

# Happenstance and the Pattern: The Historical Reenactment of the Chernobyl Disaster Causes

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**Abstract:** The most known versions of the Chernobyl Nuclear Power Plant (NPP) accident root causes in 1986 are analyzed. There are a lot of versions that are still discussed at the different levels of the information space. Three official versions of root causes identified by the nuclear and radiation safety authorities and six most popular from the moment of the accident till now versions of root causes proposed by famous scientists and supported by scientific research institutes are considered at this work. The main purpose of this article is not to refute the discussed versions but to find out the possibilities of the Chernobyl NPP personnel influence on the events sequence during the accident. The fact that at all versions of the Chernobyl NPP accident root causes personnel had no possibility to act by alternative way is noticed by authors. In other words, among the remainder root causes that are discussed in this article there are no root causes with the personnel's direct guilt. The issue of shifting blame away from the personnel is consequently raised. The clarification of the Chernobyl NPP root cause is formulated by authors as an important scientific and socio-political issue.

**Key words:** accident, root cause, chernobyl NPP, personnel, error analysis

## 1. Introduction

There are few witnesses and elimination participants that were working in the nuclear energy at the period of the Chernobyl disaster. The IAEA put the endpoint in 1986, then IAEA put the greasy endpoint in 1992 by publishing the report "INSAG-7" [1]. But why until now all these events excites not only ordinary people, but also scientists.

Till now there are a lot of different versions of root causes of the Chernobyl disaster [1-12]. Also in YouTube there are a lot of materials on the topic of the Chernobyl accident, which are, on the one hand, the result of the periodic information surge before the anniversary. But other notes are also visible. For example, Professor I.N. Ostrecov says bluntly: "... diversion with the goal of the collapse of the USSR as an ideological adversary and an enemy in the Cold

War ..." [7]. Other, less-informed and less knowledgeable authors, simply do not believe to the official versions about the guilt of the Chernobyl NPP's personnel, they say: it could not be that the ignoramus worked at the best NPP of the USSR.

Thus, until now, 34 years later, there is a contradiction between the official point of view and the civil one. This contradiction means that there is a problem of clarifying the causes of the most serious technological accident of mankind. This is not just an actual topic, but also an urgent scientific and social problem. The solution to the problem can only be found on the basis of deep scientific historical research.

## 2. Objective

This article is devoted to the problem of the clarification of the Chernobyl NPP's personnel role during the sequences of the events of the Chernobyl disaster.

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The main purpose of this article is not to refute the discussed versions of Chernobyl disaster but to find out if the Chernobyl NPP personnel had the possibilities of influence on the events sequence during the accident at all the variants.

### 3. Material and Methods

To carry out our investigation and for the historical reenactment we use conclusions concerning causes of the Chernobyl disaster taken from the official information [1-4], from the results of the investigations that were carried out by independent scientists and nuclear energy specialists [5-11], from the results of the investigation that were carried out by Vasilij Begun as a scientist [12], from the results of own observations that were carried out by Vasilij Begun as a witness and the elimination participant of the Chernobyl disaster.

We use ASSET methodology [13] to carry out the analysis of the events of the Chernobyl accident. We use our models which are based on the THERP method [14] with different taxonomies for describing human malfunction [14, 15] and are presented in Ref. [12] to evaluate the human factor influence. Probabilistic safety analysis [16, 17] with models described in Ref. [12] is used for the analysis of the events sequences.

All the conclusions concerning the role of the Chernobyl NPP's personnel will be based on the analysis of the possibilities of influence on the direct cause of the accident with corresponding root cause versions.

