EARTHQUAKE IN THE "SCHWÄBISCHE ALB"/GERMANY SEPTEMBER 3, 1978

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Summary
The earthquake in the Schwäbische Alb on September 3, 1978 had a local network magnitude of 5.7 and thus is counted as one of the strongest earthquakes which are to be expected in the Federal Republic of Germany. The related intensity has been determined of 7.5 to 8 (MSK-scale). Above all this report presents the effects on mechanical and electrical components. These effects were caused, without exception, by displacements due to the fact that no technical measures had been planned for accepting horizontal forces.

It is shown that mechanical components retain their functionability even if the buildings in which they are located suffer substantial damage in part. This also applies to electrical installations in general.

The intensity of 8 (MSK) corresponds to the "safe shutdown earthquake" stipulated for the sites of the Biblis and Philippsburg nuclear power stations. Usually reports of earthquakes present descriptions of damages to buildings but not of mechanical and electrical components. For this reason the effects of this earthquake on electric power and industrial facilities are of main interest. In order to define a realistic design procedure for power plants it is necessary to have information about the effects on all safety relevant structures. Surely the lack of information on that subject is one of the main reasons that the current seismic design process is reasonable conservative or unrealistic. According this procedure a reinforced and well constructed building which may resist an earthquake intensity of 7 without any damage would have been reinforced much more. The seismic design of nuclear power plants involves a number of steps including a lot of conservatisms: the definition of a design basis seismic ground motion, consideration of soil-structure interaction effects, development of floor response spectra and the final stress analysis. No feature of each step should be considered independently and without keeping in mind the overall seismic design process.

The nature of the damage documented confirms anew the opinion proferred by renowned experts that the methods and analysis assumptions, used in nuclear power station earthquake design, vastly over-estimate the real earthquake effects. Such a large number of "conservative" estimates could result in constructional designs which are of disadvantage for normal operation and inspections of the plant.

For these reasons this paper should provide an incentive to bring the analytical assumptions and calculational methods into line with reality.

Damage evaluation

The damage to dwellings was in part considerable. In total approx. 50 houses are ready for demolition related to a sum of approximately 10,000 damage reports. Crumbling areas of inner and outer plaster, broken-off chimney tops, exposed roof areas of varying sizes and cracks in walls were the most frequent and superficially recognizable effects. These could be assigned to the following causes:

- Discountinuities in the rigidity of the building materials (e.g. reinforced concrete girdes and masonry)
- Rigidity changes in the structures (e.g. bay windows, superstructures)
- Shear strains in the masonry from floor displacement

No damage whatsoever occurred to reinforced concrete buildings of locally mixed concrete, apart from one exception. Likewise the earthquake strains on steel constructions remained without effect.

Representing the characteristics of the effects to mechanical components one example is given in Fig. 1 and 2. The water-filled vessel which is mounted on a sectional steel frame approx. 4 m above the floor remained undamaged (picture 1) although the piping was rigidly connected to the building wall. At the points where both the horizontal steel sections are embedded in the wall it can be seen that the mortar has been loosened from the wall. In this case the filling of the mounting holes with mortar was the only fortuitous measure for taking horizontal forces. Features which would have implied possible movements of the vessel are not to be recognized. Likewise the connected lines remained unimpaired.

In the same boiler house which has been considerably damaged the heating boiler is installed. The boiler itself has an operating weight of approx. 33 t and an operating pressure of 12 bar. During the earthquake the plant was not in operation.

The support of the boiler (Fig. 2) consists of an approximately 10 cm high concrete base on which the boiler stands without any mounting arrangement. An anchor or device against horizontal or vertical forces is not present.

The boiler was displaced 2.5 cm in one direction as a result of the earthquake stresses (Fig. 2). Damage which would have impaired the functionability of the plant in some way or other (e.g. flange leakages etc.) had not occurred. Neither could any effects be established on the flanged burner of the boiler which represents the largest excentric mass of the vessel.

