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THE EXPLOSION HAZARD OF THE LIQUID METAL COOLED, FAST BREEDER REACTOR (LMFBR)

AND

THE UNCONSTITUTIONALITY OF THE AEC'S CIVILIAN NUCLEAR POWER PROGRAM

By

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My Rebuttal To The
U.S. Atomic Energy Commission's Comments
On My Original Statement In Opposition
To The LMFBR Demonstration Plant
And
My Original Statement and the AEC's Comments

July, 1973
(Second Edition, Dec. 1974)

Note: This treatise was written especially for the layman's comprehension, so that those who are not "experts" can assess their safety relative to the LMFBR.

This second edition includes the AEC's comments on this treatise and my rebuttal to these comments.

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P R E F A C E

The U.S. Atomic Energy Commission's plans for developing and building 1000 or so liquid-metal-cooled, fast breeder nuclear power reactors (LMFBR) throughout the United States raises frightening questions about the hazard to man which these LMFBRs pose. The eventual size of these LMFBRs according to plans involves about eleven (11) tons of deadly Plutonium radioactivity per LMFBR core, which is the fuel, in addition to the hazardous "fission product" radioactivity--Strontium-90, Cesium-137, Iodine-131, and the like. The Plutonium hazard alone from one large LMFBR is awesome. For example, the Plutonium has the potential for causing 200,000 billion cases of human lung cancer due to the immediate fall-out effects of an hypothesized LMFBR explosion in which the Plutonium is dispersed into the Environment, based on reputable estimates of the Plutonium hazard.* This potential is so great that it would seem to be enough to render the land area of the United States permanently uninhabitable for human-beings because of the threat of lung cancer alone that would be posed if, for illustration, the plutonium were dispersed uniformly by an LMFBR nuclear explosion. The Plutonium contamination would also seem to be permanent because of the 100,000 year life of Plutonium, unless the rains have a special cleansing action that I am not aware of. In the absence of a definitive report from the AEC or other authority on the biological consequences of such Plutonium dispersal, and until such a report is issued, we ought to assume that the Plutonium hazard is as great as is supposed above.

The question of the maximum explosion potential for the LMFBR,

* Based on authoritative estimates. See Gofman, p.1 herein.

then, becomes a matter of extremely grave concern to the health and safety of the People; i.e., whether it is possible for an LMFBR to suffer an explosion which exceeds the explosion containment strength of the reactor plant, since such an explosion could vaporize the fuel into fine, dust-like particles and inject them into the Environment for eventual spreading across the land as it is mixed with ordinary dust and blown by the winds.

Recently, Dr. Pittman of the U.S. Atomic Energy Commission stated on a television program that even the little amounts of Plutonium in the nuclear waste materials must not be allowed "to come in contact with Man's Environment," which supports my premise that the Plutonium in an LMFBR "absolutely must not be allowed to be spewed into the environment by a reactor plant explosion," a premise I adopted in my statement in opposition to the LMFBR Demonstration Plant.

It is the question of the LMFBR explosion potential which this treatise examines. It is concluded that the maximum explosion potential for the LMFBR is unknown, and may never be known; and that explosions greatly exceeding economic containment are theoretically conceivable. The profound implication these conclusions have for the health and safety of the People should command the attention of thoughtful people to this treatise. This treatise was written especially for the layman's comprehension so that the non-expert can assess his or her safety and well-being, as well as the "nuclear scientist."

This treatise also raises a fundamental, constitutional issue--the illegitimacy of the AEC's civilian nuclear power promotion program, especially the LMFBR development program, and

the AEC's authority to decide for the People the acceptability of the associated risks. The fundamental safety issues and this Constitutional issue are deemed by this author to be inseparable, which is why the two different issues are contained in this treatise.

I would like to acknowledge the help of Dr. Thomas Cochran, who has provided me with editorial comments on my draft of this rebuttal, and who brought to my attention some key LMFBR technical documents. I wish to thank Dr. Lynton K. Caldwell of Indiana University who was instrumental in providing me with an office and other aids for my studies; and Mr. Peter Strong, Mr. John Becker, Dr. Elizabeth Seeberg, and others, who helped me financially so that I could pursue this work. Finally, I also would like to thank the People of the United States, who paid for my post-doctoral grant which enabled me to perform studies and prepare this treatise, and to Indiana University for the opportunity to study. Of course, the opinions expressed herein are my own, and should not be assumed to be connected with Indiana University or any member of its faculty.

Richard E. Webb

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NOTE: At various places in this Rebuttal the reader is referred by a superscript reference number for additional discussion contained in "Notes and References" in the back. The supercript number will be followed by the symbol "(*)" in such cases.

INTRODUCTION

The Joint Committee on Atomic Energy of the U.S. Congress (JCAE) recently published its <u>Hearings</u> on the LMFBR Demonstration Plant, which were held in September, 1972.[1] My Statement in opposition to this nuclear project was printed in the <u>Hearings</u>, along with the U.S. Atomic Energy Commission (AEC) Staff Review of my Statement. This supplement is my rebuttal to the AEC's comments. (My original Statement and the AEC's Review, which make up Appendix 5 of the JCAE <u>Hearings</u>, are attached at the end of this rebuttal as Appendix A.)

Briefly, in my Statement I asserted that the maximum explosion potential for the LMFBR has not been scientifically established, contrary to ~~implied~~ AEC claims;[2] and that this means that the AEC has not proved that the deadly Plutonium* and fission product radioactivity could not be spewed into the Environment by a reactor explosion, despite the massive structures designed to withstand explosions. I also asserted that the AEC's civilian nuclear power program, which the LMFBR is a part of, is unconstitutional. I referred the JCAE to my doctoral dissertation[9] for the basis of my assertion on the safety issue, which I supplemented with additional and supporting information, and to the legal memoranda, and attached treatises thereto, submitted to the U.S. District Court in connection with my civil suit <u>Webb</u> v. <u>AEC</u> for the basis of my constitutional claim. For these reasons I urged that the LMFBR Demonstration Plants should not be built. I asserted that more theoretical and experimental research would have

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* For a discussion of the dangers of Plutonium to the nation's Environment, see "Time for a Moratorium," by Dr. John W. Gofman, re-printed in the <u>Congressional Record</u>, March 15, 1973, pp. E.1550-1553.

to be undertakened to establish the maximum explosion potential, if the nation wants to develop the LMFBR; and that if Congress wants to continue with civilian nuclear power, Congress should request authority from the People by a constitutional amendment proposition, so that the People can exercise their right to make the basic value judgments as to the necessity for and safety of this program--a right not heretofore given-up to Congress, nor to any agency of the federal government, since the People had not granted Congress the power to promote manufactures.

Before proceeding, I want to point out that the JCAE omitted the lead-off quotation which I included as a preface to my Statement. (See appendix B.) This quotation is a more pessimistic assertion than my assertion of the LMFBR explosion hazard, since it judges that the maximum explosion allowed by the laws of nature is unacceptable economically. The quote is credible because it was made by a major LMFBR designer. Thus, by its omission the full measure of the concern for the LMFBR explosion potential that I attempted to convey to the JCAE was left out. The omitted quotation and associated reference are again as follows:

> "It is, in our view, unlikely that one will be able to design for the worst accident permitted by the laws of nature and end up with an economically interesting system, even after extensive additional research and development has been carried out."

[Reference:] P.M. Murphy, et al, of the General Electric Co. at the International Conference on Sodium Technology and Large Fast Reactor Design, held at Argonne National Laboratory, November, 1968, ANL-7520, pp.356,357. (This statement was made in support of a recommendation to use probability theory in assessing LMFBR safety.)

In order to better appreciate at the outset the seriousness of my concern for the LMFBR explosion potential, some classic calculations by Hicks and Menzies[3] for assumed accident conditions, which have not been ruled out as impossible, and which included the Doppler safety mechanism (to be explained shortly), show nuclear "excursions" (nuclear runaways) yielding energy-release values of the order of 150 lb. of TNT equivalent explosion, which begins to approach the limit for economic containment. Similar calculations by "Wolfe and Wall"[4] yielded explosions of the order of 500 lb. TNT (equivalent), but with initial "reactivity" conditions that were six times less severe than what was assumed by Hicks and Menzies; i.e., Hicks and Menzies theory predicted much smaller explosions than Wolfe's theory. If Wolfe's values are adjusted for the Hicks and Menzies' reactivity condition, an explosion of about 6700 lb. TNT (equivalent) is estimated. (The upper limit for economical containment has been implied at 1000 lb. TNT.[5] Also, Wolfe claims that Hicks and Menzies's results have been revised, and are now in general agreement with his results, which is discussed on pp. 135-136 herein.) Even higher values cannot be ruled out, because the maximum explosion potential for the LMFBR has not been scientifically established, as I discussed in my Statement and will elaborate on in this Rebuttal; e.g., 20,000 lb. TNT equivalent is conceivable.

REBUTTAL

The AEC letter forwarding its Staff Review concludes that my Statement "offers no justification for reversing the AEC's current plans for designing, constructing and operating the LMFBR Demonstration Plant." However, the AEC's staff review provides no valid basis for this conclusion. Indeed, the staff review does not positively deny my allegations. Rather, the AEC avoided facing the issues I raised by the use of <u>rhetoric</u>, but not without retracting their basic assurance of safety given in the LMFBR

Demonstration Plant <u>Environmental Statement</u>. Only in several instances did the AEC discuss <u>specifics</u> concerning my Statement. However, all of these specifical claims, except one, are unfounded and unsubstantiated, besides being undocumented; and the exceptional claim is based on inconclusive data, and is also not to the point. Because the allegations in my Statement are of obvious critical importance to the health and safety of the People and their Posterity, and the Quality of the Environment, it is necessary to evaluate the AEC's staff review carefully and completely.

I will first describe basically how the LMFBR explosion hazard arises and the main problem to be solved in predicting the explosion potential. This basic theory will hopefully enable the layman to follow this evaluation, including my original statement. Then a summary of this Rebuttal will follow. Afterwards, I will dispose of the AEC's rhetorical comments, and then concentrate on the AEC's <u>specifical comments</u> to show that the LMFBR safety R&D (research and development) program is not well along as the AEC's staff review implies; but that it is still relatively in the beginning stage, and that it certainly has not progressed to where there is justification for a commitment to build the Demonstration Plant(s) from the standpoint of a scientific ground upon which to calculate an acceptable upper bound for the LMFBR explosion potential.

The section of the AEC's staff review under the heading "Constitutionality of the Atomic Energy Act" deals with the constitutional issue I raised. Comment on this section is deferred until after the safety issues are first discussed, since the link between the constitutional issue and the safety issues depends on the illumination of the philosophy underlying the safety issues.

I understand that some people cannot perceive any link between the two issues; but I believe the two are inseparable and ask those skeptics to consider my arguments, given in the later section entitled "Inseparability of the LMFBR Safety Issues and the Constitutional Issue," pp. 154-161.

The Basic Theory of LMFBR Explosion Hazard

Basically, the LMFBR contains bundles of vertical fuel rods packed together to form the "core," which produces most of the heat of the reactor. A coolant in the form of liquid metal (sodium) is pumped through the core to remove the heat and transfer it to the steam-turbine systems for electricity generation. The coolant passage space within the core is the narrow space between adjacent fuel rods. In addition, the core is pierced by non-fuel "control rods," which are used to control the nuclear reaction. Surrounding the core is a "blanket" of fertile nuclear material, again in the form of rods, which is converted to fissionable fuel (Plutonium) by the "neutron" radiation from the core. (This conversion into fissionable fuel is called "breeding.")

