *Old Guidelines*) came into force on 20 July 1981. There were no seismic safety guidelines when KK Unit 1 was approved in 1977, so the government established an expert committee specifically to establish a seismic design standard for the proposed nuclear power plant. The committee concluded that the plant should be built to withstand a magnitude 6.9 earthquake (Mj6.9 on the Japanese seismic scale) arising from the Kihinomiya Fault 20 kilometers from the site.

The committee assessed the Kihinomiya Fault to be 17.5 kilometers long, even though one member of the panel disputed this finding. There are other faults running very close to the Kihinomiya Fault and Tokyo University seismologist Tokihiko Matsuda was concerned that they might form a single fault zone.[3] If so, he believed a M8 earthquake could conceivably occur. When his views were ignored, he resigned in protest. Matsuda was vindicated in October 2004 when the Headquarters of Earthquake Research Promotion (HERP) officially recognized the Kihinomiya Fault and faults to the north thereof as a single 91-kilometer Nagaoka Plain western boundary fault zone. HERP judged that this fault zone could give rise to a M8 earthquake.

Despite Matsuda's warning, KK Unit 1 was only designed to withstand a M6.9 earthquake arising from the Kihinomiya Fault. The remaining six KK units were approved under the *Old Guidelines*, but they too were designed to withstand the same earthquake as Unit 1.

As a basis for seismic resistance design, a so-called $S_1$ ground motion[4] of 300 Gal was chosen. Under the *Old Guidelines*, $S_1$ ("maximum design earthquake") was considered to be an earthquake ground motion that could actually occur. In addition, a so-called $S_2$ ground motion of 450 Gal was chosen. $S_2$ ("extreme design earthquake") was considered to be an almost inconceivable hypothetical earthquake ground motion. The *Old Guidelines* required that nuclear power plants be designed so that the most important equipment for safety purposes, such as the reactor and the spent fuel pool, must be able to retain their safety functions under $S_2$ conditions. In the case of KK, the $S_2$ earthquake was assumed to be a M6.5 earthquake centered directly beneath the plant. This was the default standard required under the *Old Guidelines* for cases where no fault had been identified that would give rise to a greater ground motion.

**Review of Seismic Guidelines**

After the Southern Hyogo Prefecture Earthquake, which struck Kobe City on 17 January 1995 and killed around 6,500 people, the nuclear establishment could no longer ignore the defects of the *Old Guidelines*, so a comprehensive review was commenced in 3 February 1995. It took over eleven years to revise the guidelines and *New Guidelines* finally come into force on 19 September 2006.

Under the *New Guidelines*, back checks are being carried out at all nuclear power plants to determine (1) what earthquake and what ground motion the plants should be designed to withstand and (2) whether the plants are able to withstand such an earthquake. All electric power companies have submitted interim or final reports to the Nuclear and Industrial Safety Agency (NISA). They have all increased the size of the earthquake and the ground motion their nuclear power plants need to be able to withstand. They have all also indicated that their plants were designed with sufficient leeway to withstand such an earthquake, but they are reinforcing their plants anyway.

**Niigata Chuetsu-Oki Earthquake**

While these back checks were being carried out, the Niigata Chuetsu-Oki Earthquake struck KK. Although the earthquake was only M6.8 (Mj6.8 Japanese seismic scale, moment magnitude Mw6.6), the ground motion was many times greater than the plant was designed to withstand. When Unit 1 was originally designed, the calculations indicated that a M6.9 earthquake arising from the Kihinomiya Fault would only cause a ground motion of 222 Gal ($S_1$), while a M6.5 earthquake directly beneath the plant would only cause a ground motion of 274 Gal ($S_2$). However, to be on the safe side, design basis ground motion $S_1$ was set at 300 Gal, while design basis ground motion $S_2$ was set at 450 Gal. In the event, these figures turned out to be gross under-estimates. During the Chuetsu-Oki Earthquake the ground motion at the "free surface of the base stratum" for KK Unit 1 was calculated to be 1,699 Gal.[5]

It is not fully understood why the earthquake shook the plant so much more violently than predicted, but it appears that the seismic waves were amplified in some way as they were transmitted through the ground. A similar phenomenon was observed in the Southern Hyogo Prefecture Earthquake, suggesting a tendency for seismic waves arising

from strong earthquakes to be amplified in soft ground. Perhaps the soft and folded ground beneath KK focused the seismic waves like a lens. Whatever the physical cause of the violent shaking of the plant, the local people knew from the start that there were problems with the ground on which KK was built. It is hard to believe that TEPCO was unaware of the problems.

TEPCO only took into account land faults when designing KK. However, it is now known that there are important submarine active faults in the area. Experts disagree about the nature of the fault that caused the Chuetsu-Oki Earthquake, but they agree that it was a submarine active fault. During the debate about KK Unit 1, Tokihiko Matsuda and Geological Survey of Japan's Toshihiro Kakimi pointed out that a survey should be carried out to look for submarine active faults.[6] TEPCO did not follow their advice, even though a precedent already existed for such a survey. Before deliberations about KK even began, Shikoku Electric Power Company had already carried out two offshore surveys and found a large submarine active fault near its proposed Ikata nuclear power plant. Matsuda and Kakimi were well aware of this precedent, because Shikoku Electric carried out the surveys at their suggestion. By the time TEPCO constructed KK Units 6 & 7, it certainly knew there were submarine active faults in the area, but it chose to conceal this information.