The effects on vessels were compiled from our own investigations or from descriptions of the company owners. Reports of damage sent to official administrative agencies or to the insurance company represented on the emergency board were not investigated. Thus it may be assumed that the effects on mechanical and electrical component parts which have been viewed and partly documented here do not only present just a representative summary but also record them in their entirety.

Concerning piping systems no sort of damage or leakages has arisen to or from any of the steel piping and its connections. No report of this type of damage has been made to official agencies.

Damage occurred to electrical components at positions where unrestrained displacements were made possible due to the dynamical excitation. In approx. 40 transformers the non-vibration resistant Buchholz-type protective relays had been triggered. In one case a short-circuit had been caused at the bend of two 20 kV cables which was initiated by the earthquake but, however, whose cause was attributed to the false mounting of the cable heads. Falling chimney debris or the swinging of low-voltage overhead lines caused several mutual contacts and thus short-circuits.

In one transformer station a large transformer of approximately 2 t weight was thrown from the guide rail and had temporarily leaned against the wall of the prefabricated concrete building.

A similar event also occurred to another transformer. The shaking caused the transformer of 1.5 t weight to spring over the raised edge of 15 mm height. It was displaced by almost the full wheel breadth of 50 mm.

Damage or functional faults were never established in the switchgear of public power supplies nor in those of the factories mentioned. In one case a switchgear building had a rotational displacement of approx. 3.5 cm .
In spite of the substantial damage to the building which documents large earthquake accelerations, the switch cabinets were fully unimpaired.

Batteries are located in separate rooms of low-voltage distributor buildings to provide control current supply. These had been partly displaced by several centimetres from their seating during the earthquake.
Similar batteries are located on approx. 1.4 m high wooden frames with two storage levels. These wooden frames were overthrown. The fire brigade had sprayed an extinguishing agent in order to avoid subsequent damage from spilled acid. This extinguishing agent combined to form corrosive gases which partly corroded bare metal contacts in the neighbouring switch rooms.

Earthquake effects were neither established on the plant components themselves nor on the turbine and generator supports.

The mounting and supports of this type of component is already designed to take horizontal forces for functional reasons.

Rather strikingly it has been shown that mechanical component parts remain functional even if the buildings, in which they are located, have been partly substantially damaged thus implying high intensities at these positions. This applies (with a few exceptions- untypical for modern constructions) equally as well to electrical components and independently of installation locations. That is, the same is applicable to components which were installed at foundation level as to those which were mounted on walls of floors.

The observation that the effects on components were less than those to be expected from analysis and hypothetical calculation assumptions is confirmed by the descriptions of damage for the earthquakesin Japan, Friaul and Managua. Intensities of 7 to 10 were measured for these earthquakes.

Should a comparison be made between the effects on mechanical and electrical components in the region of Albstadt and those which could have been expected in a nuclear power station then the following is of importance:

- Structures and components of todays nuclear power stations in the Federal Republic of Germany are conceived, constructed, analyzed and designed taking aspects of dynamical loadings due to earthquakes into account, among other effects.
- The quality of materials is greater by far than those of all other technical plants.
- The monitoring of material quality and building construction ensures that structures and component parts are actually able to accept the loadings.

These reasons on the one hand and observations on the other hand demonstrate that a nuclear power station sited in Albstadt would have accepted such earthquake loadings without damage.
This statement could even be made plausible as well for a nuclear power station of non-earthquake resistant design of the present structures, components and piping systems in Albstadt are compared with the reinforced concrete buildings and plant structures of a nuclear power station that must in any case, inter alia, be of a design to permit acceptance of the loads arising from normal operation and those from incidents.

The earthquake effects on mechanical and electrical component parts are less than those which could be expected as implied from the damage to buildings which are not of earthquake resistant design. Thus it would appear possible to preclude damage from earthquakes of an intensity not greater than could possibly be expected at German sites by conforming with set constructive minimum requirements for vessels and piping systems which include electrical components and their supports.