The explosion hazard arises because of a phenemenon called "nuclear runaway," which is an extremely rapid rise and fall in the reactor power to extreme peak levels that yields an explosive burst of energy before the "nuclear excursion" is terminated. (This is also called a "power excursion.") The reactor parameter or quantity that determines whether a runaway will be triggered is the "reactivity," and is to be controlled in order to avoid a nuclear runaway. When the reactivity is made zero, the reactor power level will remain constant; and the reactor is said to be "critical," which is the desired condition for normal, steady,

full-power operations. When the reactivity is made positive (increased), but not too high, the reactor power level will rise at a controllable rate, and the reactor is [illegible] said to be "supercritical." When the reactivity is decreased to below zero (made negative), the power level will decay or fall; and the reactor would be said to be "sub-critical."

But if the reactivity should increase above a threshold level, called "prompt critical," then an uncontrollable nuclear runaway will occur, which can end in core destruction, and conceivably a disastrous explosion. During the nuclear runaway the reactor is said to be "super-prompt-critical." Again, if the reactivity is below prompt critical, but still positive (above zero), the power level will rise relatively slow in a controllable rate due to the action of something called "delayed neutrons," which need not be described here. (See Appendix C for a deeper insight.) As we shall see, an unchecked <u>supercritical</u> power transient can lead to fuel overheating and then a rise in the reactivity to trigger a <u>super-prompt-critical</u> power transient, or nuclear runaway. (See footnote on page 9.)

The reactor "control rods" are the mechanical devices used to control the reactor's <u>reactivity</u>. They are regulated, or moved in and out of the core of the reactor (the fuel region), to control the reactivity during normal operation in order to control and maneuver the power level. Control rod withdrawal increases the reactivity, and control rod insertion decreases the reactivity. The control rods also have a crucial emergency function to be described shortly.

The mechanisms by which the reactivity is <u>increased</u> in an LMFBR accident situation are: fuel compaction, and perhaps something called fuel "implosion"; control rod withdrawal; and sodium-coolant expulsion or voiding from the interior of the reactor core. The mechanisms for <u>decreasing</u> the reactivity during an accident are: core expansion; fuel temperature rise (the Doppler effect); and control rod insertion. Increasing, or decreasing, the reactivity is sometimes referred to as "inserting" positive, or negative, reactivity, as the case may be.

The reactivity is measured in "percent" units. About .35% reactivity is sufficient to make the reactor prompt-critical for an LMFBR (and about .7% for a water-cooled reactor). In general, a 2% reduction in the reactor core volume by fuel compaction produces about 1% positive reactivity (+1% reactivity).[6] Conversely, a 2% increase in the core volume by fuel expansion produces about 1% negative reactivity (-1% reactivity insertion). Therefore, slight compaction of the core can render the core super-prompt-critical and trigger a nuclear runaway, inasmuch as .35% reactivity equals

prompt-critical. Due to the coolant space in the core, the potential for core compaction is about 50%, and therefore the potential for reactivity insertion is great; although the reactivity could not increase much beyond +1% without causing a disastrous explosion and reversal of the compaction process.[7] Unchecked control rod withdrawal, and sodium expulsion due to sodium over-heating and boiling, can each add enough reactivity to cause a nuclear runaway, as well as fuel or core compaction.[8]

It is the slight expansion of the core in response to the build-up of energy, and hence pressure, during a nuclear runaway that decreases the reactivity to below prompt-critical so as to terminate the nuclear runaway. (The Doppler temperature effect assists the core expansion effect in inserting negative reactivity.) Since the maximum net reactivity in a runaway will be about 1% for disastrous explosions, only the initial amounts of core expansion (about 1% increase in core volume) is needed to end even the worst nuclear runaway. If the energy generated during the runaway (called the "energy yield" or "energy released") is strong enough, the core expansion process will take the form of an explosion. The expansion of the core due to explosion will ultimately render the reactor permanently subcritical (shutdown), if we can still call a destroyed reactor a "reactor," as the core is "disassembled" by the explosion.

The severity of the nuclear runaway depends in part on the <u>rate</u> at which the reactivity increases above prompt-critical--i.e., the <u>reactivity insertion rate</u>. A higher rate means that more reactivity can be "inserted" before expansive pressures build up than the case of a lower reactivity insertion rate, which in turn means that more expansion is then required for terminating the runaway. But before the core can expand and reduce the reactivity, the fuel materials must first accelerate outward, which takes time and, thereby, delays the termination of the run-

away beyond the point in time when the expansive pressures first appear. This time delay in expansion allows the runaway power level to continue to increase rapidly, and hence, to increase the energy yield before expansion terminates the runaway. Since a higher reactivity insertion rate requires more expansion to stop the runaway, this time delay is lengthened, thereby worsening the energy yield. Any such delay is dangerous, since the energy yield could very quickly (of the order of a few millionths of a second) become extremely severe, producing a disastrous explosion. Therefore, a greater reactivity insertion rate means more core expansion is needed to terminate the runaway, which in turn means increased time delay before termination, which in turn means a higher energy yield and, ultimately, a greater explosion.

There is, however, another phenomenon besides the initial reactivity insertion rate which the severity of an LMFBR nuclear runaway accident depends, and this is called an autocatalytic reactivity effect, which is the main focus of my concerns for the LMFBR explosion hazard, and is defined as an increase in the reactivity during or after an initial nuclear runaway due to some cause which offsets the negative reactivity inserted by core expansion and the Doppler effect. If autocatalysis occurs, the termination of the nuclear runaway will be delayed, or the runaway could even be made worse by increasing the reactivity instead of decreasing it during the runaway; or if the runaway is already terminated, a second runaway could be triggered. An autocatalytic effect, then, worsens the total energy yield in an LMFBR accident and the resultant explosion.[9]

The LMFBR has the potential for nuclear runaway and autocatalytic reactivity effects because the core contains so much concentrated fuel which is not arranged in the most reactive configuration. This is because the fuel is arranged in bundles of

fuel rods (about 0.2 inch in diameter) which are spaced apart for coolant passage. About 50% of the initial core volume is taken-up by these coolant passages. The coolant passages, therefore, provide space for fuel compaction. Should the fuel overheat and then melt down or slump, the core can then become compacted and insert the reactivity to trigger a runaway. Since only 2% volume reduction can raise the reactivity to prompt critical, and 2% more can result in a disastrous explosion, we can see the potential ease for runaway due to core meltdown.**

Strictly speaking, any spontaneous rise in the reactivity while/below prompt-critical is also "autocatalytic," as it produces a worsening power excursion,* and can lead into a nuclear runaway. So, in the strict sense, any core compaction, implosion, or coolant expulsion that occur upon core overheating to increase the reactivity spontaneously are autocatalytic effects.

A core overheating and meltdown situation can be created by an "over-power accident", which I'll call a slow power excursion or rise, short of nuclear runaway, which heats the fuel at a greater rate than what the reactor coolant can remove; or/by a loss-of-cooling accident in which the reactor coolant slows down as it passes normally through the core (due to loss of pumping), or is expelled from the core as it is boiled, or simply drains through a pipe rupture.

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* As the reactivity is increased, while it is still below the threshold for nuclear runaway (prompt critical), the power excursion will become stronger, making it harder to control the reactor.

** Since the potential for core volume reduction is 50%.

The fuel motion under meltdown can be vigorous as molten and hot solid fuel is pushed by the boiling, flashing, and exploding sodium coolant, and other high pressure forces, or as the fuel is acted on by gravity. The fuel motion upon core meltdown, then, determines the reactivity insertion rate at prompt-critical, which could be severe. Recall that sodium coolant expulsion due to boiling is another way which reactivity can be added to trigger a nuclear runaway. Other ways include control rod ejection and dropping a fuel rod bundle into a critical core during a refueling operation. These other ways could produce a severe reactivity insertion rate as well. (Although, it is not clear that a single control rod ejection by itself could trigger a nuclear runaway*; but it could induce a power excursion, and core meltdown, and then a runaway.)

(Incidentally, the LMFBR core will contain about 250 bundles of fuel rods, all bunched together; and each bundle will contain about 200 fuel rods, making about 50,000 fuel rods total in the core. The number of control rods will be about 50, although these are much larger than a single fuel rod.)

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* Apparently, a single-control-rod-ejection accident can directly initiate a nuclear runaway, at least in the German LMFBR Demonstration Plant, SNR-300.[185] See pp. 211-212 herein.

The concern for <u>autocatalytic</u> <u>reactivity</u> <u>effects</u> arises because of the <u>non-uniform</u> nature of core meltdown and expansion. If the core were uniform and expanded uniformly as the result of a nuclear runaway, there would be no question but that the expansion would reduce the reactivity and terminate the runaway without autocatalysis. But because the expansion process will be highly non-uniform (i.e., the fuel motion will be haphazard) and because of the large amount of concentrated fuel in an LMFBR (the core contains enough fuel to make ten to forty separate "critical" reactors if fully compacted)[10(n)], there is the valid concern that the fuel will, on its way toward overall core expansion, collect in a different super-prompt-critical configuration long enough (of the order of 5/1000 second) to amplify the initial nuclear runaway or cause a very severe secondary runaway. These autocatalytic effects due to <u>fuel</u> <u>motion</u> during or right after a nuclear runaway, then, become a matter of grave concern. For an initial runaway could add enough energy to melt the whole core and even vaporize it to explosive pressures. Under these conditions, the motion of fuel can conceivably generate very severe autocatalytic reactivity effects ending in a disastrous explosion. For example, an initial runaway could be terminated by slight expansion of the core in the initial phase of the explosion. But because there is so much fuel that is relatively loosely arranged, the expansion of fuel in one region of the core could conceivably compact another region of the core and make the overall reactor

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The symbol (n) means refer to Note No. 10 in Notes and References in the back for addition discussion.

[redacted] super-prompt-critical again. This "explosive compaction" could make the "reactivity insertion rate" for the second runaway very high, because the reactivity is rising with explosive fuel velocities, which tends to produce an even greater runaway. Furthermore, with explosive compaction, the momentum of the fuel would be toward increasing local compaction, and, therefore, increasing reactivity, delaying the core expansion (shutdown) process until it can overcome the momentum, which would make the runaway all the more worse. The process is extremely complicated to analyze.

A special case of fuel motion is "implosion," where the fuel in the core explodes or expands inward or into an inner, hollow cavity that may have been created in the core upon meltdown. Implosion is neither compaction, nor overall core expansion; but it can be autocatalytic, as it tends to bring fuel together, like compaction, and thereby raise the reactivity. Thus, implosion further complicates the calculation of core behavior in an LMFBR accident to predict whether net autocatalytic reactivity behavior is possible.

The primary purpose of my evaluation of LMFBR safety, given in this rebuttal, is to convey to the layman the extreme complexity involved in calculating <u>fuel motion</u> under LMFBR accident situations or conditions, and to show that disastrous autocatalytic nuclear runaways due to fuel motion may very well be possible, and certainly have not been scientifically investigated, and that the maximum explosion potential has not therefore been established. That is, it may very well be possible for an LMFBR to suffer a disastrous nuclear explosion, releasing a large fraction, if not virtually all, of the core's Plutonium and fission product radioactivity into the Environment, as the science of LMFBRs is not well established in this regard.

