Studies of Nuclear Hazards
and Constitutional Law

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The Matter of the Planned Use of
Mixed Plutonium Dioxide - Uranium-Dioxide
Nuclear Fuel in the Grundremmingen Reactor

To whom it may concern:

According to information given to me, the atomic power authorities in Germany are considering a plan to use mixed Plutonium-Uranium-dioxide nuclear fuel in the two Grundremmingen boiling water reactors in Bavaria. I feel it my duty to set down in this letter for those who are interested the primary nuclear hazards associated with the use of Plutonium-enriched, mixed-oxide fuel, as I conceive these hazards to be.

The use of the mixed-oxide fuel will increase substantially the amount of Plutonium in the core of the reactor, I assume. Even with the use of conventional nuclear fuel in a light water reactor - Uranium dioxide enriched in Uranium-235 fissionable isotope - Plutonium builds up in the reactor core as a by-product of the nuclear reactions in the core, namely, the conversion of the abundant Uranium-238 isotope in the core fuel into plutonium. I recall that about 500 to 800 kilograms of Plutonium accumulates in the core (maximum). These figures apply to a pressurized water reactor. Perhaps the boiling water reactor has more of a build-up of Plutonium, due to its greater fuel loading of uranium-oxide (169 tonnes for a BWR versus 100 tonnes for a PWR). According to estimates made by Professor A. Weiss of Munich and myself, based on data from official safety analysis reports for the Grundremmingen reactors (though I do not have these data with me now), the planned use of mixed-oxide, Plutonium-enriched fuel in the Grundremmingen boiling water reactor will involve the maximum amount of Plutonium in the core at any one time of 1500 kilograms (this estimate needs to be confirmed or re-checked); although I have seen a unofficial paper asserting that as much as 2500 kilograms of Plutonium will build up (I cannot confirm this). A figure of 1500 to 2500 kilograms of Plutonium in the core is plausible; for after all the purpose of using the mixed-oxide fuel is to recycle Plutonium in the core in the place of the Uranium-235 fissionable material. There is about 169 tonnes of uranium dioxide in the core of a large BWR reactor (3300 MWth) using conventional nuclear fuel at about 2.2% enrichment in U-235. This means that there is approximately 3700 kilograms of fissionable material in the core (U-235) for a uranium core: 0.022 x 169,000 kg = 3718 kg of U-235. Plutonium-239 has a fission cross-section of 742 barns versus 542 barns for U-235 for thermal neutrons, which means that less Plutonium is needed for the self-sustaining fission reaction in the reactor core, or so I assume. So, I crudely estimate that for a core fully loaded with mixed-oxide fuel, assuming the fissionable isotope U-235 is fully substituted by Plutonium, the maximum Plutonium content would be 2700 kg: 3718 x 542/742 = 2715 kg plutonium. So, perhaps the 1500 kg figure for plutonium as estimated by A. Weiss means that the planned use of mixed-oxide fuel in the Grudremmingen reactors is such that only part of the core fuel loading will be with mixed-oxide fuel, but in the future the industry will use a full core loading of mixed-oxide fuel, or maximum Plutonium inventory of 2700 kg.

Thus, we can suppose that for a core loaded with mixed-oxide Plutonium-enriched fuel, instead of U-235-enriched uranium fuel, the amount of Plutonium in the core would be substantially greater than in a uranium core which contains Plutonium only as a by-product of the fission reactions in the core. Therefore, it is fair to assume that the Grundremmingen reactors will contain much more Plutonium in their cores, if mixed-oxide fuel is used - say 1500 kilograms, or more, as compared to about 500 to 800 kilograms (perhaps mroe) without the use of mixed-oxide fuel.

I cannot say at this point that the planned use of mixed-oxide fuel in the Grudremmingen reactors will result in a substaintial increase in the maximum amount of plutonium in the reactor core at any one time; but certainly for a core fully loaded with mixed-oxide fuel, there should be a substantial increase in the amount of plutonium in the core: I crudely estimate an increase from 800 to 1200 kg plutonium (maximum build-up of Plutonium from the U-238) to 2700 kg plutonium (core fully loaded with mixed-oxide fuel). Without more reliable and more detailed data I can only assume that the use of mixed-oxide fuel in the core will result in a substantial increase in the amount of plutonium in the core.

