# REVIEW OF CURRENT STANDARDS AND PRACTICE FOR EARTHQUAKE INSTRUMENTATION AT NUCLEAR PLANTS

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## SYNOPSIS

Strong motion recording systems are in use at well over 50 nuclear power plants in several seismically active countries. Automatic seismic shutdown devices are used at several plants, primarily in Japan, whereas other plants depend on evaluation by the operating staff as to whether safe operation can continue. Criteria for instrument capabilities and locations have been developed, principally in the United States (1970 and 1974) and by the International Atomic Energy Agency (IAEA) (1975) as guides to adequate instrumentation. Several countries are in the early stages of instrument criteria development.

## STANDARDS OF THE I.A.E.A.

The I.A.E.A. Division of Nuclear Safety and Environmental Protection issued a draft Safety Guide, Aseismic Analysis and Testing of Nuclear Power Plants[1] in late 1975. Chapter 5 of this Guide, Seismic Instrumentation, recommends that triaxial strong motion recorders be installed:

- In the free field
- On the reactor building base mat
- On another Category I structure base mat
- On the base mat of other important Category I structures if necessary
- On the most representative floors of some Category I buildings

The Guide also suggests that strong motion devices should be considered for installation on typical Category I equipment and piping to understand the response of the main safety related items of this type. Efforts to install these devices are recommended in spite of the severe environmental conditions and maintenance difficulties often encountered.

Instrumentation which would help verify the adequacy of the design analysis is suggested as very useful in areas of high seismicity.

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## STANDARDS AND PRACTICE IN THE UNITED STATES

Prior to 1971, triaxial strong motion accelerographs were installed at selected nuclear plants on a case-by-case basis. The current U. S. Nuclear Regulatory Commission (NRC) regulation, Regulatory Guide 1.12, "Instrumentation for Earthquakes,"[2] is a revision of former Safety Guide 12[3] and references the industry-developed standard ANSI N18.5, "Earthquake Instrumentation Criteria for Nuclear Power Plants."[4] The composite recommendations of Guide 1.12 and ANSI N18.5 are:

For Safe Shutdown Earthquake (SSE) maximum foundation acceleration of less than 0.3g:

- Triaxial time history sensor units to be located at the free field, on the containment foundation and on the containment structure or reactor building. The containment foundation (or free field) sensor may be omitted if soil-structure interaction is negligible.

- A triaxial peak accelerograph on the reactor equipment, reactor piping and either Seismic Category I equipment or piping.

- A triaxial seismic switch on the containment foundation.

- A triaxial response spectrum recorder on the containment foundation with capability to provide signals to the control room.

- Triaxial response spectrum recorders on reactor equipment or piping supports, at the foundation of an independent Seismic Category I structure where response is different from the containment structure and either a Seismic Category I equipment or piping support (or floor location).

For SSE maximum foundation acceleration of 0.3g or greater (in addition to the above):

- A triaxial time history sensor unit on an independent Seismic Category I structure where the response is different from the containment structure.

- A triaxial peak accelerograph on Seismic Category I equipment or piping in an independent Seismic Category I structure where the response is different from the containment structure.

- A triaxial seismic switch on reactor equipment or piping supports.

- An additional triaxial response spectrum recorder so that both reactor equipment and reactor piping locations are monitored.

In practice most plant owners in the United States have installed systems which meet the minimum requirements of the Regulatory Guide. In a few cases, particularly along the Pacific Coast, utilities have gone beyond the minimum requirements by increasing the number of sensor locations. Southern California Edison Company has developed a Seismic Surveillance System which combines data recording, instrument maintenance and analysis procedures.[5]

The U. S. Nuclear Regulatory Commission has issued Standard Technical Specifications[6] for periodic maintenance which call for a Channel Check (monthly), a Channel Functional Test (semi-annually), and a Channel Calibration (at refueling intervals). The Channel Check is a qualitative verification of the functional status of the instrument, sensor or system. The Channel Functional Test is a determination that an instrument, sensor or system responds to a known input in such a way as to verify operability. Channel Calibration is the determination and adjustment, if necessary, required to verify that the channel output responds within a specified range and accuracy to the known input.

The Channel Check and Channel Functional Test requirements are satisfied by the use of built-in test controls along with visual inspection procedures. Channel Calibration requires tilt testing or shake table testing to verify the dynamic response of the systems. An ad-hoc group of the American Nuclear Society (ANS) 2 Site Evaluation Subcommittee is preparing a proposed addendum to ANSI N18.5 which is similar to but with more detail than the Standard Technical Specifications.[7] A number of the U. S. nuclear plants have maintenance contracts with the seismic instrument manufacturer in which the Channel Check and Channel Functional Test functions are performed and periodic visits made to the site by factory engineers.[8]

Working Group 2.10 of the ANS 2 Site Evaluation Subcommittee is preparing a proposed standard, "Guidelines for Retrieval, Review, Processing and Evaluation of Records Obtained from Seismic Instrumentation."[13] In this proposed standard a Decision Tree is used to describe in detail the necessary evaluation steps between event occurrence and continued operation or recertification of the plant.