One of the main tasks of the work should be to find out the root cause of the disaster. Let us recall that the root cause in nuclear energy is a circumstance that created the conditions for the presence or manifestation of a direct cause [13, 17]. In other words, the root cause is the fundamental cause of an initiating event, correction of which will prevent recurrence of the initiating event [18]. The direct cause is a phenomenon, process, event or condition that caused an abnormal operation [13, 17]. In other words, the direct cause is the latent weakness that allows or causes the observed

cause of an initiating event to happen, including the reasons for the latent weakness [18]. In the case of Chernobyl disaster all the investigators are agreed that the direct cause was an uncontrolled increase of reactivity (power) [1-12]. But why did this happen? In accordance with the international ASSET methodology [13], after determining of the direct cause, the purpose of further investigation of the events is to identify the root causes and develop such corrective actions so that such occurrence does not recur. Until a completion of the full investigation of the accident with finding out the root cause, the operation of the unit under investigation and the units with the same construction is prohibited. So maybe, in connection with these circumstances an expedited investigation [2] was set that year? Has the international community agreed with the wording of the commission so as not to stop the Nuclear Power Plant's Units? It was easier to accept and continue further work — an ordinary psychology. This conclusion is confirmed by facts given in the next paragraph.

It is well known that the official version of the root cause has changed three times [1-4]. The first version, prepared by the Soviet delegation specifically for the IAEA expert meeting held in Vienna in August 1986, contained the following conclusions about the causes of the accident at the Chernobyl NPP unit 4: "the prime cause of the accident was an extremely improbable combination of violations of instructions and operating rules committed by the staff of the unit" [2]. At the same time, in this document [2] there was no scientific evidence or other proof that the actions of the personnel of the Chernobyl NPP unit 4, which led to the largest technogenic disaster in the entire history of a mankind, was really constituted an "extremely improbable combination". After its announcement in Vienna, the stated concept of the exceptional guilt of the Chernobyl NPP's personnel became the official concept of the USSR, and all previous studies, acts, reports which was in contradiction to this version were classified and hidden even from specialists.

The USSR State Committee for the Supervision of Safety in Industry and Nuclear Power 5 years after the Chernobyl accident, in 1991, was trying to understand why the actions of Chernobyl NPP's personnel caused a disaster, especially since the actions were performed not by one person but by the shift team. The Commission was created for the purposes of the investigation. This Commission comes to the next conclusion in the report (second version): "the Chernobyl accident, which was initiated by erroneous actions on the part of the operating personnel, had disproportionately disastrous consequences because of deficiencies in the design of the reactor" [3]. Since the USSR State Committee for the Supervision of Safety in Industry and Nuclear Power had the status of the regulatory body, the Commission in the analysis paid special attention to the review and assessment of the compliance of the reactor design and the actions of the operating personnel with the regulatory, technical and operational documentation that was in force during the design and operation of the unit 4 of the Chernobyl NPP.

The Governmental Commission of Ukraine 10 years after the Chernobyl accident, in 1996, by summarizing the principal facts, conclusions and results of previously performed studies, including Refs. [2] and [3], and critically examining them, and in some cases, adjusting them based on additional analysis, makes in the corresponding report the following conclusion about the causes (third version) of the accident at the unit 4 of the Chernobyl NPP: "The root causes of the accident are the specific nuclear-physical characteristics of RBMK-1000, due to the design of its core; low efficiency of the control and protection system; incorrect design of the reactor emergency protection rods; low quality of the standard technological regulations" [4].

The fourth version was voiced much later by a well-known theoretician in the field of nuclear safety, the world-renowned Sweden professor B.R. Sehgal in his lecture [5]. He as a leader of the project gave this

lecture in Stockholm in 1998 for the scientists participants of the quadripartite project on Nuclear Power Reactors Safety. Later, these results were published in a scientific journal [6]. Professor B. R. Sehgal placed the description of the Chernobyl accident under the heading "How the Trap Was Set" (literally: "How the trap was organized") [5, 6]. The report describes all the actions of the personnel, factors and circumstances of the accident, but there are no direct indications on the organizers.

The fifth version was openly voiced by no less famous professor Igor Ostrecov [7], which was already discussed at the beginning. He, as a specialist in nuclear physics and nuclear energy and as a witness of the elimination of the Chernobyl disaster, said that the Chernobyl NPP's personnel had no possibilities to interfere in the work of the Unit 4 of the Chernobyl NPP without permission from Moscow. Thus, all the actions of the NPP's employees were coordinated with the higher management, which, he believes, acted in the interests of another country. That is, the root cause is diversion, betrayal [7].