So far, I have but touched on the Dopper effect, which has an important mitigating effect on the nuclear runaway. This Doppler effect promptly inserts negative reactivity as the fuel temperature climbs during the runaway, so as to reduce the reactivity and slow down the runaway, giving time for core expansion to occur and render the core subcritical with less energy release. Thus, Doppler is designed to reduce the severity of the runaway. Without it, the explosion potential of the LMFBR would unquestionably be too high. However, the reactivity reduction potential of the Doppler effect is limited to about 1% negative reactivity, which means that autocatalytic reactivity effects [illegible] could override or nullify the Doppler effect.

Another important aspect of LMFBR accidents is the "reactor scram" function, which is the rapid insertion of the reactor control rods to render the core subcritical in an emergency, and thereby avoid prompt-criticality (i.e., nuclear runaway). The SCRAM, then, shuts down the reactor so as to ensure against overheating and melting, and thus core compaction and the resultant nuclear runaway, provided that the coolant is still present to remove the "decay heat" produced by the decaying radioactivity that builds up with reactor operation. Failure to SCRAM upon detection of a core-overheat situation is expected to be the most probable way in which a nuclear runaway can occur, as the power level would remain high to effect meltdown or coolant expulsion--the main reactivity rise mechanisms.

However, once the reactor is super-prompt-critical, the control rod scram function is of no use since the runaway is extremely rapid (lasting only about 1/1000 of a second), and will be over before the control rods could be inserted appreciably. Furthermore, once the core melted-down or exploded, it seems possible that a control rod scram would not be of any help in preventing secondary nuclear runaways, as (1) the core could be so distorted as to not permit control rod insertion, since these rods are fitted into the core with little clearance;[179(h)] (2) the control rods themselves could be damaged or ejected by the explosion;* or (3) the reactivity rise due to meltdown could override the negative reactivity "worth" of the control rod scram. In addition, there is the concern that the core could suffer overheating leading to a runaway before being detected quickly enough for the SCRAM to be initiated in time to control the situation.

Finally, it is useful to compare the LMFBR with the commercial water-cooled nuclear reactor of today--the so-called "light water reactor," or the LWR. The LMFBR is greatly different than the LWR from a core meltdown and nuclear runaway standpoint. A large LMFBR has a much higher "power density" in the core at normal, full-power conditions, by about 10 times (The power density is the power produced in one unit of core volume.); a much greater concentration of fuel; and a much more rapid nuclear runaway given the same reactivity rise, which is a consequence of the greater fuel concentration and the different reactor coolant. LWRs have such a low fuel concentration, on the other hand, that they are not susceptible to nuclear runaway upon fuel meltdown, even if the fuel were

* Control rod ejection could cause a nuclear runaway in itself.

fully compacted, according to Forbes[11] (a point which should be confirmed). The higher power density means that the LMFBR is all the more prone to meltdown should the core suffer coolant interruption, and in that respect is more prone to nuclear runaway. The higher power density means also that the heating due to the intense radioactivity buildup in the core is greater because the radioactivity is more concentrated. This heating, called "decay heat," exists even when the reactor is subcritical, and can by itself under certain conditions cause meltdown and bring about nuclear runaway in the LMFBR. (For example, it is conceivable that the core could be distorted by an explosion such that it would not be amenable to cooling. Because of the decay heat, the core would melt down, even if the fission power level were negligible, and trigger a secondary explosion.) Nor does the LMFBR inherently shutdown (become subcritical) should the core loose its coolant, as is the case for an LWR. Instead, a reduction of coolant in the LMFBR core can by itself raise the reactivity and trigger a nuclear runaway as mentioned before; whereas the LWR requires the presence of the water coolant in the core to make the reactor critical, because of its low fuel concentration.

In other words the LMFBR has so much fissionable material in concentrated form that it is prone to suffer nuclear runaway and explosion accidents if the core configuration or condition is perturbed slightly. Indeed, a mild local perturbation in the core of an LMFBR could generate a strong enough over-power transient so as to melt down the entire core and lead to an even stronger nuclear runaway, the bounds of which have not been

scientifically determined. Again, my concern for <u>autocatalytic reactivity</u> effects is that a core undergoing a nuclear runaway may possibly be capable, during an early phase of the explosion, of either compacting or imploding part of its fuel so as to amplify the initial nuclear runaway or to trigger stronger secondary nuclear runaways that end in a disastrous explosion. Core explosion is given the name "core disassembly," although this term could imply relatively non-violent core disruption or expansion as well. Core disassembly is the reverse of compaction or implosion and eventually stops the nuclear runaway by virtue of the fact that the fuel is blown apart so that it can no longer sustain an atomic fission chain reaction to generate energy. But, if the energy created by the runaway is great enough, the disassembly would occur explosively. It is crucial to predict the <u>fuel motion</u> during the accident to determine whether the fuel will implode or compact in an autocatalytic manner, or whether the fuel disassembles permanently without chance for re-assembly into a critical mass, and runaway, later on.

Complicating a prediction of the motion of fuel, and thus the strength of nuclear explosions (I shall use the term "nuclear explosion" to denote the combination of the nuclear runaway and the explosion which follows.), is the existence of a myraid of different pressure sources, such as sodium coolant boiling, which can itself be explosive, gaseous by-products of the fission process, and fuel vapor, and other effects, all of which are inter-related and dependent on the conditions of the reactor at the onset of trouble. These complications, plus the difficulty in predicting theoretically whether autocatalytic reactivity effects

due to the complicated fuel motion can occur, and then confirming the theoretical predictions experimentally, is the central problem which my Statement, and this Rebuttal of the AEC's comments, address.

If the reader would like a better appreciation for the nuclear runaway phenomenon and the sensitivity of fuel-motion-induced autocatalysis, I refer him or her to Appendix C, which explains the matter in more detail, but still in layman's terms. Also, if the reader has not yet read my original statement and the AEC's review, it is recommended that he or she do so now before proceeding with this Rebuttal. Both are reproduced in Appendix A.

Summary

The AEC staff review is a combination of deceptive rhetoric and unfounded specifical comment, which offers no evidence to refute or detract from my allegation that the maximum explosion potential of the LMFBR has not been scientifically established. That is, an upper bound of the worst possible explosion has not been established to be within the explosion containment capability of an economical LMFBR plant design.

In view of the enormous hazard to the People and their Posterity due to the radioactive Plutonium and fission product radioactivity that will be present in a large LMFBR, the JCAE and the citizenry should play close attention to this Rebuttal, since the basic scientific and technical issues involved must be grasped if the People are to pursue and obtain safety against the dangers of radioactivity contamination of the Environment. For one large LMFBR will contain about eleven (11) tons of Plutonium radioactivity. This source of radioactivity alone has the potential for creating

200,000 billion Plutonium dust-like particles, each capable of producing lung cancer, based on toxicity figures which have not been disputed to my knowledge. (See footnote on page 1.) Furthermore, this Plutonium decays extremely slowly--requiring 24,000 years to decay to one-half of its initial strength, or more than 100,000 years to decay substantially. The unbounded explosion potential for the LMFBR means that there is valid concern whether the Plutonium, and the fission product radioactivity, could be dispersed into the Environment by an explosion in the form of very fine, dust-like particles. If this is possible, the potential for land contamination would be awesome; e.g., if spread uniformly over one million square miles of land area (roughly the land area of the United States east of the Mississippi River), each 100 feet by 100 feet plot of land would be contaiminated with one "millicurie" of Plutonium, or 100,000 Plutonium particles, each particle capable of producing lung cancer in humans. It would seem that there would be virtually no escape from inhaling just one of these Plutonium particles as they are rained on the land. Moreover, the 100,000 year life of the Plutonium would seem to mean that the population in the United States, where the explosion is assumed to occur, would be forever exposed to Plutonium hazard in the ordinary dust in our homes and outside atmosphere.

Responding to my Statement the AEC states rhetorically that the LMFBR Program Plan:

> "covers all questions relating to the LMFBR Safety program and in particular such questions as raised by Dr. Webb, . . ."[12]

This AEC statement is simply not true. The Plan avoids a definite

commitment to full-scale, core meltdown/nuclear runaway tests,* which I contended would be necessary in order to verify the LMFBR "accident analysis codes"--the computer methods and technical assumptions used in predicting the LMFBR explosion potential. The Plan also avoids any commitment or reference to carrying out a complete, theoretical investigation of the maximum LMFBR explosion potential--i.e., the worst possible accident and the worst conceivable accident which cannot be ruled out as impossible. As the AEC comments state, only those accident situations which are "realistic" will be analyzed, injecting subjective judgments into the analysis of LMFBR safety. This means further that only those accidents which have a high enough <u>assumed</u> probability will be analyzed and guarded against for the protection of the public and the Environment. That is, the public's protection against the worst possible explosion accident will not be <u>guaranteed</u>. Further, because the maximum explosion potential is not known, it may or may not be that the more credible (high probability) reactor malfunctions produce the worst possible explosion, because of the peculiar nature of LMFBR phenomena, which remains elusive.

The AEC's rhetorical reference to "extensive in-pile and out-of-pile testing," which are the "experiments" being performed by the AEC, can be deceptive to the layman since these experiments have no relation to full-scale, core-destruct tests, which I claimed are necessary to <u>verify</u> the accident analysis codes, and which the <u>Program Plan</u> even does not rule out.

As to the AEC's <u>specifical</u> comments:

1. The AEC states that the VENUS reactor disassembly code, which is one of the computer analysis methods, or accident analysis codes, used for determining the energy created during

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* Such tests would have to be underground.

a nuclear runaway accident and the resultant explosion force,

> "takes into consideration autocatalytic reactivity effects such as fuel motion."

(Recall that autocatalytic reactivity effects are those effects which would greatly worsen a nuclear explosion, if they should exist to a substantial degree.) The AEC's statement about the VENUS code is unfounded. The reactivity theory used in VENUS (called "perturbation theory") applies theoretically only to very slight fuel movement, and not to large fuel movement.[13] The dissertation by Dr. Jay Boudreau, which I cited as Reference No. 22 in my Statement, verifies that the VENUS code is not capable of predicting autocatalytic reactivity phenomena for large fuel movement, and concluded that "autocatalysis can occur"* and that

> "The potential for added energy release in the second and third excursions warrants further study."

The AEC ignored this reference. My dissertation[9] (p.40) asserts that the "peturbation theory," used in VENUS, has not been justified for use in predicting the autocatalytic reactivity potential of fuel "imploding" into hollow cavities within the reactor core that could be formed upon meltdown. The AEC did not address this contention, either; nor my general contention that:

> "the calculational methods for determining the maximum explosion possible in an LMFBR have not been developed to include all possibilities, and their combinations, for autocatalytic phenomena during and after an initial nuclear runaway."[14]

2. The "in-pile meltdown tests" performed in the TREAT

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* I have reviewed Boudreau's dissertation, and concluded that he did not prove that autocatalysis can occur, but only that the potential exists.

reactor that were cited by the AEC have no relation to the "full-scale reactor meltdown tests" which I claimed would be necessary to verify accident analysis codes. The full-scale tests I referred to involve nuclear runaways that are triggered when the reactor core (fuel) melts and compacts, including autocatalytic effects that may arise as the fuel moves or explodes in response to the runaway. The TREAT "in-pile meltdown tests" on the other hand involve only several LMFBR fuel rods (one to seven) which are placed inside of a non-LMFBR test reactor (TREAT);[15] whereas, an LMFBR contains about 75,000 such fuel rods.[16] In order to produce nuclear runaways, a critical mass of LMFBR fuel is needed, which requires the order of 50,000 rods. So, the TREAT test fuel rods can't be made to undergo nuclear runaways. Further, in order to investigate the potential for autocatalytic reactivity effects during runaways, the full-scale, LMFBR core loading of fuel must be used in such tests.

