DEVELOPMENT OF REQUIREMENTS FOR SEISMIC UPGRADING OF EQUIPMENT OF EXISTING WWER-440 AND WWER-1000 TYPE NPP's

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1. INTRODUCTION

The first NPP's with WWER-type reactors have been projected and built without calculation of seismic influences or on the base of simplified calculations, namely "Novovoronezskaya" and "Kolskaya" NPP's in Russia, "Kozloduy" NPP, units 1-4, in Bulgaria, "Bohunice" NPP in Slovakia, the first unit WWER-1000 of "Yuznoukrainskaya" NPP in Ukraine.

In connection with change of seismology data and safety demands it is arised the necessity of checking up and ensuring of technology systems seismic resistance at numerous units with WWER-type reactors in Russia, Armenia, Ukraine, Bulgaria, Hungary, Czechoslovakia.

2. TRADITIONAL METHODS AND APPROACHES

VNIIAM as a head institute of former USSR in a sphere of designing and testing of most of NPP equipment types is responsible for their seismic resistance. We use traditional methods of seismic resistance ensuring, namely: seismic solidity and seismic stability calculations on stages of new equipment designing, additional calculations of equipment placed at NPPs in cases of seismic influence data or safety requirements changes; laboratory testing on vibrostands for checking up of calculation data and examination of mechanisms capacity for work during of earthquakes. We are carrying out these investigations on the base standards and demands in force with using of the modern banks of mathematic programmes and experimental methods. VNIIAM carried out a lot of calculations and tests of different types of equipment, namely: numerous heat exchangers, steam and water pipeline valves, water treatment filters, ventilators, steam generators, pipelines of safety systems [1,2,3]. In 1985-1987 Design Bureau "Hidropress", VNIIAM and Syzran Turbine Building Plant carried out the elaboration, testing and serial production of hydroamortizators (snubbers) with load capacity from 5 to 450 tons for NPPs of former USSR [4]. VNIIAM also worked out and ensured the new constructions of snubbers with reliable and increased period of unrepair operation [5].

3. SCIENTIFIC-ORGANIZATION STEPS

The numerous institutes and undertaking of the former USSR carry out the works in sphere of NPP equipment seismic resistance, namely Design Bureau "Hidropress",

VNIIAM, Atomenergoproject,CKTI, faculties and laboratories of the different education institutes, atomic machine-building plants. With the purpose of co-ordination and improvement of investigations VNIIAM since 1985 has organized the annual conferences which were held by turns in Kirghizia on base of Polytechnical Institute (at Issik-Cool lake) and in the North Caucasus on the base of Naltchik University (near Elbrus mountain). The latter conferences (in 1988 in the North Caucasus and in 1988 in Kirghizia) were held with participation of specialists from Bulgaria, Czechoslovakia and Hungary [6,7]. In accordance with the decision of the second conference that was offered by Mr. Kostarev from CKTI specialists of leading enterprises carried out the test calculations of agreed equipment types using their own methods and mathematical programmes. Special group of experts carried out the analysis of results and worked out the recommendations [8]. Periodic journal "Soviet Energy Technology" ("Energomashinostroenie") regularly published the materials of the conferences. This journal also is published in English. The last name of the journal is "Heavy Machine-Building" (Tyajoloe Mashinostroenie).

In Moscow in March 1986 IAEA organized the specialists meeting on earthquake ground motion and antiseismic evaluation of NPPs. Specialists from more than 20 countries took part in that meeting. Dr. Kirillov, Dr. Ambriashvili, Dr. Kaznovsky and other soviet specialists took part in that meeting as members of Organization committee and as lecturers.

