REVIEW OF NUCLEAR TECHNOLOGICAL TRANSFER AS SUPPORT OF THE BEST FUTURE PERFORMANCE

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Abstract. *In this paper the authors want to demonstrate with historical arguments the importance of the technological transfer in the nuclear area. Why is it necessary to do this? Because there are many people in the research institutes who do not understand the importance of the professional technological transfer for the industry. They are not comfortable to let the specialized people do this, being afraid that their work could be stolen, and choose to do it themselves. But in this case the results are not the same. That is the reason why we want to draw your attention to some wonderful historical examples of the technological transfer in nuclear area, in order to avoid such unpractical situations from now one. Starting with Einstein and following with Hahn and Strassmann, it is necessary to learn something about. We also show the steps pursued to build the first nuclear reactor, great achievement for the entire world, which would not have been possible if the researchers had kept their secrets in the laboratory. As we like to be fair, it is necessary to mention not only the good points of the nuclear history, but also the bad one: the construction of the nuclear bomb. But, as Otto Hahn thought, the people have to believe in the atom peace destiny and its positive power. The purpose of this historical pleading is that nothing would be possible without the great scientific discoveries and professional technological transfer.*

Keywords: *nuclear energy discovery, technological transfer.*

1. INTRODUCTION

Due to his genius, Einstein became the creator of relativity theory and also the thinker that intuited the genesis of nuclear energy. In 1905, he published in 'Annalen der Physik' Journal a notice of only two and a half pages in which he put forth an essential question: „is the material inertia dependent on its energy content?" The Einstein's answer was positive: „The mass of a body is a measure of its energy content. If energy is changed, then the mass will change accordingly, too" [1]. Mathematical, this idea was transposed into famous formula [1]:

$$E = m\cdot c^2$$

That shows that the energy E contained in a body is equal to its mass „m" multiplied by the square of the speed light (c = 300000 km/s). Einstein himself calculated that a variation of the mass of one gram could lead to release of a huge energy of $9\cdot 10^{13}$ J.

The experimental verification possibility appeared simultaneously with the nuclear fission discovery. By its nature, this reaction involves a variation of mass sufficiently sensitive to test Einstein's theory. Here are the main movie events that finally led, to the historic discovery of nuclear fission.

In 1932, James Chadwick discovered the neutron, thereby opening the prospect of new and spectacular types of nuclear reactions. For example, Enrico Fermi tried to get new transuranium elements bombarding with neutrons some heavy elements obtaining sensational results.

Otto Hahn, Lise Meitner and Fritz Strassmann began in 1934 to reproduce the Fermi's experiences and thereby to investigate more deeply the phenomenon of getting artificial elements. Similar investigations were also started in Paris by a group of physicists led by Jean Frédéric Joliot-Curie. In 1938, Fermi received the Nobel Prize for Physics for „demonstrating the existence of new radioactive elements produced by neutron irradiation and the discovery of nuclear reactions induced by slow neutrons" [2].

At that time, both he and the scientists from Berlin were convinced that in laboratory heavier elements than uranium were obtained whose atomic numbers were: 93, 94, 95 and 96. In reality, their experiences hid new phenomena that were so revolutionary, that they could not be intuited.

The first transuranium elements, neptunium and plutonium, were obtained in 1940 by Erwin Mattison, Mc Millan and Glen Theodore Seaborg [3]. After four years of research dedicated to nuclear reactions produced by bombardment with neutrons, Hahn and Strassmann discovered the nuclear fission phenomenon. As result of neutrons bombardment, the uranium nucleus burst in two smaller nuclei, a phenomenon similar to cellular division. These results were so surprising that they seemed contrary to what nuclear physics had achieved in previous years.

On 16 January 1939, Meitner and Frish sent to 'Nature' Journal two short communications which dealt with a theoretic interpretation of the nuclear fission phenomenon. At the same time, they advanced the hypothesis of the instability of heavy nuclei with respect to changing their shape.

