Tape 4 Side A

But it was very quickly discovered that the water itself did not have much contamination, but the silt was affected. And the concentration of radioactive elements in the silt under the cooling pond was up to 10-5 curie while the concentration of radioactivity in the water was no more than 10-8 or 10-9 curie per litre. These were the maximum numbers.

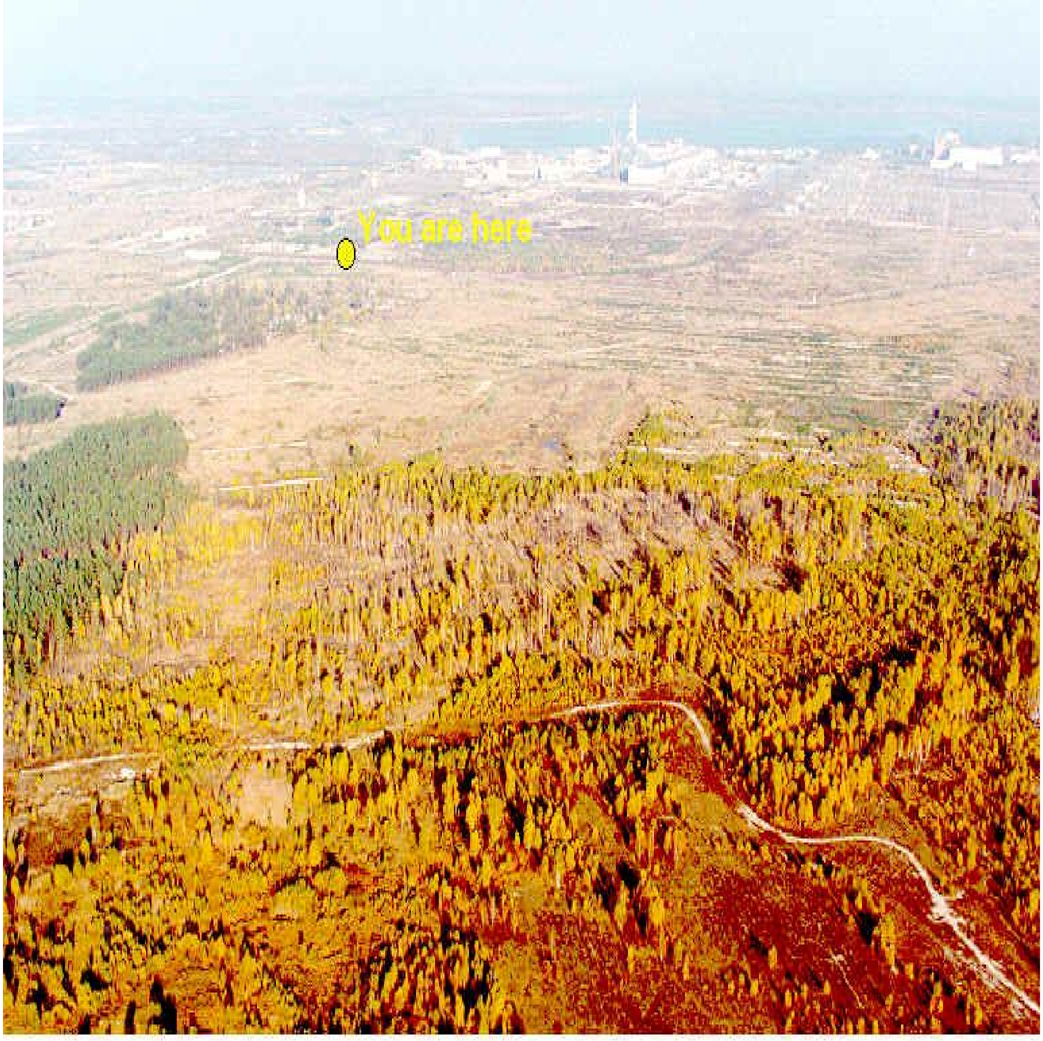
A lot of dams was constructed, dykes, that were meant to hold the contaminated debris, foliage and all that had contaminated the surface of the water and prevent radioactivity from spreading along the Pripyat and the Dnieper. All this work was done by the Soviet Ministry of Water and by the Ukrainian Ministry of Water—done within a remarkably short time.

