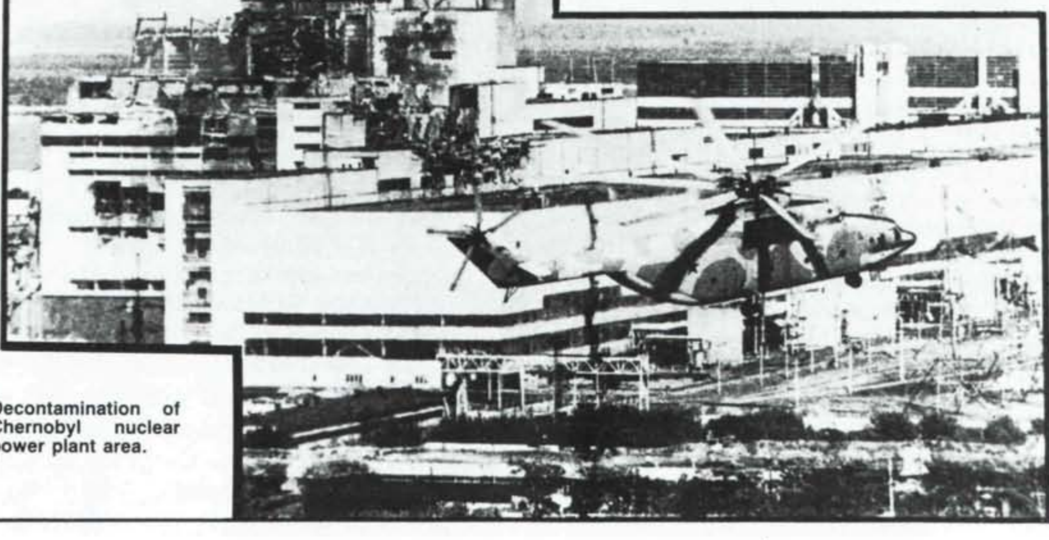
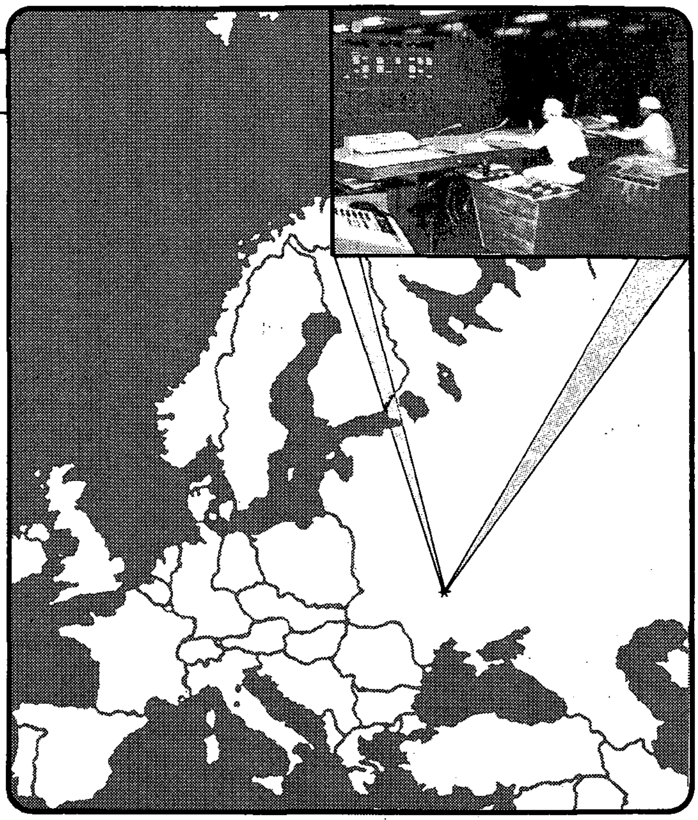
Radiation measurements and monitoring in Chernobyl nuclear power plant area.

These scenes of the Soviet response to Chernobyl were part of the USSR display at the post-accident review meeting at IAEA from 25 to 29 August 1986. (See *News in brief* for an account of that meeting.) The photo on page 5 shows the Chernobyl plant's control room before the accident.



