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Ob petdesetletnici prvega jedrskega reaktorja
Fiftieth Anniversary of the First Nuclear Reactor

MILAN OSREDKAR

Odkritje jedrske reakcije (1938), pri kateri se jedro izotopa urana 235, če je zajelo nevtron, razcepi, predvsem pa odkritje, da se pri tem sprostijo še dva do trije nevtroni (1939), je takoj navedlo na možnost nastanka verižne reakcije in sproščanje velikih količin energije za uporabo, npr. v elektrarnah ali pa za jedrsko bombo. Francoski fiziki Joliot, Haldan in Kowarski so to zamisel leta 1939 patentirali. Laboratorijske raziskave so možnost verižne reakcije v celoti potrjevale, izpeljal in s tem dokončno dokazal pa je ni takrat še nihče. Francoski znanstveniki so se namenili, da bi postavili napravo za potek verižne reakcije, prehitela pa jih je vojna. Zato so vse naprave preselili in nadaljevali delo v Angliji. Približno hkrati je Američan Seaborg na velikem ciklotronu v Kaliforniji z nevtroni bombardiral izotop urana 238 in ugotovil, da nastane pri tem nov, do takrat neznan element. Imenoval ga plutonij, ki je tudi uporaben za verižno reakcijo.

Težišče dela za uresničitev verižne reakcije je tako prešlo v ZDA. Predsednik Roosevelt je namreč leta 1941 sprejel pobudo za izdelavo jedrske bombe, ki jo je dal madžarski begunec Szilard prek Einsteina. Ta odločitev je pomenila, da je v treh letih iz nič nastal industrijski orjak, velik kakor vsa takratna ameriška avtomobilska industrija. Ta načrt imenovan najprej »metalurški projekt«, pozneje pa »projekt Manhattan«, je dobil nalogo, da izdela naprave in številna, do takrat neznana gradiva, potrebna za izvedbo verižne reakcije in izdelavo jedrske bombe.

Nalogo, kako izpeljati in dokazati verižno reakcijo, je dobil nobelovec Fermi. Tudi on je leta 1938 pobegnil iz Italije in bil eden najboljših jedrskih fizikov svoje generacije. Okrog 50 ton naravnega urana, nekaj ga je imel v obliki kovine, nekaj pa oksida, in 400 ton posebej prečiščenega grafita je zložil v kopo. Ko je 2. decembra 1942 iz kope počasi vlekel kadmijeve krmilne plošče, so merilniki pokazali, da je fluks nevtronov začel naglo naraščati. To je bil dokaz, da je prvič v zgodovini stekla uranska verižna reakcija, da je bila kopa »kritična«.

The discovery of the nuclear reaction (in 1938), in which the nucleus of the Uranium 235 isotope capturing a neutron splits, and above all the discovery of the simultaneous generation of two to three new neutrons (in 1939), lead immediately to the possibility of a chain reaction and the loosening of large quantities of energy for use, e.g., in power stations or for a nuclear bomb. The French physicists Joliot, Haldan and Kowarski patented this idea in 1939. Laboratory research entirely confirmed possibility of the chain reaction, although realisation and final proof was produced by nobody at that time. French scientists intended to build a pile for the chain reaction process, but the war overtook them. The equipment was moved in totality to England. At approximately the same time, the American Seaborg, using a large cyclotrone in California, bombarded the Uranium 238 isotope with neutrons and discovered a new, as yet unknown element. He called it Plutonium, which is also applicable for the chain reaction.

The centre of work for realisation of the chain reaction was thus transferred to the USA. In 1941, namely, president Roosevelt accepted the idea of the development of a nuclear bomb, proposed by the Hungarian refugee, Szilard through Einstein. This decision meant that in the three following years an industrial giant sprang up from scratch, growing to a size larger than the whole American car industry at that time. The plan, called the »metallurgical project« — later the »Manhattan project« was given the task of building aparata and finding numerous unknown materials needed for the creation of the chain reaction and the production of a nuclear bomb.