The dams were designed and built immediately but this was also accompanied by research work. Additionally, Celites were added into the bodies of dams—Celites, shipped from Armenia and Georgia, had a high sorption capacity—to capture all the microparticles and all the components of radioactive elements that were in the water and to prevent them from spreading further. As of today, we can say that this goal has been achieved.

Around the same time when the Government Commission was already final, led by Boris Yevdokimovich Shcherbina and there were no further substitutions or replacements, around that time, by a Government decision, a Coordinating Council for the Chernobyl issues was created in the Academy of Sciences, led by Anatoly Petrovich Alexandrov, and I was assigned as his First Deputy. The composition included heads of the main institutions associated with the work around Chernobyl and also leading experts, such as academician Sokolov, academician Mikhalevich and academician Trefilov, who were associated with particular tasks of ecological or technical nature related to the liquidation of the consequences of the accident.

It needs mentioning that when the work became organized like this, when the effort was distributed across various institutions and supervisors, then, of course, there was much more order and clarity than in the first days when all the emergency problems were solved but not all work had gone smoothly.

For example, the status of contamination on the roofs of buildings of the 3rd and 4th blocks was measured many times. And, each time considerably different figures and results were reported, from astonishingly high to relatively moderate. That’s why I personally and also the military specialists [had to go there]—who by this time had very successfully deployed a research centre at the village of Ovruch that allowed a large contingent of military specialists to consciously perform decontamination tasks, measurement tasks, all the tasks that they had been assigned. This centre was doing very extensive work on measuring radioactivity and the release of radioactivity, on wind transfer, on the dynamic conditions of various areas, and made a big contribution to the scientific research and practical plans of all this work done in Chernobyl. And these problems were not easily solved.



"Red Forest". Source: wiki.

For example, not far from the station was a heavily contaminated forest (up to several roentgens per hour such radiation at the beginning it had) which was named the "Red Forest". Here is the fate of this forest. Various suggestions were made. First, to not touch it and leave it as is with its radiation, counting on nature itself to somehow recycle it all, that is, the needles, that are the most contaminated, would fall off, after which the needles could be gathered and buried, while the tree trunks, branches, all these would remain relatively clean. The second proposal, conversely, was to burn this entire forest down and even experiments were carried out on burning parts of this contaminated forest. But these experiments showed that the products of combustion will nevertheless carry away a large amount of radioactivity with them. Finally, a decision was made to chop down part of the forest, transport it, bury it, and to simply convert the remaining area into a burial ground, to restrict access to it, which has been done. And the radioactive impact of the "Red Forest" on the city and its surroundings sharply decreased after the said operations were carried out.

A big discussion arose about the so-called Compton effect. Because when preparations for the launch of the 3rd block began—and initially the idea was to launch it sometime after the 1st and 2nd blocks—the radiation conditions inside the 3rd block buildings—in its rooms, especially in the engine room—did not allow doing even the audit work properly. The first assumption was that it is the internal contamination of the building. After decontamination was carried out, the level of activity in this room lowered but still remained relatively high, reaching tens and sometimes hundreds of milliroentgens per hour at certain spots and up to a roentgen per hour at other spots in the engine room. Then an initial assumption was made that the source of such high activity was the roof of the 3rd block on which was a lot of scattered fuel. And this was preventing the creation of acceptable radiation conditions. Because even though the more than 600 rooms of the 3rd block were cleaned, washed, the radiation condition in the engine room nevertheless remained quite high.