Decontamination of Chernobyl nuclear power plant area.

The Soviet Union and the development of nuclear power



An overview of plans and the Chernobyl accident

by A. Petrosyants

In June 1986, 32 years had gone by since the world's first nuclear power station went into operation at Obninsk in the Soviet Union. By now peaceful nuclear power has thoroughly established itself in many countries of the world. The production of electricity by nuclear power stations relative to other plants has grown impressively, reaching 15% in some countries and as much as 40 to 65% of the total electric power produced in some others.*

The Soviet Union belongs to the lucky few on this planet who are richly endowed with organic fuel resources. The country's coal reserves constitute half of the aggregate coal reserves of the world, and the amounts of coal actually extracted put the Soviet Union in second place among coal mining countries. In oil production, including gas condensate, the Soviet Union is in first place. The country's hydropower resources are also far from being exhausted.

The development of electric power in the Soviet Union could rely on the country's own resources for a long time, but the rich natural resources available for power production are by no means evenly distributed over its territory: About 90% of the fuel resources and 80% of the hydro resources are in the Asiatic part of the Soviet Union. On the other hand, about 70% of the population lives in the European part of the USSR, and it is naturally here that demand is greatest. This is why studies aimed at finding alternative sources to cover the energy deficit indicated the economic wisdom of constructing nuclear power stations in the European part of the Soviet Union.

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* See the article "Worldwide nuclear power status and trends" in this edition of the *IAEA Bulletin*.

By 1986 the Soviet Union had become the third largest producer of nuclear power in the world. In 1985, to give one example, Soviet nuclear plants produced nearly 170 000 million kilowatt-hours of electric power. The aggregate installed power of the Soviet nuclear units now in operation is 28 400 megawatts-electric (MWe).

The successes of nuclear power are quite obvious, although at the same time it has to be confessed that nuclear power is by no means being accepted with equal willingness in different regions of the world. The United States of America for example, was one of the leading countries in the world in nuclear power, in terms of the scale of plant construction and the rate at which new plants were introduced; however, in the last few years (since the middle of the 1970s) that country's attitude to nuclear power has undergone a radical change — the brakes have been applied to the growth of nuclear power, and so far there has been no appreciable change in the new policy.

Stages of nuclear development

We can discern two main stages in the development of nuclear power. The first stage, which lasted from the middle of the 1960s to the middle of the 1970s, could be called — possibly with some exaggeration — the phase of "euphoria". This period was characterized by a vast surge of orders for nuclear power stations, rapid construction, relatively low unit capital costs and optimistic forecasts of future development. The Soviet Union, I might say, cannot really be counted among the countries which felt this pristine euphoria: Our approach to the mushrooming of nuclear power plants was somewhat reserved and perhaps even a bit critical, although it was definitely positive.

During the second phase, lasting until the middle of the 1980s, many countries re-evaluated the role of nuclear power; the rapid growth of the earlier period fell off substantially and the economic competitiveness of nuclear power stations began to diminish. At present the approach to nuclear power in many countries, including most of the industrialized countries of the West, is dictated largely by the availability of energy resources. Countries which are poorly endowed with traditional energy resources tend to favour the development of nuclear power. The rapid rate of nuclear power development in the countries of the European Economic Community is governed to a large extent by their desire to reduce their dependence on imported oil. This applies in particular to France and Belgium; it is also true of Switzerland and some others.

The Soviet Union, which had opened the age of nuclear power, moved forward more cautiously perhaps but nevertheless took a positive approach to nuclear power; here the development of nuclear power on a really broad scale began only after the 1970s. We believe that nuclear power will satisfy man's growing energy requirements in the foreseeable future, and we believe also that it is the energy source which will have the least damaging ecological consequences. We feel that nuclear power will promote the "energy independence" of individual countries and will thereby exercise a stabilizing effect on the world economy and on international relations.

