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UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

Briefing on NRC Activities Related to the Recent Japanese Earthquake

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Agenda

- Key Points
- Earthquake Description & Impact on Japanese Nuclear Power Plant
- United States Seismic Design for Existing and Future Nuclear Power Plants
- Lessons Learned

Key Points

- All units at the Japanese nuclear power plant nearest to the earthquake shut down, and nuclear safety was not compromised.
- US plants are designed for postulated seismic activity at each plant's specific location.
- NRC has established process for utilizing lessons learned from events.

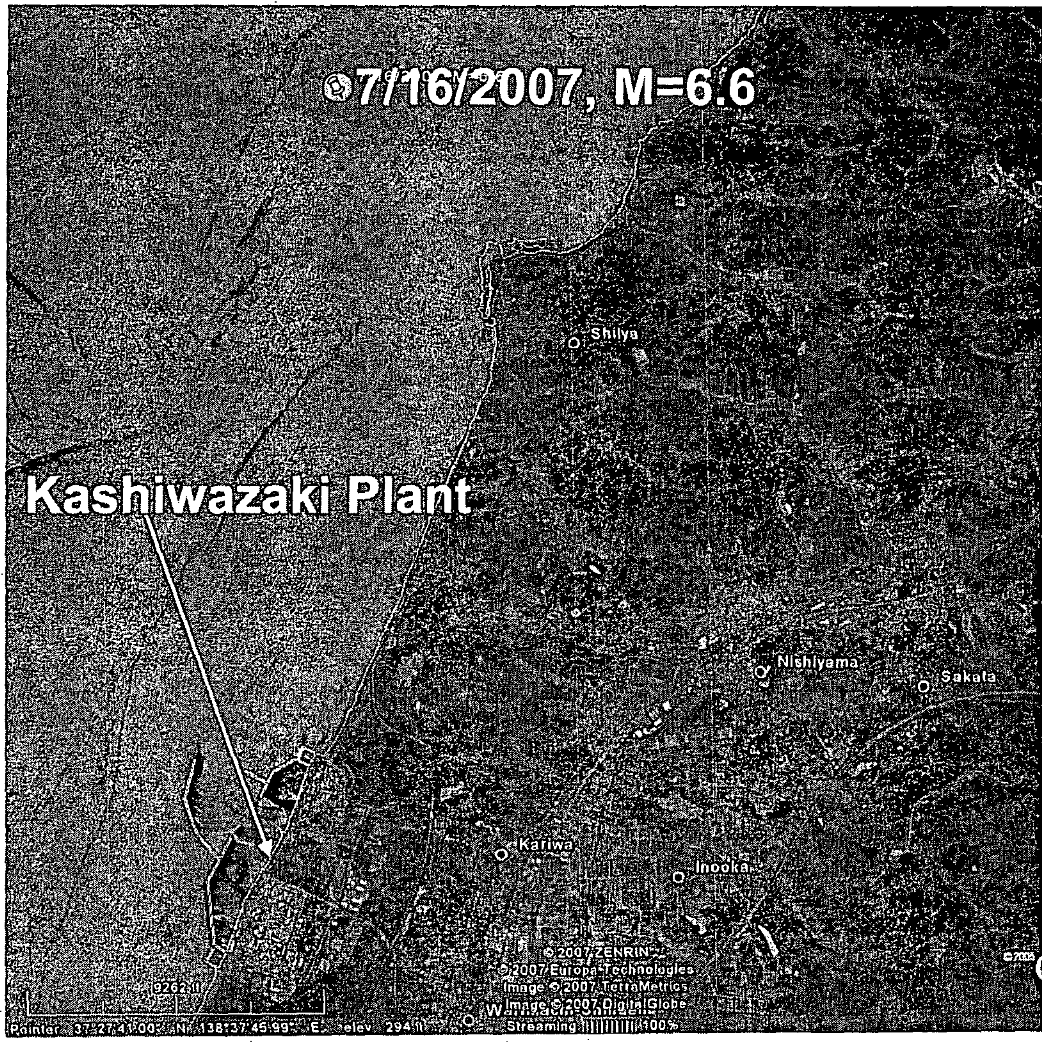
Earthquake Description

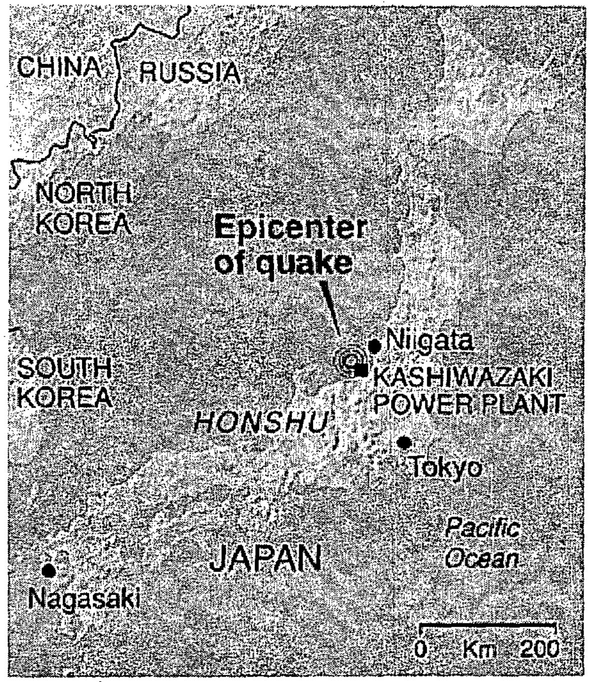
- Niigata Earthquake occurred on July 16, 2007 at 10:13 AM local time.
- Magnitude of the earthquake was 6.6.
- Earthquake occurred at a depth of 10 km beneath the surface.