Such a substantial increase in the amount of the Plutonium in the core would have serious effects on the nuclear accident hazards:

1. The increased amount of Plutonium in the core of the reactor greatly increases the potential harmful consequences of catastrophic nuclear accidents - namely, the potentials for Plutonium release into the atmosphere in a reactor eruption and the consequent ruinous Plutonium contamination of the land. Accordingly to my analysis, a 75 percent release of Plutonium in a catastrophic nuclear accident in a pressurized water reactor using conventional nuclear fuel could result in permanent abandonment of about 200,000 square kilometers of land - about the size of West Germany - due to Plutonium fallout alone, not considering the release and fallout of the fission products. I refer to my report *Catastrophic Nuclear Accident Hazards - A Warning for Europe* (August 1984, page 131). The use of mixed Plutonium-uranium oxide fuel (Plutonium-enriched fuel) could increase the size land area which could be potentially ruined by Plutonium fallout contamination by three to five fold - or about 600,000 square kilometers to one million square kilometers, depending on the actually loading of the Plutonium in the core. Plutonium dust fallout on the land would create a lung cancer hazard - breathing Plutonium dust.

2. The increased amount of Plutonium in the core would substantially reduce the "delayed neutron fraction" of the reactor. This would affect seriously the <u>reactivity accident</u> hazards of the reactor. A "reactivity accident" is an uncontrolled increase in the "reactivity" of the reactor resulting in a runaway increase in the reactor power level - a power excursion - as occurred in the Chernobyl nuclear accident. A smaller delayed neutron fraction worsens the possibilities for catastrophic reactivity accidents. This is because when the reactivity rises to above the level equal to the delayed neutron fraction, a rapid power excursion would occur. Hence, a much smaller delayed neutron fraction means that a rapid power excursion is more likely to occur in accidents involving uncontrolled increases in the reactivity.

Even without the use of Plutonium-enriched fuel, the reactivity accident hazards of light water reactors, including Boiling Water Reactors, are extremely serious and demand an urgent full review and investigation of these reactor accident hazards, as part of the needed full general review of the safety of nuclear power plants by society that I have called for. I refer to the following works which I have published:

- *The Accident Hazards of Nuclear Power Plants* (University of Massachusetts Press, 1976).

- *Boiling Water Reactors - Reactivity Accidents and Unstable Power Oscillations* (1989)

- *The Risks of Catastrophic Accidents at Nuclear Power*

Plants, a paper for the Conference on the Future of Nuclear Energy, held in Barcelona, Spain, 25 April 1990. A German translation of this paper is also available.

- *The Chernobyl Nuclear Accident: A Summary Analysis of its Cause and Consequences, with a Comparative Analysis of the Accident Hazards of the Western Reactors*, August 1, 1986. A German translation is also included.

- *Catastrophic Nuclear Accident Hazards - A Warning for Europe*, August 1984 with a May 1985 Supplement.

- *An Analysis and Evaluation of the Accident Hazards of, and the official Safety Arguments for, the Sizewell-B Type Pressurized Water Reactor proposed for the Hinkley Point Reactor Site in England*, (November 20, 1989).

With the use of Plutonium-enriched fuel, and the smaller delayed neutron fraction that results, the reactivity accident hazards are seriously affected, making it all the more necessary for a full review of the reactivity accident hazards of the reactor when considering a license application to use the Plutonium-enriched fuel.

Also, the use of plutontium-enriched fuel (increased plutonium content in the core) could conceivably adversely affect the temperature coefficient of reactivity for the reactor coolant. This would in turn affect the reactivity accident hazards.

The smaller delayed neutron fraction would also affect the question of the stability of the reactor. As discussed in my treatise *Boiling Water Reactors - Reactivity Accidents and Unstable Power Oscillations*, a "divergent" power oscillation occurred in a large modern boiling water reactor near Chicago in 1988 (the LaSalle BWR) in a loss-of-coolant-flow mishap. Such unstable power oscillations were not predicted in the safety analysis calculations for the design of the reactor. The LaSalle event has serious implications for the accident hazards of boiling water reactors. Again, I refer to the above-cited treatise, *Boiling Water Reactors - Reactivity Accidents and Unstable Power Oscillations*. A divergent power oscillations has also occurred in a German BWR, according to information given to me by officials of the U.S. Nuclear Regulatory Commission; but so far I have not been able to learn the specific reactor in which the event occurred.

I learned of the fact of the unstable power oscillations event in the

LaSalle reactor in 1989 in the course of my investigations into the reactor operating experience in the United States as part of my research and evaluation of the nuclear accident hazards. I immediately informed the atomic licensing and supervisory authority in the Land Schleswig-Holstein, Dr. Gustav Sauer. (I chose to inform the Schlewsig-Holstein Government atomic authorities, since I was told that they would be most likely to investigate the matter, and since two BWRs operate in Schleswig-Holstein. Also, I had no financial means nor time to inform other authorities in Germany.) Dr. Sauer told me that he did not know about the LaSalle instability event, when I first informed him of the fact. He contacted me later to confirm that such an event occurred.