So we started taking various measurements using a specially-designed collimator, which showed that the activity on the roof is not the only source affecting the radiation conditions in the 3rd block. It was the neighbouring 4th block which because of the Compton effect—the reradiation and reflection of a part of the gamma rays coming out through the roof of the 4th block—was the main source of the elevated radiation environment in the engine hall of the 3rd block. So many discussions were had on this topic, so many surveys, so many measurements, and in the end, it turned out that the main source of contamination was the contamination on the roof of the 3rd block. This was the main cause. Although, of course, the Compton effect had its share in the radiation environment; somewhere around 10 milliroentgens per hour and maybe even less than 10 milliroentgens per hour was radiated from the 4th block. That's why a decision was made to completely replace the roof of the 3rd block, put in a new one with appropriate safety devices that would allow the necessary work to continue and launch the 3rd block of the Chernobyl NPP in time.

Around the same time when the fate of the 3rd block was decided—well, because of such conditions its launch had been delayed from summer, for when it was planned, to autumn—the necessity of setting up and launching work on the 5th and 6th blocks was very keenly discussed. These blocks were in very different states of readiness. The 5th block was almost ready and could practically be launched within a few months after decontamination, and the 6th block was in the initial stage.

There were considerable discussions. The public was protesting against the continued construction of the 5th and 6th blocks and their entering into service, because they felt that it was too much power, 6 gigawatts, on a single site, especially in abnormal radiation conditions. Ukraine’s energy demands dictated the need for introducing more and more power capacities. This question was discussed at the Government Commission and was escalated to higher levels, and ultimately it was decided to defer the issue and that in the next year, 1987, and possibly in 1988, no construction work will be done on 5th and 6th blocks. All the effort of decontaminators needed to be focussed on fully normalizing the conditions in the 3rd block and also on cleaning the construction base. There was a construction base on the territory where machinery and materials needed for the construction of the 5th and 6th blocks were stored. This base was quite contaminated. So to save the considerable amount of expensive equipment stored there, a special workshop was constructed at the Chernobyl Nuclear Power Plant, a decontamination workshop. And this workshop began to regularly decontaminate the most valuable equipment and send it to various parts of the Soviet Union for practical utilization.

At the time when active work began on the decontamination and launch preparation of the 3rd block, at the same time work truly unfolded not on the planning but the construction of the city of Slavutych. And the pace of construction was increasing all the time and this made a lot of sense because, after about 4-5 months of operating the 1st and 2nd blocks in a shift mode of work, it had become obvious that psychologically and even physically it was very hard work. Even with long breaks for rest, the operators still had to be at the control panel for 10-12 hours. There was a problem of prolonged separation from families, working in unusual conditions. All this created such problems that it became evident that the shift method, in this case, was certainly not optimal. It was a forced measure that had played a big role at the time when it was used. But to make it the primary method of work based on that, it was absolutely obvious that this was impossible. Therefore the speed of construction of the city of Slavutych, as the main city of power engineers, was greatly increased. For example, Boris Yevdokimovich Shcherbina, as I remember, made such trips almost every month to monitor how the construction of Slavutych is progressing, how equipping is moving along, how facilities are being outfitted. In other words, this issue was constantly under his control, as were all the other issues related to the Chernobyl accident.

Somewhere in the middle of 1987, in the summer of 1987, finally appeared robots made by our own Soviet hands. For example, robots made at the Kurchatov Institute of Nuclear Energy. These were reconnaissance robots which we couldn't get in time from anywhere, from any country in the world. So we made these recon-robots ourselves that, in the most complicated geometrical conditions, in wreckage, in high radiation fields, could advance to practically any distance in a guided manner, and do radiation and thermal reconnaissance of the situation, provide the needed information. These robots have played a huge role even today because many interesting things have been discovered with their help regarding the questions related to the nature and consequences of the accident. But I am not sure that they will gather any additional information.