As the sixth version we will take into account the opinion of the Member of the Russian Academy of Sciences Valery Legasov voiced by him in his famous tapes, which were recorded by him shortly before his death [8]. He is a great, internationally recognized scientist and one of the leaders of the elimination of the Chernobyl disaster, a terminally ill person (as a result of irradiation) who could not be dishonest while slowly dying, therefore we consider his opinion to be absolutely correct, and the root cause is the wrong paradigm of safety: "The reason is obviously in the philosophy of safety. If the safety philosophy would have been correct, then our specialists would have the way to find out the correct technical solutions under this philosophy. Because our specialists are educated professionals, intelligent people, who are know how to calculate and how to do a lot of other things" [8]. But this also implies the absence of personnel fault.

The seventh widely discussed version of the root cause has also very general nature — the unpreparedness of modern mankind for the competent use of huge energy due to the lack of fundamental knowledge about the nature of the atom and the processes of nuclear transformations [9]. This is the statement of the Nikolai Karpan, the former deputy chief engineer on science and nuclear safety of the Chernobyl Nuclear Power Plant.

The eighth version of the root cause is the wrong choice of the Chernobyl NPP's site geographical location which is situated on the tectonic split. Supposed that the Chernobyl accident was caused by a local earthquake. The supporters of this version have strong evidence. We will not discount this version.

Let us also describe the ninth version of the root cause voiced by the nuclear energy specialist Ernst Gomberg. He worked as an engineer of mounting of Nuclear Power Plants equipment and then trained professionals for a mounting of Nuclear Power Plants equipment. He stated that all troubles are due to incorrect calculations of boiling in thin long vertical tubes (RBMK technological channels (fuel channels and special channels)) [10, 11]. He stated that such boiling process is difficult or almost impossible to control along the whole length (7 meters) of the RBMK's technological channel [10, 11]. Thus, sooner or later breakdowns of the RBMK's technological channels should have occurred, which, in principle, took place repeatedly both at Chernobyl NPP and at the Leningrad NPP before 1986 [1, 10, 11].

#### 4. Results and Discussion

The results of our investigation are summarized in Table 1. We give in that Table 1 the analysis of possible versions of root causes and the corresponding influence of the personnel of the Chernobyl NPP by indicating: the short description of root cause version; identification of the supposed guilty party; corresponding short description of the corrective

actions including corrective actions that should be implemented in relation to the Chernobyl NPP's personnel; the stage of corrective actions implementation at the moment of article publication.

The first version of root cause belongs to the institute of the RBMK's Chief Designer. This version was later confirmed by the modeling and theoretical calculations, which was carried out by that institute. The essence of the calculations is simple: if all the requirements of technical and operational documentation that were available at the moment of the accident were fulfilled, then everything would be fine, that is, personnel who violated the rules were guilty. Thus, the cause of the Chernobyl accident in that version of root cause is operator errors, the human factor. But why did the competent operators make mistakes?

Let us deeply analyze the possibilities of Chernobyl NPP's personnel influence on the events of the accident in the cases number 1 and 2 versions of root cause (see Table 1). In all these three cases personnel errors are the part of the formulation of the root cause.

Professor B.R. Sehgal in his investigations [5, 6] analyzes in detail the errors made by the operators, which, of course, were. He stated: "It is one of history's ironies that the worst nuclear accident in the world began as a test to improve safety" [5, 6]. The headings with the description of the Chernobyl accident in his lecture in Stockholm in 1998 [5] and later in his article in 2006 [6] are the same ("How the Trap Was Set") and are not casual. He characterizes the initial event of the accident as a decision to start that test at 1 a.m. on April 25: "The accident really began 24 hours earlier, since the mistakes made then slowly set the scene that culminated in the explosion on April 26" [6]. In his investigation he pointed out that "the atmosphere was not conducive to the operators performing a cautious test" [6]. He was surprised and emphasized that there were the substantial discrepancies between the official position of the USSR representatives concerning the personnel and the facts that really were happened.