I subsequently investigated the LaSalle instability event quite extensively. In parallel with this investigation I undertook further research into the reactivity accident hazards of light water reactors. The results of this additional research ~~is~~ are set down in a treatise I have issued on the subject of reactivity accident hazards and unstable power oscillations in boiling water reactors - the one cited above, *Boiling Water Reactors - Reactivity Accidents and Unstable Power Oscillations*. I have given a copy of the treatise in the autumn of 1989 to the Schleswig-Holstein atomic authorities (and also to the atomic authorities in Nordrhein-Westfalen). (The Schleswig-Holstein Government paid me a financial reward for the treatise.) The treatise concludes with a call for a full investigation into the accident hazards of nuclear power plants, including reactivity accident hazards and the matter of unstable power oscillations.

I have just learned that the Schleswig-Holstein atomic authority has taken no action in regard to the recommendations in the treatise for an investigation into the reactivity accident hazards of BWRs, including unstable power oscillations. It has been almost two years since the Schleswig-Holstein licensing authority has had my treatise *Boiling Water Reactors - Reactivity Accidents and Unstable Power Oscillations*, and yet they have not given the treatise to any experts for review and evaluation with respect to the reactivity accident hazards and the matter of the occurrence of unstable power oscillations in reactors.

I have been informed that the Schleswig-Holstein atomic authority might order a review of the safety of nuclear power plants perhaps one year from now, and that such a review might include a review of my treatise *Boiling Water Reactors - Reactivity Accidents and Unstable Power Oscillations*, and an investigation of the matters treated therein. In the meantime there appears to be no investigation into the serious matter of unstable power oscillations in boiling water reactors. The planned licensing proceedings for the question of the use of Plutonium-enriched fuel (MOX) in the Grundremmingen BWR reactor would be an appropriate occasion for the public to seek a full investigation of the hazards of reactivity accidents and unstable power oscillations in boiling water reactors, inasmuch as the licensing authorities do not seem to be investigating the safety issues raised in my treatise *Boiling Water Reactors - Reactivity Accidents and Unstable Power Oscillations.* One official of the Bavarian atomic licensing authority, Dr. Seidl, said that he knows of no occurrence of divergent power oscillations in a BWR in Germany; and yet an official of the U.S. Nuclear Regulatory Commission has informed me that such an occurrence occurred in a German BWR. I caution that the hazards of power oscillations in a BWR are extremely complicated to evaluate. I refer to my treatise *Boiling Water Reactors - Reactivity Accidents and Unstable Power Oscillations.* I have not concluded that the potential for unstable power oscillations in BWRs constitutes serious reactor accident hazards more than other reactor accident hazards; but there are many questions as set down in my treatise that need to be investigated about the possibility of unstable power osciallations in a BWR. The research to make the investigation would be formidable.

Incidentally, in the course of my investigations into the reactivity accident hazards of PWRs and BWRs in 1989 I uncovered the existence of a secret report of the United States Nuclear Regulatory Commission (Brookhaven Laboratory) reviewing the reactivity accident hazards of pressurized water reactors and boiling water reactors. I obtained the report from the United States Government through legal procedures under the Freedom of Information Act. This document needs to be injected into the Grudremmingen licensing proceedings regarding the use of mixed-oxide fuel and the questions of the effects of the use of the mixed-oxide fuel on the reactivity accident hazards of the reactors.

3. The increased amount of Plutonium in the core by the planned use of Plutonium-enriched fuel substantially increases the possibility of an atomic bomb size explosion in the Grundremmingen reactor in a core meltdown accident. It is a legitimate question to ask whether or not the Plutonium in the core could separate from the uranium dioxide in the fuel material in a core meltdown, due to chemical reactions, and/or physical processes, and then concentrate to form a critical assembly of Plutonium-enriched material on fast neutrons alone. It is known that Plutonium can exist in the chemical form Plutonium mono-oxide, which is a gas! If gaseous Plutonium mono-oxide would form in a core meltdown, it would assumedly separate from the molten core material, where it could then conceivably react with oxygen elsewhere in the reactor to form Plutonium dioxide, which is not gaseous, and then precipitate and concentrate in solid form. A mass of Plutonium-enriched material would present a danger of a catastrophic nuclear explosions due to a process called "autocatalytic assembly" of nuclear fissionable material. Such a process has a theoretical potential for

atomic bomb size explosions, with no limit of the explosion potential yet established. I refer to a supplement to my report *Catastrophic Nuclear Accident Hazards - A Warning for Europe*, dated April 1986, on atomic bomb size explosion hazards of nuclear reactors, and my 1989 treatise *An Analysis and Evaluation of the Accident Hazards of, and the official Safety Arguments for, the Sizewell-B Type Pressurized Water Reactor proposed for the Hinkley Point Reactor Site in England* (November 20, 1989).