- Earthquake epicenter was about 8-10 km from the Kashiwazaki-Kariwa Nuclear Power Plant.
- Earthquake caused a reported 11 fatalities, multiple injuries, collapsed houses, cracked highways.

Kashiwazaki-Kariwa Nuclear Power Plant Description

- World's largest nuclear power plant in terms of power output capacity.
- 7-Unit plant producing 8,210 MW (Palo Verde, the largest US plant, has an output capacity of 3,880 MW).
- Units 3, 4, and 7 operating before event.
- Unit 2 was starting up.
- Units 1, 5, and 6 were shut down.

Location of Earthquake & Plant





Source: International Herald Tribune

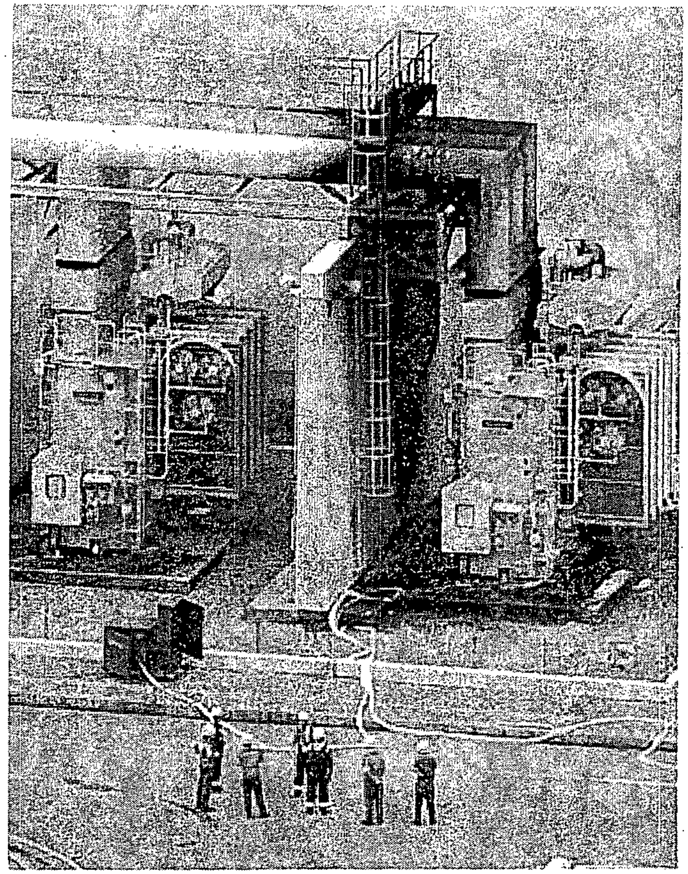
Source: Google Earth

Impact on Kashiwazaki-Kariwa

- Operating units automatically shut down.
- Transformer fire outside Unit 3.
- Small liquid and gaseous radiological releases.
- Drums of low level solid radioactive waste fell over.
- Minor damage to other plant equipment.
- Seven workers suffered minor injuries.