4. CALCULATIONAL-EXPERIMENTAL METHOD OF EXAMINATION AND ENSURING OF EQUIPMENT SEISMIC RESISTANCE AT NPPs DIRECTLY

As it is known the seismic influence on structures and equipment have a resonance nature. Ground and level-by-level response spectra have peaks in natural frequency range from 1 to 10 Hz approximately. Therefore the natural dynamic characteristics (frequencies, decrements and modes) have decisive influence on equipment and pipelines seismic resistance. It is obvious that natural dynamic characteristics of any concrete unit depend on its design and materials as well as on dynamic properties of all joined elements (supports, pipelines, isolation, etc.). Any concrete unit can not be seismically resistant by itself (separately from other connected elements). Disregard of this fact can lead to serious troubles. Unfortunately the best mathematical programmes and computers are not able to reproduce dynamic correlation between all elements of NPPs. The same problem exists for vibration test on special stands because their sizes and bearing capacity do not permit to test the real technological systems of NPPs. The test of smollsized models does not solve this problem too. Therefore VNIIAM since 1980 has organized systematic calculational-experimental examinations at the starting and operating NPPs directly [9,10]. This method is as followed. With the help of external power influence the vibrations of examinating unit are excited and at the same time registration of vibrations are carried out with the help of transducers of acceleration, velocity and shift. Analysis of experimental data permits to receive the values of the natural dynamic characteristics (first of all natural frequencies and decrements) of units in their real joint with other elements of NPPs. Experimental data then are used for seismic resistance calculations with application of appropriate mathematical programmes. For excitation of the oscillations at the early

stages we used the shock method with the analysis of the damped vibrations. Subsequently VNIIAM together with Naltchik University worked out and mastered special small-sized automated connectable electromechanical vibrators of directed action. These vibrators operate in frequency range from 1 to 50 Hz in the regimes of smooth or step change with regulated velocity [11,12]. At present we use the shock method for dynamic test of equipment at NPPs only in the cases of hard access to units or dangerous radioactivity. Vibration excitation of technological filled structures with the help of the underground explosions is a very perspective method. During the demonstration tests at the "Bohunice" NPP the specialists of VNIIAM carried out the test of the main circulation pump with the help of the small-sized connectable vibrator. At the same time the specialists of Skoda-Plzen under leadership of Dr Masopust carried out the investigations with the help of the large vibration machines placed on the floor of the reactor room and within technologic tunnels. Specialists of the Moscow institute "Hydroproject" carried out small series of electric equipment and panels vibration tests with the help of small vibrators at the several NPPs. More extensive similar investigations are executed by Research Center Applied Nucleonic Co., California. However is seams to us VNIIAM has did much work in the sphere of experimental investigations at NPPs directly. Our method includes the following stages:

- correcting of equipment list which must be checked-up;
- detailed study of design documentation;
- visual and tool-making inspection of equipment at NPP for checking up the correspondence of equipment and its mounting to technical documentation;
- carrying out of the dynamic tests, including measurements of actual dynamic characteristics;
- calculation check-up op equipment seismic resistance, using experimental values of natural dynamic characteristics;
- development of concrete procedures for equipment seismic resistance ensuring, when it isn't confirmed;
- recommendations realization control.

Our method is realized at 22 starting and operating units of NPPs with reactors of various types (WWER-440, WWER-1000, RBMK). The following types of equipment were checked-up: heat-exchangers, deaerators, pressure compensators, pumps, tanks, water treatment filters, ventilators, pipelines, energy and special valves, pipelines in the engine-rooms, conditioners, etc. Number of equipment types at single NPP unit was equal to 15-60, number of equipment units up to 200. List of NPPs and reactor types is shown in Table 1.

Table 1. List of inspected by VNIIAM NPPs and reactor types

No.	NPP name	Country	Unit	Reactor type
1	Yuznoukrainskaya	Ukraine	1	WWER-1000
			2	WWER-1000
2	Kozloduy	Bulgaria	1	WWER-440/230
			2	WWER-440/230

			3	WWER-440/230
			4	WWER-440/230
			5	WWER-1000
3	Zaporozskaya	Ukraine	1	WWER-1000
			2	WWER-1000
4	Armyanskaya	Armenia	1	WWER-440/270
			2	WWER-440/270
5	Bohunice	Slovakia	1	WWER-440/230
			2	WWER-440/230
			3	WWER-440/213 *)
			4	WWER-440/213 *)
6	Chernobylskaya	Ukraine	1	RBMK-1000
			2	RBMK-1000
			3	RBMK-1000
7	Kurskaya	Russia	1	RBMK-1000
			2	RBMK-1000
			3	RBMK-1000
			4	RBMK-1000