The TREAT tests mentioned by the AEC measure only the explosion potential of "molten fuel / coolant interaction" (i.e., the sodium vapor explosion which can occur when molten fuel is injected into liquid sodium coolant, similar to a steam explosion in a water-cooled reactor);[15] whereas, the full-scale tests I referred to would determine the force of nuclear explosions due to severe nuclear runaways in which the fuel is heated to vapor and explodes, which would be assisted by the sodium vapor explosion caused by fuel/coolant interaction. Furthermore, these fuel/coolant interaction tests in TREAT are not conclusive, since there are other modes of fuel/coolant interaction which have yet to be tested, and because of serious shortcomings of the tests having to do with the fact that the tests do not duplicate LMFBR conditions and characteristics.

3. As to the EBR-I core meltdown incident, the AEC's comment misrepresents my Statement and asserts an unfounded conclusion from that incident, which very seriously misleads the public. Firstly, I did <u>not</u> use "the EBR-I incident as a strong justification for his [my] argument of the autocatalytic nature of fuel element melting," as the AEC claims. In my Statement I merely mentioned that the EBR-I core meltdown was caused by an "autocatalytic power excursion" (overheating) which is true. (I distinguished between a "power excursion," which is an excessive rise in the power level, which includes power rises below the prompt critical threshold, and a "superprompt critical power excursion," which is a nuclear runaway.) I mentioned the autocatalytic nature of the EBR-I power excursion as an incidental to show that autocatalytic effects are not impossible. My references for this incident, and my dissertation, which I referred the JCAE to for the basis for my Statement, mentions that the autocatalysis was found to have been caused by fuel rod bowing, as the AEC asserts, and so my Statement is not in error as the AEC implies.

My main use of the EBR-I incident, however, was to argue that it demonstrated the need for a fast acting, back-up reactor scram (shutdown) system of a different or <u>diverse</u> design, which is not provided for in the LMFBR Demonstration Plant <u>Environmental Statement</u>. The AEC ignored this point about the EBR-I incident as well.

Secondly, and more importantly, the AEC claims that the <u>fuel</u>

motion during the EBR-I meltdown had:

> "contributed to the shutdown of the reactor instead of leading the reactor into a 'runaway' condition as asserted by Dr. Webb."

This statement too is unfounded.* (Again, I did not assert that fuel melting was leading the reactor into a runaway condition.) The published analyses of this incident, which I referenced in my Statement, concluded that the reactor was shutdown by the reactor's back-up scram/(shutdown) system. Whether the fuel motion assisted this shutdown, or would have averted a nuclear runaway had the shutdown system failed to operate, are questions addressed in the referenced analyses and answered negatively. That is, these questions cannot be answered conclusively from the recorded data of that incident. Indeed, a nuclear runaway would most probably have ensued if the back-up shutdown system had not operated, which even the referenced analyses admitted, since the reactor was rapidly heading toward the runaway condition, and was on the verge of runaway (within one-half second) when the back-up scram system acted. Moreover, it is entirely conceivable that fuel motion due to melting may have assisted fuel rod bowing in bringing the reactor toward the runaway condition during the time right before the back-up scram system acted, which the AEC cannot disprove.

Therefore, the AEC's implication that the EBR-I meltdown incident "demonstrated" that fuel motion upon melting provides a kind of "natural fuse" to avert nuclear runaway is simply unfounded. Even if it were true, the EBR-I reactor was so much

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* And undocumented, I should add.

smaller and different from a reactivity standpoint than a large LMFBR that no conclusion can be drawn from it as to the inherent safety mechanism which fuel motion might possibly provide for the large LMFBR.

4. The AEC refers for its final, specifical comment on the safety issues to "recent analyses" using the SAS and MELT accident analysis codes, and the results from TREAT in-pile* testing, and alleges that these findings or results are evidence that fuel motion during an LMFBR accident will shutdown the reactor before a nuclear runaway (explosion) can occur. As with the other AEC comments, this comment is grossly misleading, since it concerns nothing that establishes the maximum explosion potential of the LMFBR; and furthermore, the specific theories alluded to, which are used to predict pre-runaway core behavior, are questionable (not settled) and have certainly not been verified experimentally under LMFBR accident conditions.

It is difficult to respond to this AEC claim because the AEC referenced no document to explain and justify the claim, as is also the case for the rest of the AEC's staff review of my Statement, except for the vague reference to the LMFBR program plan, which is "presently being updated." Presumably, the AEC is alluding to a recent theory of fuel motion that was proposed to be incorporated into the MELT accident analysis code by the Hanford Engineering Development Laboratory (HEDL), a subsidiary of the Westinghouse Electric Corp. engaged in major LMFBR development work.[17] The MELT theory was applied to one commonly selected accident situation and predicted that the fuel movement during the accident is such as to avoid a nuclear runaway.

* A "pile" is an old term for a reactor (i.e., in-pile=in-reactor).

That is, the MELT fuel motion theory predicts a negative reactivity response to offset the accidental positive reactivity rise that would otherwise trigger a nuclear runaway, and hence a nuclear explosion. However, this fuel motion theory is based on very questionable, and unverified, assumptions. If a different, but plausible, assumption were made, the theory would predict a severe nuclear runaway.[18] *

The MELT fuel motion theory only applies to when the fuel rods retain their basic shape. However, once gross core meltdown occurs, or once a nuclear runaway occurs, which could produce a gross core meltdown, the theory is no longer applicable.

There are no scientifically established, accident analysis methods which can be used to predict the course of an LMFBR accident should GROSS CORE MELTDOWN AND/OR NUCLEAR RUNAWAY (GCM/NR) occur. (Recall that core meltdown can easily lead to a nuclear runaway because only about a 2% reduction in core volume via core compaction is necessary to trigger a runaway and because there is the potential for about 50% core compaction due to the space within the core for coolant passage. A nuclear runaway can also be triggered by means other than gross core meltdown, such as coolant expulsion from the core, which in turn can cause core meltdown and then secondary runaways, and so forth.) Under the condition of GCM/NR the core behavior is extremely complicated to predict because of a myraid of forces, pressures, and constraints; and no theory exists to follow the fuel movement through to its ultimate course to determine whether rapid "re-assembly" of fuel (autocatalysis) can occur to set off a disastrous nuclear explo-

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* The MELT theory predicts fuel rod clad failures at the tops of the fuel rods. But if the rods fail in the axial middle of the core (halfway up the rods), where the performance demands

sion. Even if such a theory were constructed, it could only be verified by full-scale, core-destruct tests, because of the peculiar nature of reactivity, which is the controlling parameter in LMFBR accidents. Such full-scale tests have not been performed, which is a well known fact in the nuclear establishment, and are evidently not planned. Because of these shortcomings, the maximum explosion potential of the LMFBR is not established, and will not be as things are presently planned. Furthermore, one can doubt whether a verification test program is even practical, meaning that the maximum explosion potential may never be known, even if some verification with full-scale tests were attempted. (This latter point will be expanded on later in this summary.)

The "recent analyses" using MELT and associated TREAT in-pile test results referred to by the AEC have no bearing on the problem of predicting the course of GCM/NR. Rather, these MELT analyses are attempts to justify for the selected accident situations at least that the dangerous GCM/NR condition will be avoided should reactor malfunction occur. On this point I have the following reply:

(a) Is the AEC contending that the "recent analyses" prove that GCM/NR is impossible for all possible accident situations? I doubt that the AEC contends this. If GMC/NR can occur in some cases, then it does not matter much whether the MELT code predicts that GCM/NR does not occur for some accidents, since those accidents in which GCM/NR occurs presents the conceptual possibilities for disastrous autocatalytic nuclear explosions. I have seen

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on the fuel would seem to be worst, autocatalytic reactivity effects would result.

no analyses which predict that GCM/NR cannot possibly occur in an LMFBR. I have no reason to believe that GCM/NR is impossible, and good reason to believe that GCM/NC is possible, even probable. The EBR-I gross core meltdown incident, which would have suffered a nuclear runaway had the reactor scram button been pushed one-half second later, underscores this possibility.

(b) The MELT analyses were not applied to a large-scale LMFBR, but to the Fast Flux Test Facility (FFTF), for the analyses that I could obtain. Presumably, the AEC is refering to these MELT analyses for the FFTF. The FFTF is a LMFBR-like reactor, but is substantially smaller and has in some respects greatly different, less worrisome, autocatalytic reactivity characteristics. So, it can be expected that the MELT fuel motion theories when applied to the FFTF would predict an avoidance of the dangerous GCM/NR condition for certain accidents; whereas it would not for a large LMFBR. Specifically, there is good reason to suspect that the MELT or SAS codes, when applied to a large LMFBR, would predict a GCM/NR for the loss-of-coolant flow accident because of an autocatalytic reactivity effect due to sodium coolant overheating and expulsion from the core which causes a nuclear runaway--a phenomenon which does not exist in the smaller FFTF reactor to the degree that it does in a large LMFBR. (If the MELT analyses have been applied to the large LMFBR and predicted an avoidance of GCM/NR, then the AEC should so document their claim.)

(c) The MELT analyses are alleged to be supported by TREAT in-pile tests;* however, these tests have serious shortcomings, including the fact that they do not duplicate an LMFBR environment.

* My written request for a copy of the announced technical justification document (sent to HEDL) has gone unanswered.

These shortcomings are brough out in a "limited distribution" report from Argonne National Laboratory (ANL) which recommended a program of LMFBR safety experiments,[19] which has been kept from the public by the termination of the ANL program that was studying the need for LMFBR safety test facilities. Like the accident analysis codes for handling the GCM/NR, these MELT type codes too will require full-scale, core destruct tests to verify their predictive capability, because, for one thing, the all-important reactivity changes due to fuel motion, which determines shutdown or runaway, can only be produced by full-scale reactor tests. There are other reasons as well.

(d) The MELT analyses are essentially unverified theory, which at best predict how one to seven fuel rods placed in the TREAT test reactor will initially respond to overheating situations, and cannot predict how 50,000 fuel rods in an LMFBR will behave in the aggregate. Indeed, the MELT analysis codes do not follow the fuel motion through its ultimate course, to explore the possibility that the fuel will eventually re-assemble to cause GCM/NR.