The task of executing and proving the chain reaction was given to Nobel prize winner, Fermi. He had also since 1938 been a refugee from Italy and was one of the best nuclear physicists of his generation. Some 50 tons of natural uranium, partly in the form of metal and some in the form of oxide, and 400 tons of specially purified graphite were used to build a pile. On 2nd of December 1942, while Cadmium control plates were slowly pulled

Trideset let pozneje se je pokazalo, da je to bilo res prvič le v človeški zgodovini, ne pa v zemeljski. V Oklu (Gabon) so namreč Francozi našli rudišča urana, ki so povsem nesporno kazala, da so bila pred približno dvema milijardama let, ko je bilo v naravnem uranu še nekajkrat več izotopa 235 kakor danes (0,7 %), nekatera rudišča »kritična« ob navzočnosti vode, da je potekala na več mestih verižna reakcija. Podatki o tem, kako so se po teh reakcijah obnašali oziroma zadrževali razcepki in takrat nastali plutonij, so zelo pomembni za današnje znanje in načrte, kako ravnati z radioaktivnimi odpadki.

Dogodek decembra 1942 je ustvaril stvarne temelje za nadaljnje uresničevanje možnosti za izrabo jedrske energije, tako za vodeno oziroma miroljubno uporabo kakor za jedrsko bombo. Ta zgodovinska miselna in tehnična povezanost jedrskih elektrarn in jedrske bombe je ena od usodnih okoliščin, ki so psihološko sprožile odpor proti jedrskim elektrarnam, čeprav dandanes nimajo nobene povezave z izdelavo in uporabo jedrske bombe.

O tem, kakšna naj bo uranska »kopa«, danes jo imenujemo »jedrski reaktor«, so bile že na samem začetku načelno oz. na papirju zasnovane vse možnosti. Praktično vsi tipi reaktorjev: homogeni, težkovodni, grafitni, lahkovodni, hlajeni s kovino, s plinom, visokotemperaturni, oplodni, so v zamisli znani že dolgo časa. Tudi »atomska« lokomotiva, vozilo, ladja, podmornica, letalo, raketa itn. so postali predmet študij in načrtov po vsem svetu. Jedrska energija se je zdela takrat in še lep čas potem pravi čudež, ki bo rešil svetovne energijske probleme.

To navdušenje se je z leti poleglo. Leta so pokazala, kaj je in kaj ni izvedljivo. Na primer homogeni reaktor, čeprav v mnogih pogledih izjemno privlačen, je zaradi nerešljivih korozijskih problemov po dolgotrajnih prizadevanjih končno odpadel. Grafitni plinski reaktorji v Veliki Britaniji in Franciji, ki so bili sprva postavljeni kot dvonamenski (energija in plutonij) se umikajo lahkovodnim, grafitni vodno hlajeni (sovjetski) niti tehnično, posebej pa še zaradi Černobila, nimajo prihodnosti; oplodni se šele prebijajo v industrijo. Težkovodni (kanadski) gotovo ne bo zdržal tekme z lahkovodnim (tlačnim in vrelnim), v katerega je bilo vloženega največ dela in izkušenj. V zgodnjih povojnih letih v ZDA je v tekmi, kateri reaktor bo najprimernejši za podmornico, prevladal tlačni lahkovodni reaktor. Sledil je (1957) tak reaktor za elektrarno Shippinport in danes lahkovodni reaktorji, posebej tlačni, močno prevladujejo po vsem svetu (okrog 3/4 vseh jedrskih elektrarn). Od vseh različnih zamisli o jedrskem pogonu se je uveljavil le pogon za podmornice in letalonosilke.

Jedrske elektrarne dajejo dandanes po svetu pomemben delež električne energije. Leta 1991 jih je delovalo ali bilo v gradnji skupaj 496. V nekaterih državah je njihov delež zelo pomemben (Francija 72,7 %, Belgija 54,3 %, Švedska 51,6 %, Madžarska 48,4 %, R. Koreja 47,5 % itn.). Na drugi

out, measurement devices indicated that the neutron flux was rapidly increasing. This was the proof, the first Uranium chain reaction took place in history, the pile being »critical«.