Auxiliary Transformer Fire

- Fire occurred in Unit 3 auxiliary transformer.
- Fire was extinguished approximately two hours after earthquake.
- Fire had no impact on radiological safety and no impact to the public.



(Source: Associated Press)

Liquid Radiological Release

- Small puddles of water found with minor amounts of radioactivity.
- Radioactive water had leaked through penetrations to discharge sump.
- Approximately 317 gallons of water discharged into Sea of Japan.
- Total amount of radioactivity of discharged water was very low (estimated dose to public significantly less than 1 millionth of annual limit).

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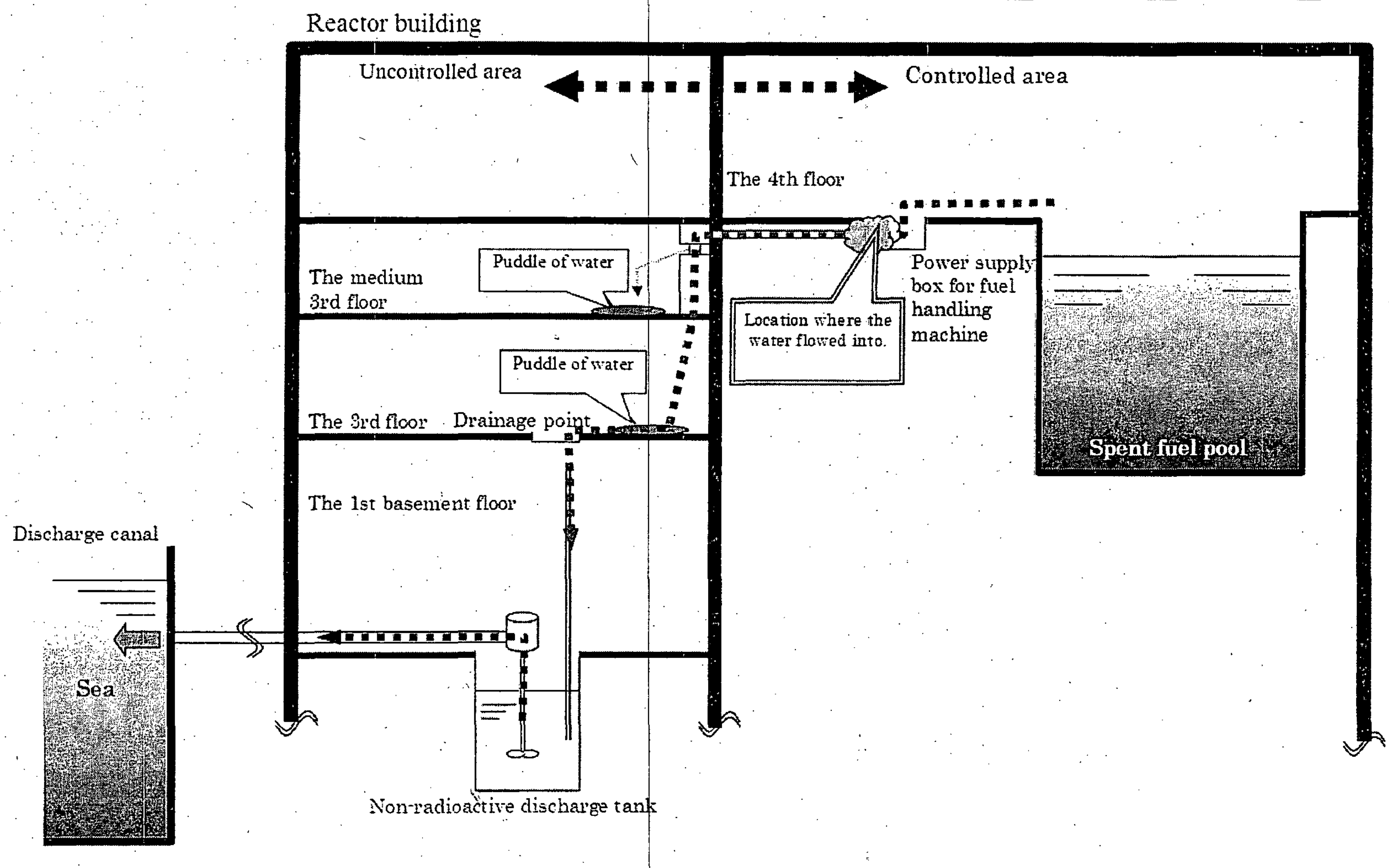
Liquid Radiological Release Flowpath