**Table 1 Versions of Root Causes of the Chernobyl Accident and the Corresponding Corrective Actions.**

No.	Root Cause	Reference	Supposed Guilty	Corrective Actions	Corrective Actions Implementation
1.	Personnel errors	Commission Report [2]; Court Orders	Personnel	Enhance the personnel training with construction of the full-scale training simulator of NPP etc	Completed
2.	Personnel errors amplified by the RBMK reactor design deficiency	Commission Report [3]	1) Designer of the RBMK reactor; 2) Personnel.	1) Improvement of the RBMK reactors construction; 2) Partial shifting blame away from the personnel.	1) Partially implemented; 2) Not implemented.
3.	RBMK reactor design deficiency	Commission Report [4]	Designer of the RBMK reactor	1) Improvement of the RBMK reactors construction; 2) Shifting blame away from the personnel.	1) Partially implemented; 2) Not implemented.
4.	The trap organized by unidentified participants disguised as the personnel errors	Lectures [5] and the article [6] of Professor Bal Raj Sehgal	Unidentified	1) Improvement of the RBMK reactors construction; 2) Shifting blame away from the personnel.	1) Partially implemented; 2) Not implemented.
5.	Diversion	Lecture of Professor Igor Ostrecov [7]	USA	1) Obtaining the redress; 2) Shifting blame away from the personnel.	1) Not implemented; 2) Not implemented.
6.	Wrong paradigm of the safety of the Nuclear Power Plants	Tapes of the Member of the Russian Academy of Sciences Valery Legasov [8]	Theoreticians of the NPPs of the USSR	1) Changing the philosophy of safety of NPPs; 2) Shifting blame away from the personnel.	1) Completed; 2) Not implemented.
7.	Unpreparedness for new dangerous technologies	Individual opinion of the nuclear energy specialist Nikolai Karpan [9]	Theoreticians of the NPPs	1) Decommissioning of all the NPPs; 2) Shifting blame away from the personnel.	1) Not implemented; 2) Not implemented.
8.	Tectonics	Scientific Reports of the Ukrainian Institutions	Designer of the Chernobyl NPP site	1) Decommissioning of the Chernobyl NPP; 2) Shifting blame away from the personnel.	1) Implemented; 2) Not implemented.
9.	Theoretical errors in the thermophysical calculations	Individual opinion of the nuclear energy specialist Ernst Gomberg [10, 11]	Theoreticians and designers of the RBMK reactor	1) Indigenous modernization or decommissioning of all RBMK reactors; 2) Shifting blame away from the personnel.	1) Not implemented; 2) Not implemented.

The later could be seen in his citation: “Soviets said that their procedures were very emphatic on that point, and that “Not even the Premier of the Soviet Union is authorized to run with less than 30 rods!”. Nevertheless, at the time of the accident, there were probably only 6 to 8 rods in the core.” [6]. And at the beginning of his article he emphasized that “Chernobyl unit #4 was a model plant – of all the RBMK-1000 type plants, it ran the best. Its operators felt they were an elite crew and they had become overconfident” [6]. Could the “overconfidence” of the operators of the best NPP reconcile the fact of “only 6 to 8 rods in the core” with the officially voiced restriction of “not less than 30”?

First two versions of root causes are not confirmed in

the independent investigation of the Ukrainian Commission completed in 1996 in the part of the Chernobyl NPP’s personnel guilt [4]. Formulation of the third version of root cause does not contain the blame of the personnel as could be seen in Table 1.

A more thorough investigation of the Chernobyl NPP’s personnel role during the sequences of the events of the Chernobyl disaster could be carried out by using the model developed by Vasilij Begun [12]. In this model the errors of the personnel are classified mainly by Reason's taxonomy [15]: errors of misunderstanding (mistakes) and the deliberate violation (violation). We had the possibility by using this model to analyze in detail all the 12 errors that are

blamed on operators [12] with considering all the factors and circumstances that accompanied the errors. Calculated based on this model the probability of collective error and the appropriate conclusions are eloquent: Personnel errors did not contribute, but occurred because there were design and physical deficiencies of the reactor, unfavorable external and internal factors that made the probability of human error for the operator close to 100%, and the probability of a sequence of erroneous collective actions was unacceptably large, weakly dependent on a specific person who make decisions and actions on NPP control panel. Thus, the personnel and operators were simply “hostages” of the circumstances. But can hostages be blamed? The consequences of this conclusion are of great social significance, because the close people and relatives of this personnel are still living with the stigma of “enemies of the people and humanity”.