Thirty years later, it was found that this event was the first only in human history, but not in terrestrial time. In Ocle (Gabun), the French found Uranium beds, undoubtedly showing that some two billiads of years ago, when the natural Uranium contained a few times more isotope 235 that today (0.7 %), some beds went »critical« due to the presence of water, enabling a chain reaction to take place at several locations. Data on how these reactions took place and contained fission products and the produced Plutonium, are very important for modern knowledge and planning of radioactive waste disposal.

The December 1942 event provided a real foundation for the following realisation of the possibilities of using nuclear energy, both for controlled peaceful use and for the nuclear bomb. This historical, ideological and technical connection between nuclear power plants and the nuclear bomb is one of the fatal circumstances, psychologically triggering opposition to nuclear power plants, which today have no connection with the production and use of the nuclear bomb.

On the subject of what kind of Uranium »pile«, which is today called a »nuclear reactor«, principles were determined on paper at the beginning. Practically all types of reactors; homogeneous, heavy water, graphite, light water, metal and gas cooled, high temperature, breeder etc. were planned a long time ago. Even »atomic« locomotive, vehicle, ship, submarine, plane, rocket etc. were studied and designed all over the world. Nuclear energy appeared at that time and even later, to be a miracle, a solution to the world energy problem.

Such euphoria ceased with age. Years have shown what may be done and what not. The homogeneous reactor, for example, though very attractive from several points of view, was eventually abandoned due to unresolved corrosion problems. Graphite-gas reactors in Great Britain and France, first built for dual purposes (energy and Plutonium), gave place to light water ones, graphite-water cooled (Soviet) have no future from the engineering aspect, but also due to the Chernobyl story; breeders being slowly introduced industrially. The heavy water (Canadian) type cannot compete with the light water (pressurised and boiling), which has compiled most of the experiences. In the early post war years in the USA, competing for submarine propulsion, pressurised light water reactor emerged. A similar reactor followed (in 1957) for the Shippingport power plant, and today light water reactors, especially pressurised, greatly predominate throughout the world (approximately 3/4 of all nuclear power plants). Of all the ideas for nuclear propulsion, only that for submarines and air craft carriers has been applied.

strani pa je odpor javnosti proti jedrskim elektrarnam postal glavni dejavnik pri energijskih odločitvah. Izvirni greh jedrske energije — jedrska bomba, ki še sedaj, tako zaradi razpada Sovjetske zveze kakor zaradi arabskih in izraelskih ambicij, vedno znova vzemirja in straši ljudi, nič manj pa prastrah pred radioaktivnostjo, zamegljujeta stvarno sliko o tem, kakšna je vloga in sprejemljivost jedrskih elektrarn. Na nobenem drugem področju sodobnega industrijskega razvoja se vprašanja o sprejemljivosti za okolje, tveganju, posledicah, obveščenosti in politizacije niso tako zaostrila. Katastrofa v Černobilu, pa tudi drugi dogodki, so zaskrbljenost javnosti upravičeno močno povečali. Zato bo o prihodnosti jedrske energije, mnogo bolj kot gospodarstvo in mnenja energetikov, odločalo mnenje javnosti.

Na to mnenje seveda vpliva veliko dejavnikov, od socialne strukture prebivalstva in sistema vrednot, do zelo pogostega nezaupanja v stroko in znanost ter izpostavljenosti vsem mogočim informacijam, resničnim ali neresničnim. Odpor proti jedrskim elektrarnam je del gibanja zelenih in se je v resnici razvil predvsem iz odpora proti jedrski bombi. Raziskave zadnjih let v Angliji kažejo, da ob besedi »jedrski« kar 55 % vprašanih pomisli na jedrsko bombo, vojno, smrt, orožje, radioaktivni udar ali eksplozijo, le 6 % na Černobil in 6 odstotkov na odpadke in onesnaženje, 25 % vprašanih pa misli, da delajo v jedrskih elektrarnah tudi jedrske bombe. Od vprašanih je bilo tudi 55 % zaskrbljenih zaradi jedrskih elektrarn, kar so utemeljevali s tem, da povzročajo jedrske elektrarne kisli dež (37 % vprašanih), da so premogovne elektrarne varnejše od jedrskih (47 %), da je naravna radioaktivnost manj nevarna od umetne (25 %) in podobno. Za razumevanje, kako javnost sprejema dogajanja, je poučen tudi podatek, da so v južni Angliji izmerili radon (ki povzroča v Angliji okrog 2500 primerov pljučnega raka na leto) v 80000 domovih in ugotovili, da je treba v 16000 domovih ukrepati za zmanjšanje koncentracije radona, vendar so ljudje za izboljšanje poskrbeli le v 300 primerih. To dokazuje, da ljudje niso pripravljeni sami ničesar ukreniti za svojo varnost, hkrati pa ustvarjajo pritisk na državo oziroma industrijo, naj vlagata milijone za dodatno zmanjšanje radioaktivnosti iz jedrske industrije, ki je že zdaj v skladu s predpisi in neprimerljivo (200-krat) manjša od aktivnosti zaradi radona. Težko bi trdili, da je poučenost javnosti pri nas boljša. Angleški podatki ponazarjajo stanje obveščenosti in obnašanje javnosti, ne spreminjajo pa neizpodbitne resnice, da bo pri odločitvah tam in pri nas imela javnost odločujočo besedo.