The uranium nucleus, excited by a neutron capture, can be divided in two approximately equal parts, called fission fragments and few neutrons. This hypothesis was confirmed by J.F. Joliot-Curie, Halban and Kowarski, which discovered that during fission, in addition to those two fission fragments, 2-3 neutrons appeared, too.

Interesting is that, although the phenomenon of splitting the uranium nucleus by neutrons bombardment – the nuclear fission - was not anticipated, the explanation and theoretical background of phenomenon were made very quickly. This signified that were created the necessary (but not sufficient) scientific premises in view to discover and understand the nuclear fission. The nuclear fission came to validate such experimental intrinsic link between energy and mass of a body and also to open a new era in the history of contemporary civilization and knowledge – the nuclear energy era.

2. MANHATTAN PROJECT AND THE FIRST NUCLEAR REACTORS

At the Fifth Theoretical Physics Conference held in Washington on 26 January 1939, Enrich Fermi and Niles Bohr attended this conference as honour guest, the latter announcing the discovery of nuclear fission in Europe.

Experimental results obtained by Hahn and Strassmann attracted the attention of the physicists from this conference and generated extensive discussions on the possibility of obtaining a nuclear chain reaction (self-maintained). The developing of such complex process consisting of a great number of nuclear fissions could produce a much higher energy than all the energy produced before by mechanical, chemical or electrical methods. Soon after the conference ending, the physics laboratories from Berkeley, Columbia, Princeton and other American Universities began to develop their own research programs in this area.

On the other hand, some scientists informed the President Roosevelt about the results of Fermi and Szilard, also suggesting the perspective for their military use: „A single bomb of this type, carried by a boat and exploded in a port, could destroy the port and part of the environment" [4]. Examining this issue, Roosevelt created the 'Uranium Committee' [4-5]. The First Report of the Uranium Committee ready for the White House contained the following ideas:

- √ achieving a nuclear chain reaction self-maintained is possible;
- √ use the chain reaction for the submarine propulsion;
- √ use the chain reaction on a new type of bomb.

As a first step for this further research, the purchase of 4 tons of graphite and 50 tons of uranium oxide was proposed, too. In June 1940 a new organism was created: National Defence Research Committee (NDRC), which aimed at the military directing of American scientific and technological effort. NDRC became thus, the tutorial forum for nuclear program, a program quite confusing at that time. In June 1941, the Office for Scientific Research and Development (OSHD) was born under the presidency of V. Bush. From the perspective of research and engineering works referring to the conception and the construction of one device assuring self-maintaining chain reactions specific to nuclear fission, the most important targets were [5]:

a. until July 1942, it was necessary to determine if is possible or not the achievement of a controlled nuclear chain reaction;
b. until January 1943, it was necessary to achieve a self-maintained chain reaction;
c. until January 1944, it was necessary to extract the first quantities of element 94 from uranium;
d. until January 1945, it was necessary to achieve first atomic bomb.

In November 1942 the work at the first nuclear reactor in the world started, designed to demonstrate the possibility of a controlled chain reaction. The construction was done under Chicago University stadium tribunes. On 2 December 1942, at 1530, from the Stagg Field, it was transmitted by telephone: „The Italian navigator reached well into the new world". This was a coded message that announced the success of Fermi and his collaborators in bringing the reactor CP-1 (Chicago Pile-1) in critical condition. Massive building contained 400 tons of graphite, 6 tons of uranium in the form of metal and 50 tons of uranium oxide. Nominal operating power was only 2 kW, which allowed the direct cooling with air of the reactor [6].

Simultaneously with the demonstration of a practical achievement of the fission chain reaction, efforts were made to select the method of enrichment of uranium. At Virginia University, Beams executed some experiments of separation of uranium using centrifugation. At Berkley, Lawrence conducted experiments based on the electromagnetic separation method and Dunning at Columbia University investigated the possibility of using the gaseous diffusion method.