Schematic diagram of the water flow into the non-radioactive discharge tank and the water discharge to the sea at Unit 6

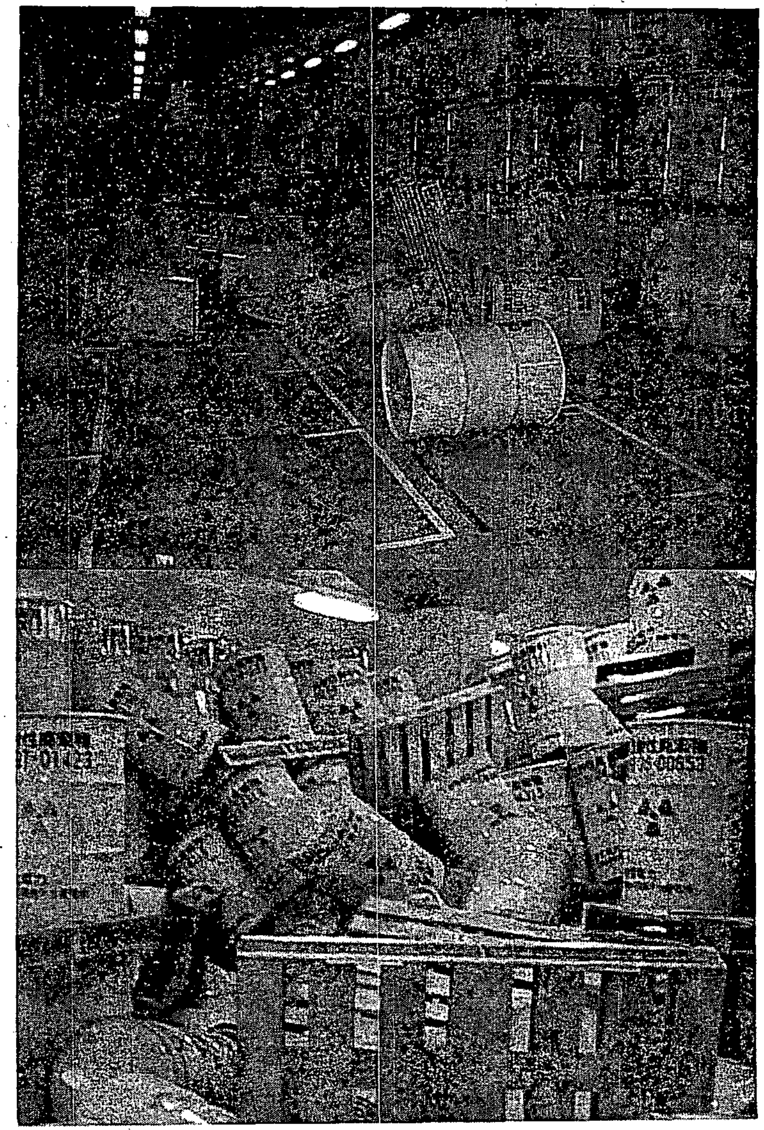
Source: Nuclear and Industrial Safety Agency

Radiological Gas & Particulate Release

- Radioactive iodine and other radioactive particulate matter found at the Unit 7 ventilation stack.
- The total amount of radioactivity released was estimated to be very low (estimated dose to public less than 1 millionth of annual limit).
- No radioactivity found at other units' stacks.

Low Level Waste Drums

- Waste drums were stacked in solid radwaste storage warehouse.
- Over 100 low level solid waste (e.g., rags, tools, gloves, supplies) drums knocked over during event.
- Several found with lids off.
- No measured release of radiation and no impact to public.



Source: Nuclear and Industrial Safety Agency

US Reactor Seismic Design

- Existing US reactors are robustly designed to withstand site-specific earthquakes such that systems and structures necessary for nuclear safety will remain functional.
- US plants are designed for an earthquake that is not likely to occur more than once every 10,000 years.

US Reactor Seismic Design

- Only 2 US nuclear power plants with active faults located nearby. Both will automatically shut down during a seismic event above a specified limit.
- Plants in the US, which are located in areas of considerably less seismic activity than California, have seismic instruments installed and requirements for manual shutdown at specified levels.