Another idea that I have repeatedly talked about and asked to be implemented—it has not been implemented yet—is the idea of creating flying robots, that is, radio-controlled aircraft models that would carry sensors on them. Sensors for radiation fields, sensors that could measure the composition of gas at various locations in the Chernobyl NPP. Well, so as to not use… [TAPE ERASED]

This text is for comrade Novikov Vladimir Mikhailovich, Dyomin Vladimir Fyodorovich and Sukhoruchkin Vladimir Konstantinovich. It is about an article that was requested to be written by the magazine Scientific American and must have a summarizing philosophical character. The provisional title of this article is "The reasons that led to the Chernobyl accident and its consequences". The article should be based on my papers, comrade Dyomin's papers, comrade Novikov's papers, comrade Sukhoruchkin's papers, but, nevertheless, these papers must be collated and processed in such a way that an integral philosophy emerges from them.

The first part of this article, I think, should be about the history of the development of Soviet nuclear energy, to remind that the world's first nuclear power plant … [TAPE ERASED] … and the principle of safety provisions in this small 5-megawatt station. At that time, the entire protection system was copied, probably from … [TAPE ERASED] … that existed in the industrial reactors and was using accumulated military experience. Then the second station, Beloyarsk nuclear station, where graphite was used as an inhibitor, but that it was already a fast-neutron reactor, and such research, and well, describe its working principle.

Thereafter, talk about the Novovoronezh station, the 1st block of which has already been built as a nuclear station designed to be operated in a continuous mode with a civilian crew, and describe the protection systems that have been used at that station.

Then, we will need to mention that both during and after the construction of the Novovoronezh NPP, the policy of our government did not attach any particular importance to the development of nuclear energy; because it was believed that by using organic sources of fuel—coal from Donbass, gas from Saratov, and then the oil reserves—we would be able to fulfil all our industrial needs; and that the nuclear energy demonstrated at Obninsk, Beloyarsk and Novovoronezh stations was more in the way of scientific research that prepared us for some future.

Explain that this, in fact, was a miscalculation in terms of resources—the capacity of the Donetsk Basin to supply coal was overestimated—and also a miscalculation in terms of transport and ecology, because at the time we did not understand the extent of land transport if energy is based on organic sources or the extent of pollution including radioactive elements.

All this must be described. This is important because of this. It is important to say that an approximately 10-year delay in the development of nuclear energy in the Soviet Union was the first cause of the Chernobyl accident, the first swallow, the first knell. Why? Well because it was already clear in the 60s that it would be expensive and practically impossible to develop industry in the European part and provide it with electricity from organic sources. And that it was necessary to put nuclear energy sources into operation, to do this quickly. And so there appeared a kind of natural desire to somehow minimize the spending on the rapid development of nuclear energy. And here, at this moment, the main fundamental philosophical mistake in our approach to safety was made.

Any approach to nuclear safety of a technologically complex and potentially dangerous device must have three elements. First, make the device itself, say, a nuclear reactor maximally safe. Second, make the operation of this device maximally safe and reliable. But the word 'maximally', in both cases, can never mean a 100 per cent reliability. Equipment can never work at 100 per cent conditions specified by the project, and fully exclude all human error, accidental or perhaps even intentional. This is impossible.

And because this maximally-safe reactor and maximally-safe operation are not always a 100-per cent safe, then the philosophy of safety requires mandatory implementation of the third element—the element that presumes that an accident will happen; and that radioactivity and other dangerous material will get out of the device. And, for these cases, a mandatory element is enclosing the dangerous device in such a mechanism that would localize the accident which, despite low probability, could still happen. It would enclose the object in what is called a containment (maybe an underground option or other possible engineering options), but the most important for reliability is to have a system that does not rely on a geographical site. And in the event of unlikely but possible troubles, these troubles would not spread to the surrounding environment, as is the case with accidents in mines. This is the third element. In Soviet nuclear energy, precisely because of the pace that had to be quite high, because ten years had been lost, this third element, from my point of view, was criminally ignored.