For reference. The human factor evaluation (so called Human Reliability Analysis) in terms of Probabilistic Safety Analysis in the USA nuclear energy is used since 1972 while carried out the work on the most fundamental till now methodology document WASH-1400 [16]. Since 1983, the THERP methodology has been operating in the USA as a national standard for calculating the possible errors of the human operator of complex systems [14]. The probability of error, according to the document, depends, in fact, not only on the competence of the operator, but also on external and internal factors, circumstances and context [12, 14, 17]. Thus, in some situations, the probability of error can reach unity (100%) even for competent and experienced operators.

The public opinion of nuclear energy specialists could be used as an indirect evidence of the innocence of the personnel on duty. The one of the authors of this article Vasilij Begun was working in the spring and summer of 1986 as a senior engineer on operation of the Division of Thermal Automatics and Measurements of the 2nd phase of the Chernobyl NPP

project (units 3 and 4 of the Chernobyl NPP). The author of the article remembers well how all the engineers tried to understand what happened and why? Everyone felt sorry for the irradiated sick people, felt hostile towards the scared runaways people, were interested in the condition of the patients of the 6th Moscow hospital, rejoiced at each recovery, bitterly escorted the dead ones. They worked 12 hours a day at the Chernobyl NPP, spent 1.5 hours for the road each way there and back, everyone knew each other, and no one (!) condemned the personnel of the shift team, that worked at unit 4 of the Chernobyl NPP on April 25-26 1986. This could mean only one thing: the actions of the personnel were not perceived as errors in the professional environment! This circumstance for our topic should be considered as very important. There was no at the Chernobyl NPP the Communist Party meeting with condemning the personnel while the Communist Party meetings at Chernobyl NPP were held every week.

## **5. Conclusion**

As a result of our investigation we could conclude that among nine considered root cause versions there are only two of them [2, 3] are related to the personnel, but both of these versions are officially refuted by the investigation of the Ukrainian Governmental Commission [4]. Thus, there are no de facto official or officially recognized reasons for the guilt of the Chernobyl NPP personnel. So why are legal and social rehabilitation not considered so far? Particularly noteworthy are the root cause versions number 4 and 5 in Table 1 — organized diversion. First of all, the fact that such an opinion is expressed by the most knowledgeable experts of the highest competencies, of the world level, and even of the parties that were opposing to each other during the Cold War [5-7] deserves attention. The qualitative and quantitative analysis of the circumstances of the events (actions of the personnel), performed based on data and models [4-6, 12] actually justifies the personnel, calling their

actions as forced under the conditions prevailing at that time. Numerical calculations of the probability of errors based on developed model [12] confirm given conclusions that the accident became inevitable immediately after the decision to start the test (experiment) on April 25 1986 and then to shut down the reactor. We should note the fact that none of the root cause versions given in Table 1 are unambiguously recognized as root cause by all the scientists and nuclear energy specialists due to unsatisfactory convergence with the definition of root cause as given in [13, 17, 18]. And this means that the investigation is not completed — this is the first. The second, as we see in Table 1, the corrective actions were performed only on the assumption that the root cause of the disaster was the personnel errors, and since this is not so, this means one thing — the accident can happen again because the root cause is not clarified - this is the essence of the root causes. During further investigations the problem of happenstance and of necessity for all the actions should be studied. The THERP methodology divides the classification of probable personnel errors into different types, among which the random errors and the errors under the weight of circumstances have significantly different probabilities, and, accordingly, it is necessary to relate these values of probabilities to the degree of guilt in the framework of the laws that were in force on the moment of the Chernobyl accident. The next task is the task of lawyers. The preparation of data to solve this problem can be performed on the basis of existing publications and knowledge by experts in the nuclear industry. And most importantly — the need for rehabilitation of operators becomes apparent.