Soviet plans call for growth

In the Soviet Union, nuclear plants contributed slightly more than 10% of all electric power generated in 1985. This is less than in some other countries, but the explanation is very simple: the USSR is richly endowed with energy resources and is in fact able to export them after satisfying all its domestic requirements. Under present plans, therefore, the development of nuclear power will go forward primarily in the European part of the USSR. We are developing all types of energy resources for the production of electric power — apart from oil, the use of which in power stations is being substantially reduced. By 1990 we expect the country's nuclear power stations to produce 360 000 million kilowatt-hours as compared with 170 000 million in 1985. This growth is impressive. However, the main point is not how much electric power the nuclear plants produce but rather the fact that nuclear power will be increasing steadily from year to year in the USSR.

The development of nuclear power in the Soviet Union is based on two main thermal reactor types: the WWER, a pressurized-water-cooled and water-moderated reactor, and the RBMK, a uranium-graphite boiling-water pressure-tube reactor. However, by the year 2000 the electric power grid in the Soviet Union will be served not only by thermal reactors: fast reactors will have joined the system as well, and will gradually supplant the thermal reactors. At present three fast reactors are operating in the Soviet Union: the BOR-600, a 12 MWe reactor in the Ulyanovsk region; the BN-350, a 1000 MW (thermal) dual-purpose reactor in Kazakhstan; and the BN-600, a 600 MWe reactor in the Urals. An 800 MWe fast reactor is under construction.

The replacement of power stations using thermal reactors by plants equipped with fast reactors will proceed slowly but steadily. We consider that this is an inevitable process and that it will continue at a substantial rate even beyond the year 2000. Thus it will be seen that nuclear power has very good prospects in our country, particularly in the European part of the Soviet Union.

We also see a very fair future — I might even say a future which stirs the imagination — for thermonuclear power, in other words controlled nuclear fusion. This enticing prospect would supply human society with an inexhaustible source of energy. The international INTOR group, founded under the aegis of the IAEA and on the initiative of the Soviet Union, with participants from the Soviet Union, the United States of America, Japan, and a small group of Western countries, has succeeded in creating a conceptual fusion reactor project on the Tokamak principle. When M.S. Gorbachev was in France and subsequently in Geneva last year, he proposed to Presidents Mitterrand and Reagan that they should continue to support the INTOR project, so that with the combined efforts of all participating countries, a prototype thermonuclear reactor — designed for a new type of nuclear power station — could be created. The countries concerned are now considering what practical steps should be taken to put this idea into effect.

Plant safety and reliability

Reliability and safety have always been critical questions for those who design, build, and operate nuclear power stations. It is not without reason that the opponents of nuclear power have consistently highlighted problems of reliability and safety at these plants.

Realizing the vital importance of reliable operation, the designers and builders of nuclear power stations and their reactors have tried to foresee all measures which they consider essential to ensure safety, including allowance for what they call "design-basis accidents". Many possible combinations of accidents have been taken into account, and the designers have endeavoured to anticipate all the steps required to prevent accidents and, particularly, to ensure safe operation when problems occur in the core of the reactor.

Even so, unexpected accidents have taken place at different times in a number of countries:

- In 1957 there was an accident in a reactor at the Windscale plant in the United Kingdom which involved a release of radioactive fission products.
- In 1959 some of the nuclear fuel elements in a reactor at Santa Susanna, California, USA, melted.

● In 1961 there was an explosion in a reactor at Idaho Falls, USA.
● In 1966 there occurred a partial core meltdown in the Enrico Fermi reactor in Detroit, USA.
● In 1979 the core melted in one of the reactors at Three Mile Island, Pennsylvania, USA.*
● In 1982 a steam generator pipe ruptured at the Ginna reactor in the United States, releasing radioactive steam to the atmosphere.

Clearly, there is no need to list all accidents that have occurred at nuclear power stations; it is enough to say that in the period from 1971 to 1985 there were 151 accidents of varying degrees of seriousness in 14 countries of the world, and that these accidents had certain consequences — sometimes quite serious consequences — for people and the environment.

The accident at Chernobyl

The accident which took place on 26 April 1986 in the fourth unit of the Chernobyl nuclear power station led to very serious consequences. Thirty-one persons have died as a result of the accident and many others have suffered damage to their health. The destruction of this RBMK reactor resulted in radioactive contamination of the region surrounding the plant over an area of about 1000 square kilometres. In this region the crop fields have been taken out of cultivation and work has had to be stopped in factories and on building sites. Several tens of thousands of persons had to be evacuated from a region with a radius of 30 kilometres around the plant.