In fairness, I must say that many experts of the Soviet Union spoke, and very actively spoke, against the construction of nuclear power plants without containments. In particular, the corresponding member of the USSR Academy of Sciences Viktor Alekseyevich Sidorenko in his doctoral thesis, and later in his book based on this doctoral thesis, was proving by all means available to him at the time, that containments were necessary. However, this point of view of the experts was not considered.

There is another definite circumstance to it. Nuclear energy in the Soviet Union has not emerged from the energy sector but from, as it were, the nuclear industry; where highly trained and disciplined personnel were used, where special military acceptance was in place for every piece of equipment; and consequently the reliability in this sphere of nuclear industry, both from personnel and equipment point of view, was very high. The 15-20 years of experience accumulated by this industry has shown that competent, reliable and precise operation of nuclear facilities, technical means of ensuring safety and proper staff training are enough to prevent big accidents with radiation outbursts from happening, at least, not at .

It was not taken into account that after the nuclear facilities move from limited industrial environment to wide usage in civil nuclear energy, the conditions will change drastically. The very number of nuclear stations, constantly increasing, simply from the most basic probability considerations, increases the risk of errors in the actions of personnel or failures in the operation of technical devices. So, from my point of view, this was a philosophical mistake; allowing operation of stations without an external localisation shelter. This mistake was fundamental.

Since when has this mistake begun to be corrected? Since the Soviet Union entered the foreign market and started constructing the first nuclear power plant for a foreign country, for Finland. As a customer, the Finnish side demanded, having studied international experience—and by this time, an international standard had developed requiring precisely the three elements of safety: a reliable reactor, reliable operation and mandatory containment. This third element was requested by the Finns. That is why the Finnish station was constructed with a cover. After this, the ice melted. The energy leadership started to regard the importance of this element with great understanding, although without fully realizing the seriousness of this issue themselves. And our design organizations started to work with containments.

The second consequence of the delay in the development of nuclear energy was the fact that there were insufficient production capacities for, say, VVER reactor shells. And it still is the most common type of reactor in the world. And its construction and operation can take into account not only our own experience but also the experience of the entire world community. So, the machine-building plants did not have enough capacity to produce the shells and other equipment for VVER reactors in the needed quantities. This is when a section of the energy community came out with a proposal. So as to not limit the plans to introduce new nuclear power capacities and considering the overload of the machine building industry, create a parallel branch in nuclear energy that would allow building sufficiently powerful reactors without using the shell concept, without burdening the machine building industry with the complex technology for manufacturing highly reliable reactor shells that are required for VVER reactors. This is how the idea of channel type RBMK reactor with graphite blocks, etc came about.

If the philosophy that mandatorily required a containment over any type of nuclear facility had been developed, then naturally RBMK, with its geometry, with its construction, as a device would simply not have appeared. It would be, so to say, outside international standards, outside international regulations. No matter how reliable or good it was in its other characteristics, it would not appear. But since this philosophy of mandatory containment was not adopted by the leadership of nuclear energy of the time, the RBMK reactor did appear.

This is why I believe that the beginning of the Chernobyl disaster must be counted from the slowdown of the development of nuclear energy in the late 50s and early 60s. After creating the first nuclear facility, we then slowed down the development of the technology of their creation, the consideration of all the safety issues related to the operation of these devices, and later we started to rush. And this rush led to a need to build more devices at the same cost. There was a need for saving. We started saving on containments. And once containment became optional, temptation arose to build another [reactor] line that would help the country without overloading the machine building industry. This is how the ideology of RBMK reactor appeared.