The practical results of producing enriched uranium on a pilot scale, have given more chances of success to the separation method by gaseous diffusion. In early 1943, at Los Alamos, the construction started under the leadership of Oppenheimer. The years 1943 and 1944 transformed these desolate places in a first level scientific, technological and military centre in the nuclear field, in a vast program having the code name Manhattan Project.

The testing of the first atomic explosion was made at Alamogordo on 16 July 1945. Its destructive effects overcame much the preliminary calculations. The released energy was equivalent to a load of 20,000 tons TNT, brightness produced by the explosion competed several times that of the sun at noon, the steel tower of polygon test was practically evaporated and the pressure wave was felt at the distance of over 200 km, where the windows of houses vibrated [5].

This was the beginning. This explosion was followed by the explosions from Hiroshima and Nagasaki. Humankind became aware of the nuclear power, but in a scary way.

The news about the detonation of first atomic bomb over Hiroshima shocked the entire world, especially Otto Hahn, who said: „the idea that by discovery of the nuclear fission I contributed to the spectrum of death, leading him to the suicide threshold; if he had not done it, was because "*he intuited and truly believed in the peace destiny of atom*" [1].

3. A SHORT PRESENTATION OF THE EVOLUTION OF NUCLEAR REACTORS TYPES

The idea of a nuclear reactor was materialized for the first time in a patent deposed at the Swiss Patent Office in May 1939, referring to a system operating with natural uranium and heavy water as moderator [6]. The first demonstration of technological achievement of a nuclear reactor was made, however, by Fermi and his colleagues in December 1942, by bringing it in a critical condition, calling it Chicago Pile One (CP-1). As the name suggests, this reactor was indeed composed of a "bunch" of graphite and uranium blocks.

In winter 1943-1944, entered into operation in Palos Park (USA) the CP-3, the first nuclear reactor that used instead of graphite, the heavy water [5-6]. Starting from this model of research nuclear reactor, the first nuclear reactors for producing plutonium for the atomic bomb were achieved, too. Such type entered into operation at Hanford (USA) in September 1944. These reactors were been moderated with graphite and cooled with H_2O. Subsequently, the nuclear reactor build at Savannah River used the heavy water as moderator to allow a more efficient conversion of U-238 into Pu-239. The heat delivered during operation of this reactor constituted a secondary product and in this aim it was taken from active area by the cooling agent and then dissipated into the atmosphere. In time, this heat becomes the main product of active zone, it being eliminated using the cooling circuit of nuclear power station (NPS) to produce the electricity [7].

The first fast neutron reactor containing as fuel the Pu-239, entered into service in Los Alamos (USA) in November 1946 and the second reactor of this kind was EBR-1 entered in service in 1951 in Arco (USA). This last reactor has demonstrated for the first time the possibility of reproducing of the nuclear fuel and the opportunity of its use for electricity generation [4-8].

Immediately after the end of the Second World War, in United Kingdom shall be established under the leadership of Sir John D.Cockroft a major nuclear research centre at Harwell, near Oxford and other two research nuclear reactors containing natural uranium and graphite. In a next step, have been built at Windscale a reactor for Pu production cooled with air and not with water, as Hanford. These reactors from Windscale have served, in addition, at the plutonium production and for testing of new cooling agents of uranium with gas, for future nuclear power stations.

In 1953-1955, it was decided to build some nuclear reactors at Calder Hall with a dual goal: the plutonium production and electricity. These eight reactors were been cooled with carbon dioxide under pressure and used as protection claddings of nuclear fuel rods a magnesium alloy called "Magnox" [8]. In 1956 entered in the service the first reactor at Calder Hall, which is considered the second nuclear power plant in the world. The first nuclear station entered in the service was in Obninsk (URSS), it being inaugurated in June 1954 and producing 5MWe [9].

The success achieved using a new type of reactor with enriched uranium and pressurized water (PWR), led immediately to its use to produce electricity. The first nuclear power station type PWR equipped with such reactor, entered into operation at Shippingport, Pensylvania, on 2 December 1957. This nuclear power station had an installed power of 60MWe and it constituted the origin of the most powerful nuclear energy chain (PWR) [4].