## References

- [1] INSAG-7, The Chernobyl Accident: Updating of INSAG-1, A report by the International Nuclear Safety Advisory Group. Safety Series No.75-INSAG-7, International Atomic Energy Agency, 1992.
- [2] USSR State Committee on the Utilization of Atomic Energy, The Accident at the Chernobyl Nuclear Power Plant and its Consequences, Information Compiled for the IAEA Experts' Meeting, Vienna, 25-29 August 1986.
- [3] Report by a Commission to the USSR State Committee for the Supervision of Safety in Industry and Nuclear Power, Causes and Circumstances of the Accident at Unit 4 of the Chernobyl Nuclear Power Plant on 26 April 1986, Moscow, 1991.
- [4] Report by a Governmental Commission of Ukraine, Causes and Circumstances of the Accident at Unit 4 of the Chernobyl Nuclear Power Plant on 26 April 1986, Actions on Accident Management and on Elimination of the Consequences, Summary of the Conclusions and Results of the International and Domestic Institutions and Organizations, (in Russian), State Committee of Ukraine on the Utilization of Atomic Energy, Kiev, 1996.
- [5] Materials of the Professor B. R. Sehgal's Lectures on Light Water Reactor Safety for the Scientists Participants of the Quadripartite Project on Nuclear Power Reactors Safety (on rights for a manuscript, in English), Stockholm, 1998.
- [6] B. R. Sehgal, Light Water Reactor (LWR) Safety, *Nuclear Engineering and Technology* 38 (2006) (8) 697-732.
- [7] Professor I. N. Ostrecov's interview on Chernobyl accident causes (in Russian), available online at: <https://www.youtube.com/watch?v=fzihrl2EUxw>.
- [8] V. A. Legasov, About the Accident at the Chernobyl Nuclear Power Plant, The Text at the Five Audio Tapes Dictated by the Member of the Russian Academy of Sciences V. A. Legasov, available online at: <http://www.pseudology.org/razbory/Legasov/00.htm>. (in Russian).
- [9] N. V. Karpan, Historical Review of the Nuclear Science and Technology Development Stages, Analysis of the Causes and the Events of the Chernobyl Disaster, Chernobyl, The Revenge of Peaceful Atom, Kiev, "Country Life", 2005. (in Russian)
- [10] E. Gomberg, Chernobyl Nuclear Power Plant — The Analysis of Two Explosions Inside the Reactor, available online at: <https://www.youtube.com/watch?v=evE6d7bJ9Uk>. (in Russian)
- [11] E. Gomberg, Arguments in Relation to Thermophysical Analysis of Two Explosions Inside the Reactor at Unit 4 of the Chernobyl Nuclear Power Plant (text in Russian), available online at: <https://drive.google.com/file/d/1bJJYykH8lw8ljTXO02RzRjH02Ka61on/view>. (in Russian)
- [12] V. V. Begun and V. N. Vasil'chenko, Analysis and account of human factor during Chernobyl Accident at 26 April 1996 by modern methods, *Nuclear & Radiation Safety (ISSN 2073-6231)* 1 (2003) 52-60.

- [13] ASSET Guidelines Revised 1991 Edition, IAEA-TECDOC-632, International Atomic Energy Agency, 1994.
- [14] A. D. Swain and H. E. Guttmann, *Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications*, Final Report, NUREG/CR-1278, United States Nuclear Regulatory Commission, 1983.
- [15] J. Reason, *Human Error*, Cambridge University Press, 1990
- [16] N. C. Rasmussen, *Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants*, WASH-1400 (NUREG 75/014), U.S. Nuclear Regulatory Commission, 1975.
- [17] V. V. Begun et al., *Probabilistic Safety Analysis for Nuclear Power Plants*, Vypol, 2000. (in Russian)
- [18] IAEA Safety Glossary, Terminology used in nuclear safety and radiation protection, STI/PUB/1290, International Atomic Energy Agency, 2007.