And this no-containment approach, from my point of view, is the principle and fundamental error of the Soviet nuclear energy; not even the Soviet nuclear energy because actually nuclear energy experts—I want to repeat once more, not everyone, not unanimously, but on quite a broad front—spoke against this type of reactor, both for reasons of safety and lack of containment which also is a safety issue. Already the first launch of this reactor in the first RBMK unit of Leningrad NPP has shown that such a large active zone, implemented in the way it has been, was very complex for the operator. During the initial launches of the first unit at the Leningrad nuclear station, there was a problem of instability of neutron flows and difficulty in managing them. This had to be changed on the go. The degree of fuel enrichment, a number of other technical measures had to be taken to make controlling the reactor easier. But yet, even after these measures—and all the experts in the Soviet Union knew this—from a control point of view, this reactor required a lot of attention from the operator and always was quite complex.

Besides, the very fact of the appearance of this RBMK device, from the perspective of international and generally normal safety standards, was illegal—the fact of its appearance. But, additionally, at least three major design mistakes were made in this device. The first design mistake was that there should be at least two emergency protection systems, as required by international standards and as common sense suggests. Moreover, one of the emergency protection systems should be based on physical principles different from the other one. And more importantly, from my point of view, one of the two systems must operate independently of the operator. This means, let’s say, one emergency protection system must be controlled by the operator automatically, semi-automatically or manually depending on the mode; and the second emergency protection system must work independently, whatever the circumstances of the operator may be, based only on an increase in parameters, say, neutron flow, power, temperature, etc and must automatically shut down the reactor. The RBMK reactor was not equipped with such a second protection system that was operator-independent and not part of the control system. This is a big mistake and had it not been made, the Chernobyl accident would not have happened.

And finally, the third design mistake, which is hard to explain, was that all the numerous emergency protection systems were accessible to the station staff. For example, there were no special double cyphers to turn off the protection systems where protection could be disabled only by using a double or even triple command—by an operator turning a key; by a simultaneous turning of a key by, say, the shift supervisor and maybe even by someone specifically responsible for safety; by a simultaneous turning of a key by the head of the station, the chief engineer or his deputy. Such technical means and devices which are generally used in many military systems, in missile complexes, in nuclear weapons, had not been used. This, of course, seems surprising and strange.

As I already said, the RBMK device is not easy to operate because instabilities, that are possible in principle, frequently occur in its working modes and this makes having simulators near every RBMK device more important. These simulators would allow continuous training of personnel to properly react when a deviation from normal operation occurs. However, for this particular device, as a matter of fact, there were no simulators.

It must be added, however, that a number of challenges with this reactor were solved very well. For example, a number of advantages of this device are already known, such as, firstly, indeed, the possibility of constructing the device without using machine building industry capacities—I mean the absence of a casing for the reactor; the possibility of refuelling the reactor while in operation allowed for having a high coefficient of power utilization in this reactor—the channel principle itself of this reactor; a number of other technical decisions—pumps that were highly reliable in this reactor. These were small advantages, of course, but nevertheless. Also, the fundamental lack of containment, as practice has shown, cannot be compensated by the tightly sealed compartments. And this issue turned out to be principle.

And, of course, it must be said that the positive reactivity coefficient in this device turned out to be unexpected for the physicists. This again was related to the first reason, the rush, with the necessity for a high pace of development of nuclear devices. Because, in principle, with the correct configuration of graphite and with less volume inserted into the zone, this graphite inhibitor could, of course, hold the vapour coefficient within allowable quantities. As practice has now shown, the sum of measures that have been taken for this reactor has made the vapour coefficient to be no more than one beta. And this value is already quite controllable and allows, with proper fast protection devices, to manage any processes. But this had not been done before and the device worked with values of positive reactivity coefficients much higher than a beta in the first place.