In 1970, the French scientists abandoned and they the chain of reactors moderated by graphite and cooled with carbon dioxide (GCR) and adopted the American type reactor with enriched uranium and pressurized water (PWR).

On 1 January 1988 there were 417 operational power reactors in 26 countries around the world, having an installed power of approximately 29700MWe. At that time were still under construction 120 reactors, with deadlines for putting into service around 1990. The share of electricity produced in the NPSs in these three countries: UK, USA and France in 1985, exceeded 50% of electricity produced in classic plants from respective countries, and in nine other countries, it represented 25-50% of total electricity produced in the respective country. After nearly three decades of existence, it can be said that nuclear energy has reached maturity, demonstrating both its need and viability. So, in Table 1[10] is presented the competitiveness of nuclear power stations (NPS) using the rapports between the costs of electric energy produced in thermal stations using the coal (fossil fuel) (TPS) and respectively in nuclear power stations (NPS) at level of 1987 [10-11].

Table 1. Rapports between the costs of electric energy produced in thermal using the coal (fossil fuel) (TPS) and respectively nuclear power stations (NPS) at level of 1987 [10]

Country	Costs rapport TPS/NPS
Belgium	1.62
Canada – Central zone	1.44
Finland	1.33
France	1.80
Germany – indigenous coal	2.02
Italy	1.40
Japan	1.37
Netherlands	1.31
Norway- high cost coal	1.38
Spain	1.19
United Kingdom	1.40
USA –central zone	0.83

To have an image of nuclear power development at 1987 level [11], in Table 2 [11] is presented the number of nuclear power reactors and their power installed in MWe and as a percentage of total installed power in NPSs in the world for the 26 countries having nuclear energy programs and implicitly operational NPSs.

For example, in Fig. 1 [12] are presented the investment costs made in nuclear power reactors in France in period 1964-1997. Thus, in France, the construction of the four last reactors entered in service – of the 1,450MWe type – also called N4 series, started between 1984 and 1991. Yet they were connected only between 1996 and 1999, or after an average of 10.5 years. Moreover, safety problems forced them to an early shut-down and their official industrial service only started in 2000 at Chooz and 2002 at Civaux, that is respectively 15.5 and 12.5 years after their construction started [12].

Table 2. Structure of electrical installed power in NPS in several countries in 1987 [11]

Country	Reactors number	MWe	[%]	Country	Reactors number	MWe	[%]
South Africa	2	1842	0.62	Japan	36	26877	9.05
Argentina	2	935	0.31	Korea	7	5380	1.81
Belgium	7	5477	1.85	United Kingdom	38	10214	3.44
Brazil	1	626	0.21	Netherlands	2	507	0.17
Bulgaria	5	2585	0.87	Pakistan	1	125	0.04
Canada	18	12142	4.09	Eastern Germany	5	1694	0.57
Czechoslovakia	8	3207	1.08	Western Germany	21	18947	6.38
Swiss Confederation	5	2932	0.99	Spain	9	6529	2.20
Finland	4	2310	0.78	Sweden	12	9646	3.25
France	53	49378	16.63	USA	106	92982	31.32
Hindustan	6	1154	0.39	Taiwan	6	4918	1.66
Italy	3	1273	0.43	Hungary	4	1645	0.55
Yugoslavia	1	632	0.21	USSR	55	32919	11.09