**Post-Mortems and the Rush to Restart**

Since the earthquake, several committees have been established to investigate three key issues: (1) the nature of the earthquake; (2) the impact of the earthquake on KK; and (3) whether it is safe to operate KK (or some KK units) in future. So far, the central government's committees have concluded that (1) the nature of the earthquake is now understood; (2) KK was not seriously damaged; and (3) that it is safe to operate KK Unit 7. Having restarted KK-7, TEPCO will presumably apply for permission to restart other units in due course.

Niigata Prefecture established two subcommittees of its own, one dealing with the earthquake itself and the condition of the ground and another dealing with the impact of the earthquake on the plant. Unlike the central government's committees, these two subcommittees include members who take a critical perspective. Neither subcommittee has reached a unanimous conclusion. The main points of contention relate to the following issues:

1) The magnitude of the design-basis earthquake: NISA and the Nuclear Safety Commission (NSC) approved restart of KK Unit 7 on the basis that it could withstand a M7.0 earthquake. However, some scientists insist it should be designed to withstand a M7.5 earthquake.
2) Movement of the ground beneath the buildings: The ground level has been measured on three occasions since the earthquake, but each time the direction and size of the inclination of the buildings was different. Boring carried out by a research team including Dr Masaaki Tateishi of Niigata University contradicts TEPCO's assessment.
3) Concerns that during an earthquake in excess of M7 the casing within which the recirculation pump motors are contained could buckle and break: KK-6&7 are Advanced Boiling Water Reactors (ABWR). This type of reactor has internal recirculation pumps. Even for a M7 earthquake, the casing of the recirculation pumps is near the limit of the seismic design standard.[7]

Nevertheless, on April 7 the chairman of the parent committee of Niigata Prefecture's two sub-committees, Seiji Shiroya, handed a biased summary of proceedings in which he expressed the view that it was safe to operate KK-7. Members of the subcommittees responded by severely challenged his conclusion and the inappropriateness of drawing any conclusions at this stage in the subcommittees' proceedings.

**New Research Shakes the Ground Beneath Japan's Seismic Standards**

Some serious defects in the seismic assessments of nuclear power plants have become very clear over the last few years. New active faults have been discovered. Active faults have been found to be longer than the electric power companies had claimed. In many cases, faults which power companies claimed were separate and unrelated are now believed to be connected. Estimates of the potential size of earthquakes are connected to the length of active faults, so reassessing the length presents serious challenges for seismic design.

In recent years HERP has reassessed the status of Japan's active faults. In many cases it has reached different conclusions from those of the power companies, but the power companies and the governments' nuclear safety agencies do not necessarily follow HERP's findings. In addition, independent researchers have made many discoveries that contradict the claims of the nuclear industry. In particular geomorphologists, Takashi Nakata, Mitsuhisa Watanabe and Yasuhiro Suzuki have found new faults and shown that shorter faults are linked together. For many years electric power companies ignored the work of geomorphologists. Recently they have found it harder to dismiss their claims, but they still refuse to accept elementary geomorphological evidence of active faults.

**Conclusion**

Proponents of nuclear power in other earthquake-prone countries point to Japan as a role model. However, the history of the seismic assessment and design of Japan's nuclear power plants suggests that it is more by luck than good management that Japan has managed to escape a nuclear earthquake catastrophe. Politics has been prioritized over safety in the siting and design of plants and politics was prioritized again in approving the restart of KK-7. Over and again, the government and TEPCO have shown that they are only too willing to sacrifice sound science for the sake of national policy.

Earthquakes are an unknown quantity at the best of times. The Japanese experience shows that when politics and vested interests are involved, even the limited knowledge that we have is distorted and perverted. Under these circumstances, it is impossible to be sure that nuclear power plants are constructed to withstand earthquakes that might occur. If the top priority is safety, wisdom suggests that it is inappropriate to construct something as technologically complex and dangerous as a nuclear power plant in an earthquake zone.

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**Notes and References**

1. Tokyo High Court, quote in *The Japan Times* on February 27, 1997.
http://search.japantimes.co.jp/cgi-bin/nn19970227a3.html

2. Stephen Hunziker and Ikuro Kamimura, *Kakuei Tanaka: a political biography of modern Japan*, Chapter 4.
http://www.rcrinc.com/tanaka/index.html

3. Niigata Nippo (Newspaper) Special Investigation Team, *Nuclear Power Plants and Earthquakes: Warning from Kashiwa-Kariwa "seismic intensity 7"*, Kodansha, 2009, p. 80~83
(Niigata Nipposha Tokubetsu Shuzaihan, *Genpatsu to Jishin: Kashiwazaki-Kariwa "Shindo 7" no Keikoku*)

4. Ground motion at the "free surface of the base stratum". Tertiary layers, or earlier bedrock that has not been eroded are generally referred to as "ground". Hypothesizing that above this ground there are no layers or structures, the surface spreading out horizontally is called the "free surface of the base stratum".

5. This figure was derived from a peak east-west ground motion of 680 Gal recorded by a monitor in the fifth floor basement of Unit 1.

6. *Niigata Nippo*, 2009 op. cit., p. 88~90.

7. Refer Nuke Info Tokyo No. 129 for detailed comments. Nuke Info Tokyo is CNIC's English newsletter. Most editions since the Chuetsu-Oki Earthquake have carried reports about the status of the Kashiwazaki-Kariwa Nuclear Power Plant.

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