(e) The promoters of the MELT code, HEDL, attached reservations to their theories:

> "it is impossible to establish the actual course of the most severe reactor accident which might possibly occur."[20]

> "Since the results reported here represent a current assessment of on-going work, a complete case for a single upper limit energy value [maximum explosion potential] is not made."[21]

Even the AEC's Directorate of Licensing stated that:

"the analyses are not sufficiently complete to provide definitive conclusions regarding the conservatism of the results."[22]

These reservations are by themselves enough to show that the AEC comment about fuel motion as a shutdown mechanism is inconclusive, which further substantiates my Statement.*

The necessity for full-scale, LMFBR nuclear runaway/destruct tests for verification of accident analysis codes does not, of course, imply that such a test program is practical. The practicality is questionable because of the practically unlimited combinations of possible accident situations and initial conditions, which may very well require a large number of full-scale, destructive tests (several at least), each involving up to ten tons or more of Plutonium. The cost of such testing (compounded because of the necessity to place the tests deeply underground), plus the hazard of Plutonium, underground testing notwithstanding, would seem to make such a test program impractical.[23] But without such tests, the accident analysis codes will not be verified.

Water-cooled nuclear reactors have been investigated for their explosion limits by whole-reactor, nuclear runaway destruct tests to some extent at least with the SPERT and BORAX tests, and unexpectedly with the SL-1 runaway accident.[24] Although these tests were not full-scale for today's water-cooled reactors, they at least were performed. Besides, the nuclear runaway and associated reactivity phenomena in the water-cooled reactor do not require <u>full-scale</u> tests to establish the maximum nuclear explosion potential

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* A recent article in Nuclear Safety, an AEC journal, by A.J. Brook reports a possibly strong mitigating effect on LMFBR explosion accidents due to fission product materials that act to shutdown a nuclear runaway before explosive pressures can build up. However,

to the "first order approximation." This is a consequence of the low fuel concentration in a water-cooled reactor core. In contrast the LMFBR, with its high fuel concentration, has yet to be tested under nuclear runaway conditions to investigate explosion limits, despite the fact that the LMFBR has a much greater theoretical explosion hazard potential, at least for/ conceivable accidents.

Overall, the AEC staff review of my Statement includes nothing to refute my Statement. Indeed, the AEC staff seems to admit that the safety issues I raise are unresolved, as they state:

> "the safety issues which were discussed in the [my] dissertation concerning the accident potential of the breeder have long been under study by the AEC <u>and continue to be addressed in the AEC's safety reviews of LMFBRs</u>. *(Emphasis added.)*

As to the constitutional issue, the AEC comment supplies no information whatsoever that even "indicates" a justification for reversing AEC plans, as the AEC claims, since the AEC staff cited only the fact that the District Court ruled in my suit, <u>Webb</u> v. <u>AEC</u>, that I lacked "standing" to challenge the constitutionality of the civilian nuclear power program. The Court, however, gave no opinion as to the constitutionality of the said program, which indicates that the issue is not so "well settled" as the AEC had claimed in the law suit. (In contrast, in <u>Pauling</u> v. <u>McElroy</u>, 278 F. 2d. 252, both the district court and the court of appeals ruled that the nuclear weapons testing program is constitutional, when plaintiff Pauling challenged that point, despite their additional ruling that Pauling lacked standing to make the challenge.) As to <u>standing</u>, I contend the district court erred in view of my right of citizenship to pursue and obtain safety, which is expressed in my State's Constitution (Bill of Rights) and protected by the Ninth Amendment

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Brook ignored autocatalysis and other conditions, and the need for confirmatory, core-destruct tests. (See pp. 148-153 herein.)

of the U.S. Constitution. But
because of my poverty, I cannot appeal the decision. (In this regard this plaintiff appealed to the Sixth Circuit Court of Appeals, but that court denied my motion to proceed in forma pauperis, i.e., to proceed without paying fees and costs and printing up numerous copies of briefs, thus precluding my appeal.)

The link between the constitutional issue* and the safety issues raised herein is that the Congress and the AEC have assumed for themselves, without authority from the People, the power to promote manufactures (civilian nuclear power), and thereby the right to make the crucial decisions involving fundamental value judgments
about the nature and extent of the dangers to the health and safety of the public that are acceptable. These value judgments include: (a) which of the accident possibilities need to be evaluated and guarded against; (b) the acceptability of departing from the "scientific method" in determining the maximum explosion potential of the selected accidents that are analyzed--the use of theories without verification; and (c) the acceptability of proceeding at all with reactors using Plutonium, even if the explosion potential were known, in view of the fact that zero probability of explosion and dispersal into the Environment is not attainable.

As to the availability of AEC-Contractor technical reports, the AEC states that "all published AEC research and development reports" are available. There are two serious inadequacies with this AEC response. The first has to do with the key word in the AEC's assurance of availability--the qualifier "published." There is, however, a category of unpublished reports, called "limited distribution reports," which emanate from the LMFBR Nuclear Safety Program at Argonne National Laboratory which are

* A glimpse of the proof of my constitutional claim is given in pages 161-175 herein.

not available to the public and which are crucial to the assessment of LMFBR safety. All such reports should be made available to the public, for how else can the public assess its safety independently of the AEC's evaluations? Furthermore, ANL documents should be published without first submitting them to the AEC for "review and comment," which occurred in one important instance at least with the publishing of ANL-7657, "Safety Problems of the Liquid-Metal-Cooled, Fast Breeder Reactor." This was the key document referenced in the LMFBR Demonstration Plant Environmental Statement.

Secondly, the AEC asserts a "cost recovery" principle in charging high fees for those reports the AEC does allow to be published ($7.60 per copy in some cases). This cost recovery rule is poorly justified. The public benefit by enabling experts outside of the nuclear establishment to critically examine the adequacy of safety analyses should outweigh the minor expense of printing extra copies of reports, which is a trifling expense compared to the cost of these immense nuclear projects. Besides, my recommendation for a "free upon request " policy applies to the "private citizen" and not to the corporations doing nuclear business. Until recently the Argonne National Laboratory issued ANL reports free upon request. The AEC has order a halt to this ANL policy, and now requires all ANL reports on LMFBR to be distributed by the AEC's Technical Information Center with the distribution approved by the AEC.

As the AEC's response reveals, under the AEC policies one must either pay high prices for "published" technical reports, or travel at

at great expense to one of the library collections of microfilm copies of published reports and read off a microfilm reader, which is a tiresome process. The AEC's rhetorical comments, then, about availability of published reports hide the fact that the AEC keeps crucial reports from public view, censors reports that are published, and charges unjustified fees for those reports that are issued. These policies thwart public inquiry into the state of the LMFBR safety R&D program. Accordingly, I reiterate that the "Joint Committee should force a change in this policy and make all documents free upon request of the private citizen."*

In conclusion, the AEC comments in response to my Statement in opposition to the LMFBR Demonstration Plant are rhetorical, unfounded, unsubstantiated, undocumented, erroneous, and misleading, and provide no basis whatsoever for not yielding to my Statement. The AEC's safety philosophy, when stripped of its rhetoric and exposed for its lack of justified and verified accident analyses, is then essentially a philosophy of "prevention;"*** i.e., prevent the reactor from overheating by careful operation and automatic safety systems--a dangerous philosophy inasmuch as human experience teaches us that man-made systems occasionally malfunction, more so for complex machines, such as LMFBRs.**

There are other considerations which need to be evaluated in deciding whether the LMFBR should be developed, such as long term radioactive waste storage, core-meltdown through the

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* Draft reports can be labeled as such.

** The EBR-I and Fermi LMFBRs experienced serious malfunctions.

*** Insted of guaranteed explosion containment.

plant bottom and into the ground below, theft and general handling of Plutonium; but these topics are beyond the scope of the scope of this Rebuttal. Finally, my Statement and this Rebuttal are regretably discouraging; but represent my truthful and objective evaluation of the subject. My personal philosophy and motivation behind this treatise are presented on pages 185-204 herein.

The AEC's Advisory Committee on Reactor Safeguards (ACRS) has just recently commented to the Chairman of the AEC that the LMFBR accident analysis codes are deficient in respect to predicting ultimate core behavior during an accident and the possibility for events leading "to significantly greater energy releases." The ACRS added:

> "Additional and continuing emphasis should be placed on the search for and investigation of possible autocatalytic effects that might occur in the abnormal states encountered in these studies."

The ACRS concluded:

> "In view of the above comments, the Committee at this time is not persuaded that the search for accident event sequences that might be significant in regard to the health and safety of the public has been completed, . . ."

Thus, the ACRS comment essentially confirms my original Statement and this Rebuttal. (See pp. 209-210 herein for the ACRS comment in full.)

Also, as a postscript, the international conference on "Engineering of Fast Reactors for Safe and Reliable Operation," held in Karlsruhe, Germany in October 9-13, 1972, before the AEC's staff review of my Statement was submitted to the JCAE, is reviewed herein. The conference reveals information and opinions which run contrary to the claims and implications in the staff review, especially in the area of mechanical damage potential of molten fuel-coolant interactions (sodium vapor explosions)

and fuel motion as a shutdown mechanism. The conference proceedings reveal that the AEC staff review mentions only the optimistic R&D findings, while neglecting the pessimistic results or shortcomings that were known prior to its staff review. Specifically, the proceedings emphasize: (a) the possibility for sodium vapor explosions causing sufficient core compaction to produce a disastrous nuclear excursion and explosion; (b) analyses of fuel motion leading to nuclear runaway, instead of a safe shutdown as the AEC reported; (c) a high mechanical damage potential of fuel-coolant interaction, instead of a low potential as the AEC implied; (d) fundamental in-pile test deficiencies; and (e) concern that the worst possible accident sequence is not encompassed by the accident analysis codes.

As a final point of summary, LMFBR nuclear explosions of the order of 20,000 lb. TNT equivalent are theoretically conceivable. In comparison, the maximum explosion containment capability for economical LMFBR designs, is about 1000 lb. TNT. Since a 20,000 lb. TNT equivalent nuclear explosion would involve complete vaporization of the plutonium fuel, and since it greatly exceeds economical containment, such an explosion potential would provide the means for injecting tons of plutonium mist into the Environment, causing unbounded disaster.

Safety Issues: Rhetoric

The first half of the section of the AEC's staff review under the heading "Safety Issues Pertinent to the LMFBR Demonstration Plant," is mostly rhetoric. However, it is important to examine the rhetoric, since it contains deceptive assurances of safety. Firstly, the rhetoric amounts to a fundamental retraction of the previous assurance of LMFBR safety given in the LMFBR Demonstration Plant Environment Statement.[25] This is explained as follows: I alleged that the maximum explosion potential of the LMFBR has not been scientifically established; whereas, the AEC in the said Environmental Statement asserted otherwise--that "it is possible to place bounds on such accidents," and that the plant systems "provide substantial margins against major potential energy releases for all classes of accidents." However, in the staff review the AEC now asserts that:

> "the safety program has as its objective the understanding of phenomena related to hypothetical events and their consequences . . .[which] will provide realistic bounds and estimates of risk . . ." (Emphasis added.)

Observe the addition of the qualifier "realistic," which is a subjective truncation of the set of "all classes of accidents" which the Environmental Statement assured would be protected against. That is, the realistic accidents will presumably be those which the AEC judges as having a high enough probability to warrant analysis and safety measures, but will not include all possible accidents, or all conceivable accidents which cannot be ruled out as physically impossible. Hence, the retraction of their safety

assurance is evident: What is realistic to some people may be unrealistic to the AEC.