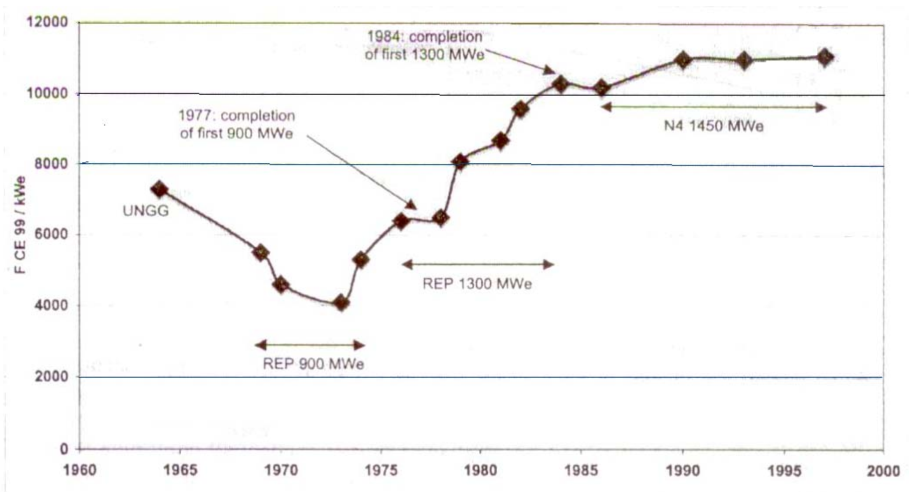

Fig. 1. Investment costs made in nuclear power reactors in France 1964-1997 [12].

In Fig. 2 [13] is presented a comparison of capacity factors of nuclear power stations (1990-2005) of five countries strong industrialized: Japan, USA, Germany, Finland and Korea and in Fig. 3 [13] is presented the repartition of energy sources in Japan.

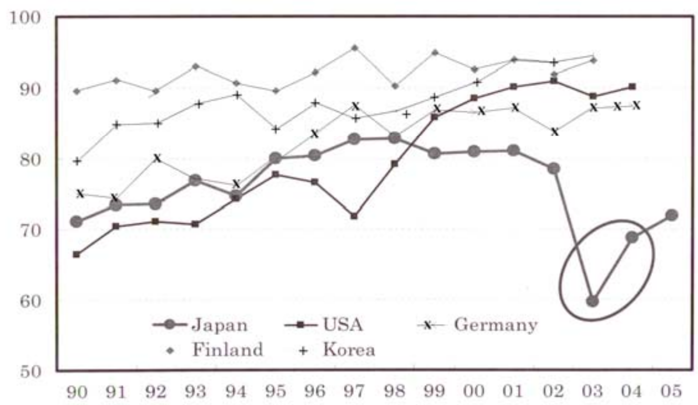

Fig. 2. Comparison of Capacity Factors of Several Countries having NPPs [13].

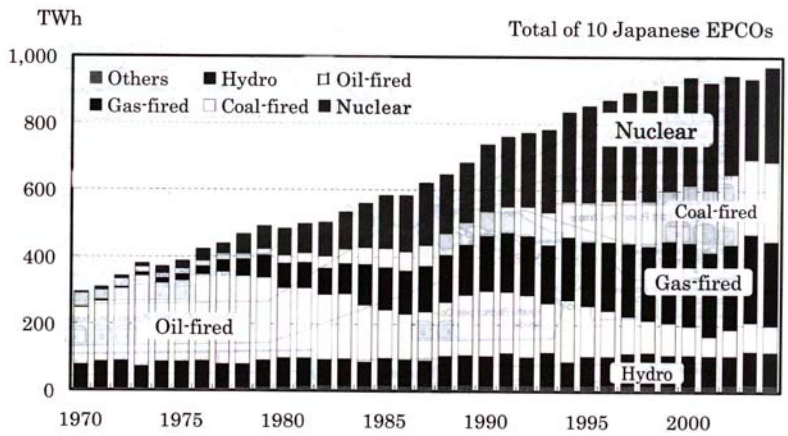

Fig. 3. Structure of energy industry in Japan in period 1970-2000 [13].

Finally, in Fig. 4 is presented the past, present and future in nuclear energy.