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NRC Seismic Activities

- NRC focused on seismic safety since 1970s:
  - Seismic Safety Margins Research Program
  - Implemented lessons learned from earthquake experience at non-nuclear facilities.
  - Implemented plant walk-downs and ensured anchorages were adequate for various structures.
  - Assessed the ability of plant equipment to withstand accidents beyond the plant's design and concluded there were large margins of safety.

New Reactor Seismic Design in US

- NRC recently issued new seismic guidance for new reactors.
- This guidance incorporates comprehensive, state of the art scientific methods.
- NRC reviews new reactor applications to verify that the latest earthquake hazard information has been considered for each site.

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Lessons Learned

- NRC will continue to collect and evaluate information related to this event.
- NRC will evaluate the lessons learned to identify any actions necessary to be implemented at operating and future reactors.
- Lessons learned from data could lead to change to regulations, issuance of regulatory guides or generic communications, or change to inspection programs, for example.
- IAEA and USGS have sent teams to Japan to review data related to event. NRC will utilize this additional data to enhance our programs.

Differences Between NRC & Japanese Seismic Requirements

NRC

GDC #2: "shall reflect: (1) Appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated, (2) appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena and (3) the importance of the safety functions to be performed"

Japanese

"the maximum design earthquake that would have the greatest effect on the proposed site based on engineering judge following a seismological review of past earthquakes, the nature of any active faults and the seismo-tectonic structure underlying the site and the surrounding region"

Differences Between NRC & Japanese Seismic Requirements

Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants," describes the nature of investigations required to obtain the geologic and seismic data necessary to determine site suitability and to provide reasonable assurance that a nuclear power plant can be constructed and operated at a proposed site without undue risk to the health and safety of the public. It describes procedures for determining the quantitative vibratory ground motion design basis at a site due to earthquakes and describes information needed to determine whether and to what extent a nuclear power plant need be designed to withstand the effects of surface faulting.

In determining the design basis earthquake ground motions, full consideration shall be given to the following items:

(i) The magnitude, epicenter, hypocenter, aftershock area and maximum intensity of earthquake ground motion (or estimated value), and resultant damage (including destruction rate of structures, overturning of tombstones, etc.) in earthquakes that have affected the site and the surrounding region in the past.

ii) The statistical expectation of the intensity of the past destructive earthquake ground motions.

(iii) The magnitude of the earthquake and the distance between the site and its center of energy release.

(iv) **Past observation records for the general region as well as those for the site, including any results of bedrock property investigations.**

Differences Between NRC & Japanese Seismic Requirements

- Safety-related SSCs are Seismic Category I
- Requires dynamic analysis
- Equipment qualification by analysis or tests

- Safety classes A, B and C
- ~~(b) Static earthquake force~~
- (i) Buildings and structures
- Horizontal seismic forces shall be determined by multiplying the weight at the height and above by the following story shear coefficient corresponding to the importance of the facility.
- Class A story shear coefficient 3.0CI
- Class B story shear coefficient 1.5CI
- Class C story shear coefficient 1.0CI
- **Here, CI of the story shear coefficient shall be 0.2 in the standard case, and shall be fixed considering the vibration**
- **characteristics of buildings and structures, the category of the ground, and so on**

- Class A
- Class B
- Class C

Differences Between NRC & Japanese Seismic Requirements

- Ground motion generally applied at the foundation level.
- Soil-structure interaction effects considered
- Damping values based on RG 1.61

- The design earthquake ground motions for seismic design of reactor facilities shall be derived from the earthquake motions at the free surface of the base stratum in the proposed site.
- Founded on bed rock, used fixed base analysis
- Damping values for structures lower than NRC

Differences Between NRC and Japanese Seismic Requirements

- SEP reviews and plant upgrades
- IPEEE seismic margins and anchorage upgrades
- PSHA implemented in Part 100.23 & RG 1.165
- Performance-based seismic demand, RG 1.208
- Seismic scram only in high seismicity areas

- New seismic criteria closer to NRC approach but not back fitted to existing plants
  - Use of PSHA
  - Higher (0.4g) minimum PGA for earthquakes not tied to faults
- Seismic scram

Seismic Events and Experience

- Off-shore fault was investigated at Diablo Canyon and plant was backfitted.
  - Humboldt Bay and GE test reactors shut down due to seismic hazard
- 2003 San Simeon recorded at Diablo Canyon.
- Japan will investigate off-shore faults near Kashiwazaki
  - Seismic scram worked
  - Safety systems worked
  - Soil liquefaction at ground
  - Radioactive airduct connections at stacks separated at all units
  - 7 out of 67 instruments at plant site worked
  - Downhole records show deamplification through overburden