The Chernobyl accident was caused by a whole series of errors and infractions of the operating rules committed by the plant staff. The catastrophic proportions of the accident were due to the large positive void coefficient of radioactivity, compounded by the fact that the reactor, owing to the staff's crass failure to observe the operating rules, entered into a dangerous state not foreseen in the design calculations.** On 25 April, at one o'clock in the morning, the plant staff began procedures to shut down the reactor, which until then had been operating at rated power. According to plan, the reactor was to be shut down for intermediate maintenance since at the time of shutdown the core, with 1659 fuel assemblies, had reached an average burnup of 10.3 megawatt-days per kilogram (MWd/kg).

Before shutdown, the administration of the Chernobyl power plant decided to carry out tests on turbogenerator No. 8 in a regime whereby the turbine rotor would be supplying plant power requirements during the rundown. The tests were to be carried out during the night, but those in charge of the plant did not prepare the experiment in the proper way and did not secure the approval of the competent organizations, even though they were obliged to do so. Furthermore, there was no adequate control over the experiment and the requisite safety measures were not taken.

Detailed information on the Chernobyl accident and its consequences was sent by us to the IAEA at the beginning of August. (See *News in brief* for an account of the post-accident review meeting at IAEA.)

The Politburo of the Central Committee of the Communist Party of the Soviet Union established, after reading the report of the Government Commission, that it was solely the irresponsibility, negligence, and undisciplined actions of the power plant staff which had led to such disastrous consequences. A number of senior workers and experts have been suspended from their posts for gross errors and inadequacies in the performance of their duties and have received severe punishment.

IAEA visit to Moscow in May

As soon as possible after the accident, the Soviet Government invited senior staff of the IAEA to come to Moscow. The Director General, Hans Blix, Deputy Director General Leonard Konstantinov and the Director of the Division of Nuclear Safety, Morris Rosen, arrived in Moscow on 5 May 1986. This IAEA delegation remained in the Soviet Union from 5 to 9 May. Extended discussions were held in Moscow at the headquarters of the State Committee on the Utilization of Atomic Energy involving, among others, the First Deputy Minister of Health of the USSR, Professor E. Vorobev; the First Deputy Chairman of the State Committee on Hydrometeorology and Environmental Protection, Professor Yu. Sedunov; and a number of other senior specialists in various disciplines related to nuclear power. During these talks we reported to the IAEA delegation on many subjects of interest to them associated with the Chernobyl accident and showed them a short film taken at the site. The film in question had been shot by staff of the Scientific Research Institute for Electrotechnology, not by film specialists, but it showed very well how things stood in Unit 4 following the accident.

On 7 May, the IAEA delegation was received by the Deputy Chairman of the Council of Ministers of the USSR, Comrade B.E. Shcherbin, who presided over the Government Commission set up to investigate the accident.

In response to a wish of the Agency's Director General, Hans Blix, the IAEA delegation flew to Kiev early on the morning of 8 May, accompanied by the Chairman of the USSR State Committee on the Utilization of Atomic Energy, in order to visit the site of the accident. During the flight from Moscow to Kiev in the Government aircraft we continued our discussions of the accident and its consequences. In Kiev we were met by the Deputy Chairman of the Council of Ministers of the Ukraine and the Deputy Minister of Foreign Affairs of the Ukraine, with whom we rode through the town by

* For further information on the TMI accident, see "Reassessing radiation releases: A closer look at source term", by Morris Rosen and Michael Jankowski, *IAEA Bulletin*, Vol. 27, No. 3 (Autumn 1985) in which the authors review the extent of core damage.