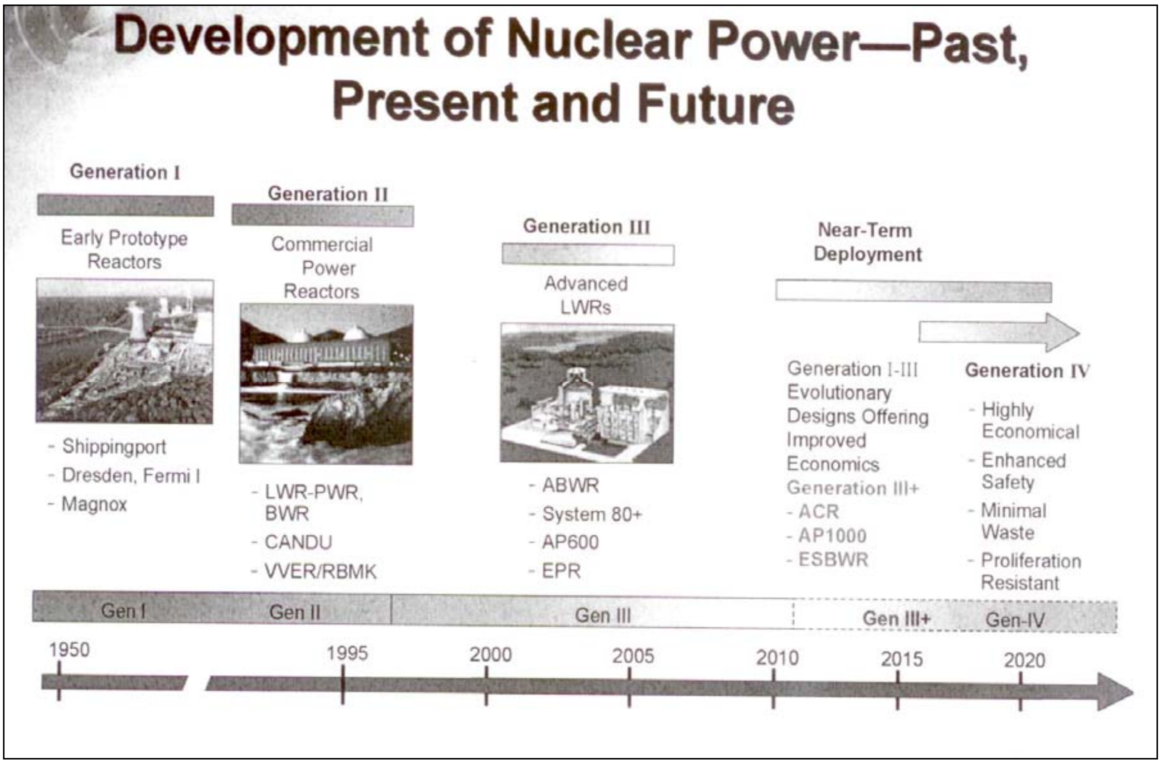

Fig. 4. Development of Nuclear Power: Past, Present and Future.

Technological transfer is seen as a process of innovation, or as a next stage for expanding the concept of innovation. In order to turn the research results to good account, technological transfer can be performed as: transfer between two research activities - from basic research to applied research, transfer between applied research and industrial applications, transfer from creative innovative activities undertaken by individuals to practice.

The paper, by historical arguments, aims to demonstrate that society cannot develop without innovation, and its results must be put into practice. This should be seen as a problem of mentality, because the innovation spirit exists, but must be educated – it is highly important to have education for technological transfer. In this respect, history offers us many lessons to be learned to apply updated methods and avoid what was wrong.

4. CONCLUSIONS

Based on historical arguments presented in this paper, the importance of the technological transfer in the nuclear field can be justified over time.

Today's the aforementioned technological achievements would not have been possible if these mentioned discoveries (for example, first nuclear reactor) had remained closed in the laboratory without being communicated, without being put in practice, without using them.

The purpose of this paper is to underline the importance of their application. In the future, the progress in the nuclear field has to follow the same way as in the past, but accelerate; especially now when the propagation of information is much easier and the usefulness of research has already been proved.

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