*) preparatory stage

Some results of checking-up of Armenian NPP equipment and pipelines seismic resistance may be cited as an example. VNIIAM checked-up the equipment and pipelines seismic resistance at Armenian NPP in 1988 and completed this work shortly before Armenian earthquake. In ,accordance with seismology requirements the maximum possible earthquake (MPE) was equal to 8 degree according to MSK-64 scale. MPE is Russian equivalent to SL-2 level of IAEA standard [13]. It was established that 14 equipment types from 26 checked-up and 4 pipelines system were not seismically resistant units. Fortunately, earthquake intensity on the NPP site was about 6 degrees. Tests at NPPs showed that dynamic measurements may be used as easy and reliable method of diagnostic of equipment state in the process of NPP operating and after strong extremal influence (accidents, earthquakes, etc.). This method also permits to reveal the errors in process of equipment mounting. It is connected with considerable influence of deformation and damages of equipment and support elements upon their natural dynamic characteristics. Then the same test are to be carried out systematically (for example once per 4 years) during the NPP operating period and especially after every extreme event (strong earthquake, etc.). All the conditions of test must be strictly identical. In this sense the experimental results which were obtained before the severe earthquake in Armenia are unique. Repeated dynamic measurements will permit to obtain very important and useful results for all countries, atomic energy firms and specialists. To conclude this paragraph we want to note that calculational-experimental method of checking-up of equipment at

operating NPPs has not yet standardized. The only official document in our country concerning this problem is the "Decision", that was signed in May 1984 by the Ministry for power machine-building and Ministry of Energetics of USSR. According to this "Decision" for carrying out inspection of any concrete NPP VNIIAM is to submit the list of equipment, the programme and investigation methods to the approval of NPP Chief Designer, NPP Directorate and the Committee of Atomic Inspection.

5. METHOD OF GROUND EXPLOSIONS

Small power influence on the testing equipment is a main and perhaps the only defect of above-described method. This fact as a rule dose not permit us to take into account the influence of nonlinearities (friction, damping, etc.). Moreover this method does not permit to check a workability of the equipment and mechanisms during and after the earthquakes. Special ground explosions give the real possibility to carry out the full-scale tests of technological systems influenced upon by the real earthquakes. Academician Nigmatullaev worked out the method of multiple linear unconcentrated short-delayed ground explosions that ensures the imitation of real earthquakes of any intensity, frequency spectrum and duration [14]. This method has been developed and successfully used during 25 years to test the seismic resistance of the industrial buildings and dwelling houses in Tadjikistan on the special polygon of the Tajik Academy of Sciences which is not far from Dushanbe. Seismic explosive polygon of the Russia Ministry of Defence near Saint-Petersbourg is based on the other principle. The polygon consist of several test platforms of different designs, sizes and carrying capacity (up to 400 tons). Explosions is carried out under foundations or supports of platforms directly. Such method permits to achieve the accelerations up to 10 g and more as well as to ensure the demanded level-by-level response spectra. The polygon is functioning about 20 years. The science leader is professor Belyaev. On the basis of generalization of Tadjik and Saint-Petersbourg polygons experience VNIIAM elaborated the project of the special seismic test complex that combine the advantages of the above-mentioned explosion methods [15]. Versions of placing complex in the North Caucasus and on the Sahalin island were considered and approved by the government bodies. However financial and organization difficulties do not permit to realize the project in the near future. Undoubtedly such complex has to be created on the basis of the international co-operation. Evidently the most optimum variant (from economic and geography position) is the improvement of Saint-Petersbourg polygon and creation on its base of international seismic test Center. We have got the consent of the Russia Ministry of Defence on this steps. Creation of such Center will permit to solve two important problems:

- carrying out of the control tests of the most important technological systems of concrete or typical NPP units;
- experimental basing of the standards, codes and guides for NPPs and their perfection.

To our opinion, the second direction is to be realized by common efforts of specialists of interested countries and firms under the patronage of IAEA.

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