Examples of accidents[26] which the AEC would regard as realistic might be: (1) blockage or starvation of coolant to one of the several hundred fuel rod bundles in the core (core subassemblies) followed by a reactor SCRAM; (2) a coolant pipe rupture, which causes a reduction in the core coolant flow and fuel overheating, again followed by a SCRAM. In each case the scramming of the control-rods controls the situation by shutting down the reactor, thereby preventing unacceptable overheating. Accidents which the AEC might regard as unrealistic might be the above two situations, but without SCRAM. The flow blockage to a single fuel bundle assembly upon failure to SCRAM causes the fuel to overheat and coolant boiling, and then meltdown. The meltdown produces some core compaction which increases the reactivity, raising the core power level beyond the designed full power level for the core, and then causing core-wide meltdown. Gross core meltdown could then lead to gross compaction of the fuel and a severe nuclear runaway. The pipe rupture accident without SCRAM causes a rapid loss of coolant flow through the core, then coolant overheating, and then expulsion, which increases the reactivity and which in turn would result in a nuclear runaway. If the runaway was mild, gross core meltdown would occur, followed conceivably by a secondary nuclear runaway, and so on.

The AEC will probably regard the coolant-pump-coastdown accident without scram, which produces a slower loss-of-coolant-flow than the pipe rupture accident, as a realistic enough accident

to warrant analyses. This accident also results in a loss of coolant flow, but at a much lower rate of flow decay than the pipe rupture case, which might mean that the pump-coastdown accident is less severe. (My uncertainty as to which is worse stems from the complexity of predicting fuel motion through to its ultimate end, and the present inadequate state of predictive analyses, which I will address later on.) There is practically an unlimited variety of such accident possibilities, which the AEC might arbitrarily categorize as <u>unrealistic</u> so as to avoid having to analyze them fully, or analyze them at all.

Consider, for example, those above accident situations without SCRAM, but with an extra malfunction or abnormality, such as a fuel rod bundle assembly placed in a wrong position in the core or unintentionaly left out of the core. Such mal-loading conditions would affect the fuel motion within the core during the accident, and, therefore, may possibly contribute to autocatalysis (by implosion, for example). As the state of the science of LMFBR core accident behavior currently exists, one cannot be sure that there are no possible situations that could end up in a disastrous explosion. This will be shown later.

The various accidents described above are in a category of accidents which I will define for later purposes as <u>possible accidents</u> -- accidents or reactor malfunctions which can definitely occur (e.g., an incident in which the coolant pumps stop and the control rods fail to SCRAM). The extremely difficult question that must be answered for possible accidents, then, is: What will be the ultimate course of core behavior during the accident? Will autocatalytic reactivity effects occur during the

accident which result in a disastrous explosion? A sub-category of the category of possible accidents are the credible accidents, which I'll define as those possible accidents which the AEC judges to be "realistic", or having a high enough probability of occurring to warrant analysis and safety measures. But since "credible" is a subjective term, an accident could be incredible in the opinion of the AEC and still be possible.

For the credible accidents, the AEC's LMFBR nuclear safety program has as its goal the development of sophisticated calculational methods aimed at attempting to predict the detailed response of the core from the start of the accident through to its ultimate end, with the hope that the predictions can serve as sufficient technical justification for a conclusion that such accidents exhibit a low, acceptable explosion potential. This procedure stems from a conviction, that has yet to be justified, that the LMFBR has a natural tendency to resist a severe explosion, given the credible accident situation at least; and that the sophisticated calculations will demonstrate this conviction. These calculational methods are necessarily sophisticated because the problem of predicting the detailed response of the core is extremely complex, involving a great many interrelations, lack of pertinent data, and the limits of mathematical and computer capability. (This will be elaborated on later.)

There is a third category of accidents, however, which I will define as those which cannot now be ruled out as impossible, and which can be referred to as conceivable accidents. Conceivable accidents certainly would now come under the AEC's

category of unrealistic accidents, although this accident category was historically used in the Fermi and EBR-II LMFBR hazards analyses. The need for this category of conceivable accidents arises because of the extremely complicated nature of core behavior under accident conditions (core meltdown, coolant expulsion from the core, coolant re-entry, explosion, etc., and the associated reactivity implications). Because of this complexity, there is one school of thought that contends that it is impractical to predict with the necessary precision the course of core behavior for possible accidents, including the credible accidents, since an error could hide a dangerous autocatalytic core condition and the associated explosion potential. Therefore, because of this impracticality, one assumes for safety conservatism various core conditions in which the fuel is acted on by forces in the worst conceivable ways which might be possible, and which certainly do not violate any known laws of nature, so as to calculate a set of maximum rates of fuel compaction or initial reactivity insertion.

Additionally, one assumes a variety of core conditions (configurations, compositions, etc.) that might be possible and which would exhibit autocatalytic reactivity effects if the core were to undergo a nuclear runaway. The severity of the nuclear explosion due to such autocatalytic effects is then determined theoretically by initiating the runaway by a range of mild initial reactivity insertion rates to start the runaway. (Recall that an autocatalytic effect inserts reactivity during a runaway to amplify it and the resultant explosion.) Of course, such calculations must be preceeded by a theoretical search for the worst such autocatalytic condition.

The above two approaches, then, determine the worst set of initial nuclear runaways calculable for this category of conceivable accidents. However, these conceivable accidents would still need to be analyzed for subsequent autocatalytic reactivity effects that may be possible in order to extend the analysis to a logical conclusion. By the foregoing process one calculates a maximum conceivable explosion to ensure that the worst possible accident is "bounded" or protected against.

Again, the reason why such conceivable accidents cannot be placed in the category of possible accidents is that the required core conditions for effecting either the high initial reactivity insertion rates or the autocatalytic effects have not been determined theoretically to be capable of being brought about in response to a possible reactor malfunction or accident sequence--at least not yet.

For example, one could assume that half of the core is thrown upwards upon a mild explosion, and then falls as a single unit back down onto the core. This conceived core "crashdown" event could result in a high rate of reactivity insertion and a very strong, secondary nuclear runaway explosion. However, this sequence cannot now be placed in the category of a possible accident, since it has not been proven that such a sequence can occur in the manner described as a result of a possible reactor malfunction, such as a coolant system rupture; although the possibility of it occurring has not been disproven either, which qualifies it as a conceivable accident. Thus, for a conceivable accident one does not have to prove that there is a possible sequence which leads into the conceived rapid reassembly

of fuel or autocatalytic core condition. Rather, one need only show that such situations do not violate any known laws of nature. For instance, in the above-mentioned crashdown event, the speed of fall, and hence the reactivity insertion rate, is limited by gravity to the height of fall.

For LMFBR safety assessments, therefore, the accident analysis categories of increasing severity are the maximum credible accident, the maximum possible accident, and the maximum conceivable accident, in that order. These three accident categories should be kept in mind, as they will be useful later on. Their distinction will enable the layman to perceive one of the fundamental safety issues that will be developed in this Rebuttal. At present, it is suffice to mention that with the FFTF and LMFBR Demonstration Plant reactors the AEC is setting a precedent by designing the explosion containment for these reactors to cope with the maximum credible accident, and not the the maximum possible accident as was the objective for the EBR-II LMFBR. For the EBR-II hazard analysis the above-mentioned "crashdown" accident* was assumed in an effort to bound or cover the "maximum possible nuclear explosion".[206] No such assumptions are being made for the FFTF and the LMFBR Demonstration Plant reactors, since presumably a nuclear explosion due to

* The crashdown accident assumed in the EBR-II hazards analysis was a conceivable accident, which was chosed to hopefully cover the worst possible accident (explosion); although the assumed accident was probably not the maximum conceivable one that could have been hypothesized without violating any known laws of nature, or rather, knowingly violating the laws of nature.

a core crashdown accident would be too large because, for one thing, the core mass is much larger in these later designs, and the nuclear explosion potential increases with the size of the core for a given reactivity condition.[4] (I estimate crudely that this crashdown accident when applied to the demonstration plant would yield a nuclear explosion equivalent to 2000 lb. TNT, which exceeds the before-mentioned economical containment limit of 1000 lb. TNT.[5]) Rather, the approach now adopted by the AEC's LMFBR nuclear safety program is, as mentioned before, to predict the exact response of the core from the start of possible malfunction.* This approach is given the name "mechanistic analysis," to signify an analysis of how the core might actually behave or respond to a real reactor malfunction, versus an analysis which merely assumes a pessimistic and hypothetical state of the core (configuration, etc.), based only on a plausible argument as to how the core might reach that state. (By "core response" it is meant the fuel and coolant motion, the core temperature changes, etc.) The "mechanistic analysis" will hopefully include all of the mechanisms or factors that, when combined, dictate the response of the core; e.g., whether the core will compact and produce autocatalytic nuclear runaway, or disassemble itself safely in a stable, shutdown configuration. These factors include the coolant flow, coolant explosions, fuel slumping, etc. The gist of this Rebuttal is to show, however, that the mechanistic analysis methods for evaluating the LMFBR explosion potential are not developed sufficiently to warrant a demon-

* But for only the <u>credible</u> <u>accidents</u>.

stration plant commitment; that extensive research and development efforts are necessary if the methods are ever to be made adequate; and that such methods will probably never be practical or adequate, which would then necessitate the conceivable accident approach.

Possibly touching on my concern for analyzing all such accidents, the AEC had only this to say:

> "The LMFBR base and development program will encompass a full consideration of accident situations."

This is little assurance for the public. Is the AEC assuring that full consideration will be given only to selected accident situations, or to all possible accident situations? Will worse conceivable accidents be included in the AEC's consideration? How will this "full consideration" be carried out administratively? Will each and every consideration from whatever quarter in the nuclear community, and the public at large, be fully documented, compiled in a single progress report series, and published, including the complete substantiation for those that are dismissed? Will this full consideration include thorough experimental confirmation of accident analyses using full-scale reactor tests? Until such questions are answered, the public must assume that the AEC's safety program does not include analyses of all possible LMFBR accidents, nor all conceivable accidents that cannot be ruled out as impossible, and that accordingly the maximum explosion potential of the LMFBR will not be theoretically established, nor verified by full-scale tests.

Regarding the AEC's realistic accident possibilities, I have no doubt that the AEC will assure that no public disaster will result should any of them ever occur. However, even the realistic accidents will not be sufficiently understood until the maximum possible LMFBR explosion potential is established. This is because, as my Statement tried to bring out, a disastrous explosion could conceivably grow out of one of the so-called realistic (credible) accidents, since the present calculational methods for predicting the course of even these accidents (fuel motion) are inadequately developed theoretically from an auto-catalytic reactivity prediction standpoint, and will not be verified by full-scale experiments. That is, as the plans now exists, we will never know about the maximum explosion potential of credible or realistic accidents until such explosions occur. Therefore, a credible accident, as well as an incredible, but still possible, accident may both be sufficient to trigger a disastrous explosion, as the state of Man's knowledge about the LMFBR exists. For a specific example, the credible coolant-pump-coastdown accident may turn out to be more severe than a coolant pipe rupture accident, which the AEC might label as incredible. Whereas the latter would probably cause a more severe initial nuclear runaway; the former might exhibit more severe secondary fuel motion subsequent to an initial nuclear runaway to produce autocatalytic effects that the latter may not, for all we know now.