US-Japan Seismic Criteria Overall View

- Basic comparisons are very high level. Differences in the end results depend on:
  - Actual design, other loads and load combinations used, differences in analytical procedures, construction procedures, codes and standards and as-built margins
  - A simple top level comparisons of seismic criteria cannot give us a comprehensive picture
- For new plants we require explicit seismic margins
- Fundamental approaches to seismic resistant design in both countries are similar, but vary in details.
- Designs resulting from criteria in both countries produce seismically robust plants.
- Our assessments are analytical, but Japan had a real test and came through safely.

General Post-earthquake Shutdown Actions at Nuclear Plants

- Each licensee has seismic instrumentation program at the site in accordance with or meet the intent of RG 1.12 (1974, 1997, previously Safety Guide 12) "Nuclear Plant Instrumentation for Earthquakes". Each licensee also has an earthquake response plan and procedures in place that meet the intent of RG 1.166 (1997) "Pre-Earthquake Planning and Immediate Nuclear Power Plant Operator Post Earthquake Actions" which endorses (with exceptions) EPRI NP-6695 (1989) "Guidelines for Nuclear Plant Response to an Earthquake."

- The threshold for a plant shutdown decision is exceedance of the operating basis earthquake (OBE) ground motion or significant plant damage occurs. The OBE is a fraction of the design basis earthquake (one-half for operating reactors, and one-third to one-half for new reactors).

- *A seismic instrumentation panel board* is located in the Control Room. An alarm is annunciated in the Control Room to indicate a seismic event is being recorded by the strong motion (> 0.01g) accelerographs. In many plants, a *second alarm is annunciated later* if the event analysis software indicates exceedance of the OBE.

- The earthquake response plan *consists* of *short-term actions, post-shutdown* inspections and tests, and long-term evaluations.

Short-Term Actions: Enable rapid determination of severity of earthquake and decision with regard to readiness of the plant for continued operation or the need for shutdown.

- Immediate operator actions to maintain plant in safe condition
- Operator walk-down inspections to identify any significant damage (~ within 8 hours of event)
- Evaluate ground motion data recorded by on-site seismic instrumentation to determine if OBE has been exceeded (Response Spectra check & Cumulative Absolute Velocity check): ~ within 4 hours of the event
- Bases for shutdown decision – OBE exceedance, damage, continued operation
- Pre-shutdown inspections – confirm plant's readiness to shutdown
- Normal plant shutdown after capability is verified

Question: How are nuclear power plants (both existing and new ones in the future) in the U.S. designed to withstand earthquakes?

- US Nuclear Power Plants are robustly designed to withstand site-specific design basis earthquakes such that nuclear safety-related structures, systems and components will remain functional without undue risk to public health and safety.

- The site-specific design basis earthquakes for US nuclear plants have a probability of exceedance of the order of once in 10,000 years.

- The site-specific design basis earthquake ground motion represents the conservative maximum earthquake potential for the site and is rationally determined based on considerations of regional and local geology, seismology, historical record of all earthquakes reported for the region and inherent uncertainties.

- The magnitudes of postulated strong earthquakes in western US (7 to 8) are significantly higher than those in central and eastern US (5 to low 6). Japan is among the most earthquake prone nations in the world and earthquakes of the magnitude of the recent Japan earthquake are not envisioned to be experienced at nuclear plant sites in the central and eastern US.

- In the 1990s, the NRC conducted an assessment of severe accident vulnerabilities of plant components beyond design basis earthquake for each operating reactor. The conclusion was that substantial seismic design capacity exists for safety-related components beyond the postulated seismic design demand.

Question: What are the lessons learned from the recent earthquake in Japan and it's impact at the Kashiwazaki plant?

- Fact: The ground motion recorded at the Kashiwazaki nuclear plant from the recent Japan earthquake exceeded the design basis of the reactors.

- Fact: The plant successfully withstood the earthquake as designed without compromising reactor and public safety, which indicates a conservative design.

- Lesson Learned: US nuclear power plants are conservatively designed for earthquake events based on site-specific maximum credible earthquakes. These plants are expected to perform as designed during a credible seismic event with reasonable assurance that there will not be undue risk to reactor and public safety.