Seveda je upravičeno vprašanje, kdo naj poskrbi, da bo javnost popolno obveščena o tem, o čemer bo odločala. Veliko odgovornost prevzemajo strokovnjaki, ki morajo obveščanju javnosti posvetiti več pozornosti. Še večja je odgovornost tistih, katerih stroka je obveščanje, pa včasih zaradi želje po zanimivih novicah ali zaradi političnih pritiskov, zanemarjajo svoje poklicne dolžnosti.

Nuclear power plants today worldwide provide an important part of electricity. In 1991, there were a total of 496 operating or constructed. In some countries, the share is very important (France 72.7 %, Belgium 54.3 %, Sweden 51.6 %, Hungary 48.4 %, R. of Korea 47.5 % etc.). On the other hand, there has been strong opposition by the public affecting major power decisions. The capital sin of nuclear energy is the nuclear bomb, which today, not only in view of the fall of the Soviet Union, but also because of Arab and Israeli ambitions, continues to alarm and intimidate people, additionally to the fear of radioactivity, fogging the real picture of the role and acceptability of nuclear power plants. In no other area of contemporary industrial development have questions of acceptability for the environment, hazards, consequences, information and politisation been so decisive. The Chernobyl catastrophe, and other events have increased the legitimate apprehension of the general public. So the future of nuclear power is to be decided not in view of economy and power requirements, but with respect to the public mood.

This mood may be influenced by several factors, from the social structure of the population and system evaluation, to the frequent distrust in experts and science, as well as being exposed to a whole range of information, true or false. Opposition to nuclear power plants is a part of the »green« movement, generated really from opposition to the nuclear bomb. Opinion polls of recent years in England have shown what the word »nuclear« means, even 55 % of respondents think of the nuclear bomb, war, death, weapons, radioactive strike or explosion, only 6 % of Chernobyl and 6 % about waste and pollution, while 25 % of respondents think that nuclear bombs are being manufactured in nuclear power plants. 55 % were even worried about nuclear power plants, because they believed that such plants produce acid rain (37 % of respondents), that coal fired power plants are safer than nuclear (47 %), natural radiactivity is less severe than the artificial form (25 %) and likewise. For an understanding of how the general public accepts events, it is also indicative that in Southern England Radon (causing 2,500 lung cancer deaths annually in England) was detected in some 80,000 houses, requiring measures to decrease the concentration level of Radon in 16,000 houses, but people have only taken measures in 300 cases. This demonstrates that people are not prepared to do something by themselves for their own safety, but they produce massive pressure on the state and industry to invest millions on an additional reduction of radioactivity from the nuclear industry, which is already within the prescribed limits and uncomparably (200 times) lower than Radon activity. It is hard to claim that the awareness of our people is better. English data illustrate the state of awareness and the behaviour of the public, but it cannot change the incontestable truth that the public will have the decisive word in decisions there and here.