Indeed, the AEC's rhetorical comments do not even assert that there now exists the understanding of the "realistic" accidents, only that the safety program has as its "objective" such an understanding. That alone is enough to call a halt to the Demonstration Plant project. For the AEC maintains that:

> "A main objective of the LMFBR Demonstration Plant is to demonstrate safety--not to 'determine' or 'investigate' it." Z

This separate AEC statement clearly conveys the thought that the accident potential of the LMFBR is well established, and that if anything does go wrong during the operation of the Demonstration Plant, the plant will simply demonstrate that the consequences will be limited to safe levels. However, in their staff review of my Statement the AEC avoids not only assurances of safety against all possible accidents, but does not even contend that they now understand the "realistic" accident potential; rather, they have "under way extensive base technology and development programs for the purpose of providing engineering and safety understanding" (emphasis added), which involves the "conduct of extensive in-pile and out-of-pile testing as well as analytic programs." In short, the AEC admits that "base technology" (research?) and development programs concerning the LMFBR accident potential is still underway, which indicates that the LMFBR Demonstration Plant does not yet have safety to demonstrate, since its laboratories are still determining and investigating the LMFBR accident potential.

The AEC in both their Environmental Statement, and now in the "Staff Review" of my Statement, seems to acknowledge that the LMFBR explosion potential is not being scientifically established, by the AEC's use of the terms "base technology" and "state of the technology." For instance, the staff review states:

> "The Commission's regulatory review will, among other things, be based on the state of the technology at that time, and on the specific features of the design being considered." (Emphasis added.)

As another example, the LMFBR Program Plan uses the term "state of the art."[27] Now there is a material difference between the terms "technology" and "science." The former implies technique, methods, or skills, and denotes "industrial arts"; whereas the latter implies observations and principles systematically made and applied that lead to knowledge about Nature. Thus, developing the technology of calculational methods intended to predict the course of LMFBR accidents falls short of developing knowledge of the maximum LMFBR accident potential. Since the health and safety of the public depends on prior knowledge of the accident potential as it is confirmed by observation in full-scale tests to exist in Nature, and not as it is predicted by unverified calculational techniques, no matter how sophisticated, reliance on mere technology of accident prediction is unwise.*

If this philosophy of relying on "base technology" rather than a scientific base is adequate for predictions of LMFBR behavior, then why is the AEC bothering to build an LMFBR Demonstration Plant? Why not go right on and design using calcula-

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* This might seem like quibbling. But since a fundamental safety issue of the LMFBR is whether to depart from the scientific method and rely on unverified theory for protection of the public health and safety, and since I must assume that the AEC's comments are

tional technology and build the thousand or so larger LMFBRs that the AEC plans to build, and save the enormous expense of one or two demonstration plants? The answer is that the AEC is not that sure of the design calculations, or realizes their limitations. For the Demo Environmental Statement lists one of the objectives of the demonstration plant as "validating technical and economic data and results of the R&D program." (p.129) But since predicting LMFBR core accident behavior is much more complicated and challenging than predicting normal LMFBR operation (i.e., operations without serious malfunction), why aren't full-scale reactor verification experiments planned for accident predictions, when such experiments (the demonstration plants) are planned to confirm predictions of normal operational behavior? The answer either is the high costs, and possibly the hazards, of the explosion experiments themselves, underground siting notwithstanding, or a reluctance to perform such tests for fear that they should prove unquestionably that the LMFBR is unsafe. More probably, it may be impractical to "validate" the calculational technology for accident predictions, which is a point that will be thoroughly discussed later on when examining the AEC's specifical comments.

As a further indication that the LMFBR demonstration plant does not now have "safety" to demonstrate, Argonne National Laboratory (ANL), which conducts the LMFBR Nuclear Safety Program, has issued no firm conclusions about the explosion potential of the LMFBR. (See ANL's latest annual report on this program, ANL-7800, which covers the period July 1969-June 1970, and which was issued in July 1971, and the subsequent monthly progress reports for ANL's Reactor Development Program, and ANL-7657, "Safety

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measured and deliberate, I deem it important to point out the significance of the terms used by the AEC.

Problems of the Liquid-Metal-Cooled Fast Breeder Reactor," by C.N. Kelber, et al. dated February 1970.) The director of the this program at ANL, W.R. Simmons, commented to me recently* that no firm conclusions have been drawn; he said only that the accident potential is being pursued "very energetically."[28] Why, then, is the AEC pressing on with the LMFBR Demonstration Plant(s) when it doesn't even have firm conclusions from its own LMFBR Nuclear Safety Program? The answer must be a "faith in technology"-- a conviction which necessarily introduces a bias in the judgments of those officials who will assess the results of the safety R&D program and decide the safety issues. Consider, for example, the "goals" of the AEC's LMFBR Nuclear Safety Program:

> "(a) To enable the designer to demonstrate that the probability of any major accident is very small and that minor accidents and mishaps cannot escalate into a major occurrence.
>
> "(b) To demonstrate that the containment design and site selection will be adequate to protect the public health and safety."[29]

These goals imply that the AEC has prejudged the safety of the LMFBR, and that their work is directed such as to prove out their pre-conceived ideas. This bias should be abolished by redefining the goals or objectives of the LMFBR Safety Program. I would suggest that the objectives should be:

(a) To determine scientifically the full accident potential of the LMFBR; and

(b) To determine the measures that must be taken to prevent those accidents that would adversely affect the health and safety of the public and the quality of the enironment.

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* In January 1973

LMFBR Program Plan: More Rhetoric

The AEC in their staff review asserted that the LMFBR Program Plan:

> "covers all questions relating to the LMFBR Safety program and in particular such questions as raised by Dr. Webb, which fall in the category of hypothetical accidents and their connsequences."

In the first place my Statement does not merely raise questions, but contains assertions. I did not question whether the accident calculational methods have been developed to include all possibilities, and their combinations, of autocatalytic reactivity phenomena. I asserted that these methods have not been so developed. (By "calculational methods" I mean the "accident analysis codes," which are computer methods used to simulate an accident by numerical calculation.) I asserted also that these methods have not been verified experimentally by any full-scale reactor accident tests, nor any whole reactor tests for that matter; that no such tests are planned; and that many such tests are necessary in order to cover the full range of accident possibilities.

I asserted also that the AEC's Environmental Statement for the demonstration plant does not assure that the LMFBR safety analyses will treat all possible accidents and that the maximum explosion potential is not known. The AEC did not deny these assertions.

Furthermore, the term "hypothetical accident" as used by the AEC is misleading. The hypothetical accidents selected for analysis by the AEC and the rest of the nuclear community are those intended mainly to represent possible accident situations,

such as the coolant pump-coastdown, without SCRAM, accident. (By "possible accidents" I mean those that are capable of happening in Nature.) The term "hypothetical", however, denotes an unproven assumption made for the purpose of analysis. Thus, the term "hypothetical accident" is more applicable to, or is synonymous with, my earlier term "conceivable accident," which I used to define a class of accidents that should be analyzed because they cannot be ruled out as impossible. By labeling the more severe accidents "hypothetical," the AEC, then, misleadingly connotes that such accidents have not been shown to be possible. But in reality the AEC's "hypothetical accidents" ~~are~~ possible. For example, a recent analysis[18] of "hypothetical accidents" included the aforesaid coolant pump-coastdown without SCRAM accident, which is an event that is certainly possible, although one could debate the probability. The foregoing is not quibbling over words, since the only way one can respond to rhetoric is to expose its deceptions.

Suppose we call my assertions "questions," the <u>LMFBR Program Plan</u> (Volume 10--Safety) does <u>not</u> cover them as the AEC claims.[12] Specifically, Task 10-1.1 of the Plan, "Plant Safety Analysis Studies," is "directed toward identification of <u>realistic</u> accidents." (Emphasis added.) There is no express assurance in the Plan that all possible accident situations, and all conceivable (hypothetical) ones which cannot be ruled out as impossible, will be identified and investigated fully. Regarding the calculational methods for LMFBR nuclear runaway accidents, such as the VENUS-type codes, the <u>Program Plan</u> seems to consider them satisfactory by stating:

> "In general, it has been concluded that such methods [as the MARS code, which the VENUS code is an improvement on , except in the treatment of

reactivity] are satisfactory within the limits of knowledge of the equation of state and Doppler coefficients, although there is still uncertainty as to how to treat large zone cores and how to treat the effects of radial or axial constraints."[30]

However, the point of my Statement is that the MARS and VENUS calculational methods have not been developed to include all possibilities for autocatalytic reactivity effects; and, therefore, the methods are <u>not</u> satisfactory. So how can the <u>Program Plan</u> cover my "questions," when it contains a conclusion that practically settles one of my foremost "questions?"

Furthermore, the <u>Program Plan</u> does not provide positively for full-scale LMFBR accident (nuclear runaway) tests, nor any size runaway tests, to verify the calculational methods for analyzing even the "realistic" accidents. Rather, the <u>Plan</u> provides only for <u>consideration</u> of such tests. Specifically, the <u>Plan</u>[31] provides for consideration of three separate experimental facilities:

1. "Transient Reactor Facilities," which test only several fuel rods at a time, with the TREAT reactor included in this category;

2. "Safety Test Facility" (STF), which tests the behavior of a fraction of an LMFBR core under accident or melt-down conditions short of a nuclear runaway explosion; and

3. "Excursion Test Facility" (ETF), which tests whole cores under nuclear runaway and explosion or disassembly conditions, and are called "integral core-destruct tests."

The TREAT reactor is a non-LMFBR reactor (or "atomic pile" to use an old expression) with a "test hole" in which several LMFBR fuel rods are placed for fuel failure testing and observation. The TREAT reactor is made to produce a pulse of power that overheats the LMFBR test rods, while not damaging the test reactor. Such tests provide some knowledge of fuel motion subsequent to fuel rod failure, and other effects. However, in order to experimentally verify the LMFBR accident analysis codes, especially in relation to autocatalytic reactivity phenomena, full-scale core-destruct tests are necessary because of the peculiar nature of reactivity in nuclear reacters, and because of other reasons as well. The TREAT reactor cannot provide this, since it involves only a few LMFBR fuel rods (one to seven rods with plans to expand to 19 or so);[32] whereas a full-scale test to duplicate a typical LMFBR would contain about 75,000 fuel rods.[16]

The Program Plan admits that the TREAT "in-pile" tests are "small-scale" tests.[170] (Strictly speaking, the TREAT tests are not even "small-scale" as this term would connote that the LMFBR is "scaled-down", when the the TREAT tests involve no LMFBR at all--i.e., no smaller size LMFBR.) This limitation of the TREAT in-pile tests (and there are others as well) is important to bring out because the AEC in its staff review cites the TREAT results as the experimental basis for its optimistic analyses of the LMFBR explosion potential.

The Program Plan identifies the STF as providing "large-scale"[171] transient experiments* for verifying the analysis codes for the pre-disassembly phase of an accident (i.e., before the core suffers a nuclear runaway and explodes), such as during core meltdown

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* "Large-scale" is somewhat misleading, since only one or several fuel rod bundles are contemplated by the Plan, vs. 250 in an LMFBR.

prior to runaway; and the ETF as providing "full-scale core destruct tests"[172] for verification of the accident analysis codes through the disassembly phase (nuclear runaway and explosion). Again, the STF would not test a full-scale LMFBR core (and its surroundings, which play a crucial role), but only a partial core size. STF could be of some value, though, for observing the behavior of the core materials (fuel motion) up to the onset of gross core meltdown and nuclear runaway. Like TREAT, however, the STF would not include the all-important reactivity effects of an LMFBR core accident, which could drastically alter the course of the core behavior by inducing surges of energy in the core.* The Program Plan admitted that the experiments in STF "stop short of total core involvement in a major accident." [33]

Incidentally, the Program Plan, issued in 1968, stated:

> "It is presently believed that . . . the Safety Test Facility (STF) will be required; an ETF may be required." [34]

To my knowledge, no definite decision has been made to build either; and the AEC's staff review avoids comment on the matter. Therefore, I fail to see how the Program Plan covers my assertion that full-scale tests are needed.