Secondly, what was calculated turned out to be significantly higher in practice than was accounted for because physical knowledge about this device was still not sufficient. This is the group of reasons that led to the trouble I wanted to speak about. And so, it's not about the operators …

Of course, the mistakes made by the operators are well known and there is no need to list them yet again. These mistakes themselves are monstrous. The actions of the station management are very hard to explain. Punishing the direct culprits of this disaster is correct because the actions did not meet regulatory requirements and showed inconsistency with the job requirements of the people who were acting in this situation. But still, this is the fault of the officials. But the main reason is not even the errors in the design of the reactor—which of course had their place and for which probably the respective specialists will have to answer—but the main reason is the violation of the basic safety principle for such devices. The lack of and the unprompted removal of the third element—placing dangerous devices in a kind of mandatory capsule that would limit the possibility of activity leaving the station or the device itself. This is the main reason for the magnitude of the accident. This is the thesis I want to be developed when we talk about the causes of the accident.

The next thesis relates to the particular specification of the design of the device, the defects in this design and the sequential description of the causes that led to the accident itself. First of all, it must be noted that this is an experiment that should not have been performed at a nuclear power plant, because the value of turbine coastdown at idle is something that should be measured on a special stand built by the designer of the turbine. And I want this to be underlined. Exactly there is where this question had to be experimentally verified. But it was not. This is what forced the station management, apparently out of good intentions, to perform this experiment— firstly.

Secondly, the absence of systematic thinking on the part of the station management involved with this case. When the first experiments in 1982 and 1983 showed that during a coastdown, the turbine does not maintain the necessary electrotechnical parameters to serve the station's own needs, nobody even thought about solving this problem from the other side, more precisely, reducing the time needed for the backup diesel generators to start and output at the required levels. But they went in the direction of increasing the coastdown time of the turbine, when, at this time, there already were diesel generators that could output at the required electrotechnical levels two to three times quicker than those installed at the Chernobyl station. The most straightforward procedure would have been to replace the diesel generators at the Chernobyl power plant with those that would perform better and all that process of tests and checks would simply have become unneeded. This fact should be noted.

Now it is necessary to describe in detail how the experiment itself went, who approved it, who didn't approve it, how procedures were violated and how the accident developed. Wherein, what is the most important element in this description? For some reason, many sources state that there was one explosion, or two explosions, or a hydrogen explosion, or a non-hydrogen explosion. As of today, it has been absolutely reliably established, and it must be unambiguously written, that there were two consecutive explosions, the second more powerful than the first. This must be noted.

Secondly, we cannot talk about the hydrogen explosion without mentioning that, in addition to the steam explosion, chemical energy related to interactions within all that molten mass was added. It must be said that all the quantitative assessments show that the power of the explosion was equivalent of around three to four tons of TNT. Today, this number can be called a reliably established number so that numbers like in tens of tons or kilotons, etc don't go around. Three or four or up to ten tons of TNT, this is the maximum that can be said.

By the characteristics of the explosion, by the glow, by the dispersion, it is clear that the system had a volumetric-detonation explosion. There was a volumetric detonation. The explosion was volumetric in nature. This means that a rapid expansion of steam, constantly thermally heated, led to the damage that was witnessed. And further, figures of fuel release, they are less clearly known.

Then we must describe the accepted scenario of what happened in the reactor with the fuel: the time when it started heating, the time when it stopped heating, the cooling system and so on. And it is very important to describe the measures that were taken and their significance. For instance, did a one-day delay in taking action have any effect at all? On the first day, the 26th, except pouring water there at night, nothing was done on the night of the 26th. The dropping of, say, sand, dolomite, clay started around the 28th. The first drops were, it seems, at the end of the day on the 27th.

All this has to be thoroughly described because it is necessary to precisely write about the physical implication of each action. Because it was as follows. For example, firstly, per the thinking of the Government Commission, there was an option to not do anything and let the graphite burn. But that would mean ejection of radioactive graphite particles over large distances. The maximum rate of combustion under the temperatures we established (the temperature of graphite combustion) is around a ton per hour. So you can calculate. Given that there are 2,400 tons, the burning would have continued for 2,400 hours. In this time, there would be an emission of radioactivity in aerosol form over large distances. This meant that the graphite fire had to be extinguished first and foremost. This is why sand was used as a means to put out the fire.