## STANDARDS AND PRACTICE IN THE FEDERAL REPUBLIC OF GERMANY

Earthquake instrumentation guidelines are under study and development in Germany.[9] A rule proposed in October 1973 requires instrumentation for all plant sites with a Sicherheitserdbeben (comparable to the U. S. Safe Shutdown Earthquake) maximum ground acceleration of 0.1g or larger. Four seismic risk Zones are defined for the country.[10] For Zone 1 two instruments are to be installed at appropriate locations in the reactor building, including one on the foundation and must be able to record the Auslegungserdbeben (comparable to the U. S. Operating Basis Earthquake or 1/2 SSE); if this design earthquake is exceeded the plant must be investigated.

For plants in Zones 2 and 3 a third instrument is to be installed in the reactor building.

In practice, the German plants are installing remote triaxial acceleration sensors at several locations, remote triaxial trigger units and central cassette tape recording systems. In addition, several seismic switches are being specified.

## STANDARDS AND PRACTICE IN JAPAN

No seismic instrumentation regulation exists in Japan, however, the Japanese Advisory Committee on Reactor Safeguards considers each plant separately and usually advises one strong motion accelerograph on the foundation of each plant.[11] Plants known to have accelerographs include Tsuruga, Tokai 1, Mihama 1, 2, Takahama 1, Hamaoka 1 and Genkai 1.[12] Several plants use seismic triggers for automatic shutdown with the trigger level usually set between 100 and 200 gals.

## STANDARDS AND PRACTICE IN OTHER COUNTRIES

India - Regulatory guidelines are expected to be developed.

Spain and Brazil - U. S. Regulatory Guide 1.12 has been used as a reference in instrument specifications.

Canada - No written regulations exist, however, the Canadian National Committee on Earthquake Engineering has made certain recommendations for nuclear plant instrumentation standards.

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## DISCUSSION

S. Arora (Canada)

What is the definition of category I equipment and Piping and is there any relationship between zones 1, 2 and 3 in West Germany and Category I, II equipment and Piping in U.S.A. ?

I.K. Aneja (U.S.A.)

The author has given a good summary of Standards and Practices as recommended by various regulatory agencies for instrumentation of Nuclear Plants. Hopefully the experiences gained from these procedures would lead to similar instrumentation programs for other costly civil works of major importance such as dams. In the case of Nuclear Power Plants so far the emphasis has been to instrument Class I category structures such as the containment vessel, and other components of Nuclear Steam Supply System (NSSS). This is due to the potential of catastrophic loss primarily to human life and secondarily to property. However nuclear power plants being designed these days are capable of producing upward of one million kilowatt of electricity and they cost as much as one billion dollars each.

Outside of NSSS and containment vessel turbine-generator is the largest component of Nuclear Power Plant. Turbine generator foundations for these plants are usually 60 ft. tall and the top of the crossover crossunder piping which are relatively flexible components may be located as much as 100 ft above the ground level. Should a major seismic damage occur to a turbine-generator of nuclear plant, it may take anywhere from a few months to several years to replace it. The writer feels that the turbine - generator unit should also be instrumented with triaxial accelerograph located at the turbine - foundation top deck so that necessary data can be accumulated for their proper design to resist expected earthquakes. The writer would appreciate any information the author can provide on the availability of existing seismic data on nuclear power plants (including historical data on damage to these plant components).

Author's Closure

With regard to the question of Mr. Arora, we wish to state that the NRC Regulatory Guide 1.29 defines Category I structures systems and components as those which must remain functional if the SSE (Safe Shutdown Earthquake) occurs. The seismic risk zones in West Germany are geographical zones for which different levels of instrumentation are requires, and they bear no relationship to the Seismic Categories.

With regard to the question of Mr. Aneja, we wish to state that the author is unaware of any nuclear plants where earthquake acceleration sensors have been located on the turbine - generator foundation. Earthquake response data for the T-G foundation would be of great value for future design input, however plant owners consider such data to be research-related rather than safety-related and are reluctant to pay for the instrumentation even though the incremental cost would be low. As far as the author knows, no damage-related acceleration records exist, but a paper titled "Structural Vibration Surveys Applied to Flexible Concrete Turbine-Generator Pedestals" is available on request.