4. It has been suggested that the use of Plutonium-enriched fuel in the Grundremmingen reactor could increase the embrittlement of the reactor vessel, by increasing the bombardment of the vessel steel with more fast (energetic) neutrons produced by Plutonium, and thereby increasing the risk of a catastrophic rupture of the reactor. It is said that the average energy of the neutrons emitted by fission is significantly greater for Plutonium than for Uranium-235. I cannot confirm this now, due to no ready access to the literature. But I can say that Plutonium emits about 25 percent more neutrons per fission. Perhaps the reactor operators plan to provide protection of the vessel steel from the increased emission of fast neutrons when using Plutonium-enriched (mixed-oxide) fuel by placing this fuel away from the outer boundary of the reactor core, and thereby provide more shielding (reactor coolant and structure material) between the Plutonium-enriched fuel and the vessel steel, so as to reduce the number of fast neutrons reaching the vessel steel from the Plutonium-enriched fuel. Therefore, I cannot say that the use of Plutonium-enriched fuel in the Grundremmingen BWR reactor would significantly increase the danger of neutron embrittlement of the reactor; but I can say that there is already the danger of catastrophic accidents due to spontaneous reactor vessel rupture that is, in my view, an unacceptable risk for the public. I refer to my various reports and treatises on the nuclear accident hazards.

It has also been suggested that the use of Plutonium-enriched fuel in experiments in the first Grundremmingen BWR might have been the cause for closing down that reactor. This is a legitimate question; for I have been told by an official of the U.S. Nuclear Regulatory Commission that the reactor vessel of the old Grundremmingen BWR reactor is being cut into pieces and examined metallurgically.

However, that reactor also suffered an accident in January 13, 1977 in which the reactor was over-pressurized and a safety value was damaged. I have learned from a U.S. Government document (a cable from the U.S. Embassy in Bonn to the State Department that was sent shortly after the accident) that the German Government Ministry for the Interior (BMI) had given the U.S. Government a copy of a report which the Ministry made of the accident. I asked my Government for a copy of the report, but I was told that it is secret, and the U.S. Government is obligated not to give the report to members of the public. I believe it is important that this report be obtained and made public; for I was told by a physicist in 1984 that the accident resulted in stretching the reactor closure bolts, causing the reactor vessel closure dome to lift and vent reactor coolant into the reactor containment vessel, causing considerable contamination. The question arises: Was the accident more serious than reported in the open literature (see Schmidt's book Reaktor Sicherheit)? Was there a danger of a catastrophic reactor explosion in that incident?

The foregoing present my views about the nuclear hazards associated with the use of Plutonium-enriched fuel (mixed oxide fuel) in the Grundremmingen reactor . I recommend that my expertise be used in the up-coming licensing proceedings on the question of using the mixed oxide fuel Pplutonium-enriched fuel) in the Grundremmingen reactor, and that the above points be fully investigated in the proceedings.

I might add that I participated in the British Government's Hinkley Point Public Inquiry into the question of building more American-type Pressurized Water REactors in Britain. The British Government's nuclear company applied for consent to build a PWR station at the Hinkley Point Nuclear Power Plant in west England. Near the end of the proceeding the British Government suddenly announced cancellation of its plan to build the PWR station at Hinkley Point and three other PWR stations. I believe that the decision was primarily the results of the extensive evidence that I presented to the Inquiry and the facts that I elicited from the officials by cross-examinations. I refer to my various reports and treatises cited above. I also seek support to write and publish a report to the Public of my analysis of the nuclear accident hazards. In this regard I am circulating a paper, titled:

Proposals for an Urgent Book on the Imminent Dangers of Catastrophic Accident at Nuclear Power Plants and for Continuing Research and Major Undertakings to Promote the Public Safety in regard to the Nuclear Hazards.

Also, I should mentioned that I have recently issued another treatise which, I believe, is of major importance for assessing the potential consequences of nuclear accidents:

A Mathematical Analysis of the Cancer Mortality Statistics of the Japanese Atomic Bomb Survivors and Workers at the Hanford Nuclear Installation - An

Evaluation of the Probability of Cancer Death by Exposure to Nuclear Radiation at Low Dose (May 4, 1991)

This treatise includes a supplement sub-titled "Summary and Addenda," dated June 18, 1991. The treatise shows that the probability of cancer death per unit dose of radiation is much greater than official estimates (up to forty times greater), and that this applies to the so-called "low" doses of radiation, contrary to official claims that there is no statistical evidence of a significant cancer effect at low doses of radiation. I refer to the treatise for details.

I have submitted this treatise and Addenda to the Institute for Radiation-Biology in Munich (Dr. A. Kellerer and Dr. Edmund Lengfelder). I have requested an evaluation of this treatise. I seek a publisher for this treatise, and a financial reward for this work.

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