** The coefficient of reactivity refers to reactor power levels; a positive coefficient indicates power is increasing.

car, walked about a little and saw how the capital of the Ukraine was preparing for its international cycling competition. After dinner we went by helicopter to the town of Chernobyl. The First Deputy Chairman of the State Nuclear Power Supervisory Board, Dr V. Sidorenko and the Vice President of the Soviet Academy of Sciences, E. Velikhov, had also come to Kiev to accompany us on the helicopter flight. Throughout the flight from Kiev to Chernobyl they gave us additional information and clarifications concerning the state and situation of the fourth unit of the power plant since the accident. We flew over the Chernobyl plant at a height of 400 metres, observed the condition of Units 1 and 2, which had not been affected by the accident, and the damage done to Unit 3 as well as Unit 4, which had been the centre of the accident. Flying over the area, we also had a panoramic view of Units 5 and 6, at present under construction, and afterwards made a short stop in the town of Chernobyl where the members of the Government Commission who were accompanying us, V. Sidorenko and E. Velikhov, got out of the helicopter. After returning to Kiev airport we boarded our aircraft and left for Moscow. Thus, on a single bright day in May we were able to visit the region of the Chernobyl plant and return to Moscow.

The USSR-IAEA communiqué

As a result of all the conversations and discussions between 5 and 9 May 1986, a joint communiqué was issued by the IAEA and the Soviet State Committee. In this communiqué the Soviet Union stated its willingness to provide information on the accident as it became available, in accordance with the wishes of the IAEA — information which the Agency's Director General proposed should subsequently be discussed at a meeting of experts convened to analyse the accident; the deliberations and the findings of this meeting could, it was suggested, then be used by the Agency's Member States in connection with their own nuclear power programmes. (Such information was sent by us to the Agency at the beginning of August 1986.)

The Soviet Union also took the decision to provide the IAEA with daily information on radiation levels at a meteorological station located 30 to 40 kilometres from the power plant and at six other stations along the western frontier of the USSR (Leningrad, Riga, Vilnyus, Brest, Rakhov and Kishinev). These data were then sent by the Agency to the national bodies concerned with radiation safety in its Member States.

The Soviet Union also declared in the communiqué that the Chernobyl accident would not affect plans for the further development of nuclear power in the Soviet Union. Ways of enhancing and improving the safety of nuclear power and international measures, to be worked out under the auspices of the IAEA, for minimizing the possible consequences of nuclear power plant accidents were likewise considered. Both parties felt that such measures might involve the development of a mechanism for timely notification of radioactive releases which could have consequences beyond a country's national frontiers, including information on radioactivity levels in the countries concerned, and possible additional technical measures at nuclear facilities to prevent accidents and alleviate their consequences.

Both parties stressed that the accident at the Chernobyl plant made the dangers of a continued nuclear arms race — since the consequences of using such weapons would be incomparably more disastrous than any power plant accident — more apparent than ever before. In this connection both parties emphasized the importance of the Agency's activities aimed at ensuring the exclusively peaceful utilization of atomic energy.

Chernobyl's impact on nuclear programmes

Finally, it should be stressed once more that while the Chernobyl accident was very serious it will have no effect — as some voices from abroad have vainly tried to suggest — on the further development and growth of nuclear power generating capacity in the USSR. The path of nuclear power development and the growth of nuclear power in the USSR are to remain unchanged.

We consider it likely that a similar attitude will prevail in Western Europe and Japan and in certain other countries of the world including the United States of America.

The Chernobyl accident has provided a lesson not only for us, the Soviet people, but for all countries concerned with the utilization of atomic energy. We have always said, and we emphasize again, that atomic energy is potentially the most dangerous kind of energy, and the Chernobyl accident has shown us once more, very convincingly, that this is true. Obviously, all of us who are working in the atomic energy field, scientists and specialists in all disciplines, must draw serious and far reaching conclusions from this lesson — conclusions of an organizational, scientific, and technological nature.

The utilization of a new and very complex technology is, alas, impossible without some setbacks. This has been demonstrated by the whole history of nuclear power development; we have not gone forward without some human sacrifices. Moreover, the losses we are talking about involve not only human sacrifices and economic detriment but, worse still, a possible loss of faith in atomic energy, this ever so important source of energy which has only recently been opened up for mankind.

But this accident has also shown how terrible the unbridled energy of the atom can be — if wrested from nuclear weapons, from bombs and rockets, at the behest of the leaders of aggressive lands. Used for warlike purposes, it could bring awful destruction and death to our world and all its people.

Editor's note: This article was submitted by the author before the post-accident technical review meeting held at the IAEA from 25 to 29 August 1986.