Že zdavnaj prej preden so postala vprašanja, povezana z varnostjo in radioaktivnostjo, vzrok za zaskrbljenost javnosti, so se ljudje, ki so delali pri razvoju jedrske energije, zavedali nevarnosti, povezane s to vrsto energije. V bistveno večji meri, kakor ob nastajanju in rasti kateregakoli drugega področja industrije (kemične, železarstva, poljedelstva ipd.), so poskrbeli, da je bila v jedrski industriji skrb za varnost in zagotavljanje varnosti ves čas v ospredju.

Prav zahteva po izboljšanju varnostnih lastnosti reaktorjev je eno od glavnih vodil pri načrtovanju novih elektrarn. Razvoj gre predvsem v smeri zagotovitve tako imenovane globinske varnosti in večje odpornosti proti neobičajnim pojavom in nezgodam, večje izrabe pasivnih samodejnih procesov in drugih ukrepov za preprečitev taljenja sredice in za preprečitev širjenja radioaktivnih snovi v primeru nepravilnega delovanja elektrarne. Seveda pa so pri nadaljnjem razvoju pomembna tudi prizadevanja po povečanju razpoložljivosti elektrarne, to je hkrati po skrajševanju časa za vzdrževanje in zamenjavo goriva, za boljšo izrabo goriva, za gospodarno obratovanje tudi manjših elektrarn, ki naj bi bile manjše investicijsko breme in manjši skok obsega električne mreže in podobno. Ta razvoj bo najbrž zelo postopen, saj vsak investitor želi, da mu dobavitelj zgradi »preizkušen« reaktor in ni pripravljen vlagati v nove modele, če mu pri tem država izdatno ne pomaga. Tudi za uvedbo hitrih oplodnih reaktorjev bo, poleg tehničnih dopolnitev in izboljšav ter mnenja javnosti, odločujoča ta okoliščina.

Analize in ukrepi za varnost delujejo prav na jedrskem področju že zelo dolgo in v vse večji meri se za oceno varnosti, tveganj in vpliva na okolje ukrepa tudi v drugih človeških, posebej industrijskih dejavnostih. Pismenost na področju jedrske varnosti, aktivna strokovna in raziskovalna dejavnost, ki omogočajo strokovno, enakopravno povezavo z enakimi dejavnostmi drugod po svetu, so poglavitna korist in dolžnost vsake države, toliko bolj če so njene zmožnosti omejene.

Avtorjev naslov: Prof. dr. Milan Osredkar, dipl. inž.
Medvedova 12
Ljubljana
Slovenija

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It is fair to ask who will take care of ensuring that they are completely informed about the subject to be decided. Great responsibility lies with professionals, who have to pay more attention to informing the general public. It is even more the responsibility of those whose job is to inform, but sometimes in the desire for attractive sensations, as well as under political pressure, they neglect their own professional duties.

Persons dealing with the development of nuclear energy knew the hazards of this kind of power long before questions connected with safety and radioactivity became reason for popular concern. Care has been taken in the nuclear industry for safety and an assurance of safety at all times as a primary goal to a much greater extent compared with the generation and growth of any other industrial domain (chemical, iron-works, agriculture etc.).

The need to improve the safety characteristics of reactors is one of the most important aims in projecting new power plants. Development is aimed at the so called depth safety assurance and greater resistance to unusual events and incidents, larger use of passive automatic processes and other means of preventing core meltdown, and the prevention of radioactive materials spreading in the case of abnormal activities of the power plant. Of course, efforts to increase the power plant availability are also important for the future development, including shorter breaks for maintenance and refuelling, better fuel utilisation, the economics of smaller power plants, which may reduce the investment burden and smaller jumps in electric network size etc. This development will apparently be gradual, since each utility wishes to obtain from the vendor a »proven« reactor, and is unwilling to give money for new models, unless the government is supporting them. Public opinions will also be a decisive factor in the introduction of fast breeder reactors, in addition to the engineering improvements and modifications.

Analyses and safety measures have a long tradition in the nuclear field, but also in other human and industrial activities for the evaluation of safety, hazards and environmental impact. Awareness in the domain of nuclear safety, active professional and research activity which enable equality with corresponding activities abroad, are of capital benefit and a duty for every country, particularly if its capabilities are limited.

Author's Address: Prof. Dr. Milan Osredkar, Dipl. Ing.
Medvedova 12
Ljubljana
Slovenia

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