With this background provided by the Program Plan it would be well to discuss the "in-pile testing in the TREAT reactor" which the AEC staff review mentions later on as experimental evidence discounting my concerns. Inasmuch as my Statement asserted that full-scale reactor experiments for verifying the accident analysis codes are lacking and, furthermore, none are being planned, the AEC's reference to the TREAT tests might be viewed, by the layman at least, as answering the need I alleged for such experimental verification.

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* Furthermore, there does not appear to be a proven experimental method for observing the fuel motion in such STF tests. (See p.124.)

The *LMFBR Program Plan*, however, reveals the limitations of in-pile testing in the TREAT reactor, and shows up the AEC's failure to address my assertion that full-scale, reactor explosion experiments, placed deeply underground, are necessary to verify accident analysis codes.

The *Program Plan* does acknowledge that there is a body of opinion in the nuclear community that asserts that an ETF is necessary in order to verify accident analysis codes:

> "[O]ne philosophy would assert that it is impossible to establish the accident through tests that are to be carried out in the STF. For example, if the meltdown tests in the STF clearly define the configuration of the fuel as a function of time and the rate of reactivity increase, then the ETF can be relatively simple, since it would be essentially a check on the ability to do explosion calculations with known initial fuel distributions and reactivity insertions rates. If, on the other hand, the tests in STF only show that a given situation may or may not lead to a criticality accident [nuclear runaway] and do not clearly define the configuration of fuel, then ETF may have to be an accurate mockup of the reactor system including the primary coolant circuits."[35]

The *Plan* goes on to state, however, that:

> "the STF tests may show that there are no *probable* meltdown conditions that lead to a secondary criticality accident; then, perhaps no ETF would be needed." (Emphasis added.)[35]

This latter statement emphasizes the subjective nature of a decision *not* to plan an ETF, even if STF tests are conducted, by the use of the phrase "probable meltdown condition." For who should

decide whether the STF ~~tests reveal no~~ such probable meltdown patterns? That is, who should decide whether a possible meltdown condition that could lead to a secondary criticality (nuclear runaway) need not be tested in an ETF because it is judged to be improbable? Who should decide that an ETF is unnecessary; or that if such ETF tests are conducted, they need not be an accurate mockup (full-scale) of the large LMFBR core to be built for commercial use, and accordingly that the People must accept awesome risks associated with LMFBR explosion containment designed by <u>unverified</u> explosion calculations? Certainly not the AEC and Congress, as they are promoting the LMFBR without Constitutional authority--i.e., without the sanction of the People. The above statements from the <u>Program Plan</u>, therefore, show up some of the crucial, subjective judgment factors entering the AEC's safety evaluations and research program, and how the <u>Plan</u> rhetorically paints the appearance of thorough research.

Despite the uncertainty in the <u>Program Plan</u> about whether an ETF will ever be built to support LMFBR research and development, the <u>Plan</u> is replete with assurances that the accident analysis codes will be "verified." For example, Figure 10-2-5 on page 10-101 of the <u>Plan</u> (Volume 10) calls for the accident analysis codes to be "Fully Tested and Verified" by 1981. But unless full-scale core destruct tests in an ETF are performed, which mockup the reactor systems that can influence the motion of the fuel and sodium coolant, the analysis codes will never be "fully tested and verified;" and such assurances to the contrary are grossly deceptive. Indeed, the <u>Program Plan</u> asserts that at least STF experiments are needed just to determine

whether an ETF is needed. Yet, there are no definite commitments to even build an STF.[157(n)]

In regards to full-scale experiments for verifying the LMFBR accident analysis codes, the authors of the _LMFBR Program Plan_ seem to be at odds with each other. For example, although the _Plan_ does not recommend definitely that such tests should be carried-out, the _Plan_ seems to assure the reader that they will be performed:

> "In F[iscal] Y[ear] 1979 and FY 1980 [which extends to June 1981] target plant PSARs [Preliminary Safety Analysis Reports] will be in preparation. Enough large-scale experiments should have been completed so that the integrated accident analysis codes could have been tested experimentally _at or near full-scale_." (Emphasis added.)[36]

But without an ETF, such assurances are empty.

The 1981 verfication date mentioned above was based on the assumption that construction of the STF and ETF started in 1971 and 1972, respectively--i.e., a ten year effort. Yet, the LMFBR Demonstration Plant is scheduled to begin operation by as early as 1978.[37] Therefore, even if the STF and ETF are begun now, which is impossible, since the required specifications have not even been developed, it would not be until or after 1983 before the accident analysis codes could be verified, by the AEC's own projections. Thus, the LMFBR Demonstration Plant could be operated for at least five years before (and if) its explosion potential is verified experimentally, or a claim of such could be made.

As asserted in my Statement, which will be elaborated on later, testing the uneconomical Demonstration Plant core size

(about 400 MWe) in an ETF does not verify the explosion potential for the 1000-3000 MWe LMFBRs that are planned. So there is no point in confirming the explosion potential of the Demonstration Plant without confirming that of the larger, "economical" LMFBRs, since there would be no point in pursuing the LMFBR further and no need to take whatever risks there are with the demonstration plants if the explosion potential of the commercial LMFBRs is unacceptable.

Common sense dictates that before the huge expense of building an LMFBR Demonstration Plant is incurred, its safety analyses should be fully verified experimentally beforehand, not afterwards. Therefore, it can be concluded that the scheduling of the LMFBR Demonstration Plant relative to an LMFBR nuclear safety program is completely backwards, and is simply a chance being taken with the public's health and safety, assuming that the safety program even anticipates full-scale core destruct tests. Putting aside the unconstitutionality problem for the moment, the AEC and Congress should justify to the public why such a chance must be taken. Furthermore, the AEC should document its consideration of STF and ETF experiments, and justify the disposition of the question of such experiments.

Regarding the considerations within the nuclear establishment of STF and ETF experiments, Argonne National Laboratory received comments on the need for such experiments in 1971 in the reviews of Volume I of a draft report of the "Fast Reactor Safety Facility Study," which was sent to the nuclear industry, other national laboratories, and the AEC for "review and comment." ANL mentioned these comments in relation to the revision of Volume I:

"Comments stressing the need for core-destruct tests were not accommodated in the revision, but further evaluation of the question will be made in the appropriate phase of the study."[38]

The AEC should release these comments, and any related memoranda that may exist which justify why such comments were not accommodated, because the Safety Facility Study project was since terminated,[39] and, therefore, it must be assumed that the "further evaluation" that was promised will not be forthcoming.*

The Volume I of the draft report was finally issued as an ANL publication under the title "Safety Problems of the Liquid Metal-Cooled Fast Breeder Reactor," by C.N. Kelber, _et al._, ANL-7657--a document mentioned earlier. This document contains a disclaimer-of-responsibility notice which states that neither the AEC, nor ANL, nor its employees who authored the document,

"assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, . . .disclosed, . . ."

This, together with the fact that this document when issued did not include the received comments which stressed the need for core-destruct tests, for balance at least, shows up a fundamental deficiency in the conduct of the civilian nuclear power program--lack of responsibility.

Now we must remember that the AEC cited this document in its _Environmental Statement_ for the LMFBR Demonstration Plant, as reference no. 54, in support of its discussion regarding explosive nuclear excursions. But it now appears that the document is _not complete_ relative at least to authoritative opinions re-

* The AEC stated that ANL has neither "prepared and/or submitted" a "report on an Excursion Test Facility."[158(n)]

garding integral core-destruct tests for verifying accident analysis codes. One can only wonder what is the accuracy, completeness, and usefulness of all documents issued dealing with LMFBR safety which are intended for public review that bear the aforesaid disclaimer.* This immunity from responsibility obviously presents the danger of the nuclear promoters withholding information that tends to retard the growth of civilian nuclear power, justified only on the hope of eventually resolving safety issues satisfactorily.

It should be now clear that the LMFBR Demonstration Plant will not be a <u>demonstration</u> of safety, as is alleged by the AEC in its <u>Environmental Statement</u> for the plant. Rather, it would be an experiment to <u>partially investigate</u> the limits of LMFBR safety, but only if the demonstration plant should suffer a serious malfunction. The LMFBR Program Office of Argonne National Laboratory listed the "purposes" of the Demonstration Plant(s) in its "Summaries of Preliminary Program Plans" for the LMFBR; but that list did <u>not</u> include the phrase "to demonstrate LMFBR safety" as one of the purposes, or any statement to that effect, as the AEC now includes in the list of purposes of the demonstration plant. The Preliminary Plan more accurately described the purposes, one of which was:

> "To validate technical and economic results of the overall R&D Program and of <u>selected</u> parts of the R&D Program; . . ." (Emphasis added.)

As for verifying accident analyses, the same "Summaries of Pre-

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* In the later section "Availability of AEC-Contractor Reports," it will be shown that there are crucial LMFBR Safety R&D reports that are <u>not</u> available to the public.

liminary Program Plans" assigned this role, of course, not to the demonstration plant(s), but to separate test facilities "for maximum-accident studies," stating:

> "These facilities are required to: develop technology, verify models and calculational methods and test safeguards systems and devices."

Therefore, the LMFBR Program Office apparently had no illusion that the purpose of the LMFBR Demonstration Plant could be to demonstrate safety. But when the Program Plan was finally issued as an AEC research and development report, the statement to "demonstrate that LMFBR power plants . . . can be operated safely,"[40] was added to the list, with the original list of purposes relegated to "other purposes." Even this statement of purpose seems to fall short of the exagerated objective in the Environmental Statement, stated flatly, "to demonstrate . . . safety."[41]

The foregoing shows that the AEC's safety philosophy is based on a subjective faith in technology; that by the time the LMFBR is ready for operation, the AEC will have found technical arguments for a conclusion that the reactor will not be "inimical to the health and safety of the public." But the AEC's subjective judgments on this matter, manifested by the AEC's promotion of the LMFBR with federal money, have no legal force, since the civilian nuclear power program is unconstitutional, as I asserted in my Statement and prove in my referenced law suit material. (A glimpse of this proof is supplied later on in this

Rebuttal.) However, because the AEC insists that its authority under the 1954 Atomic Energy Act to promote civilian nuclear power is constitutional, and that the public's health and safety is for the AEC to determine in regard to deciding the kinds and levels of risks imposed on the public that are acceptable, and in view of the shallow, rhetorical response to my Statement given in the AEC's staff review, the AEC evidently feels no necessity to justify its claims of safety to the public. Hence, the People are being forced to accept comforting, rhetorical assurances that the LMFBR is or will be safe, while the crucial safety issues are debated and disposed of out of public view.

This concludes my rebuttal to the AEC's rhetorical comments. Let us now turn to the AEC's specifical comments.

Safety Issues: Specifics

The AEC's staff review, apart from the rhetoric, does include several specifical comments. These specifics are: I. Core disassembly analysis codes; II. Close coupling of potential safety problems to a particular design; III. In-pile meltdown tests; IV. EBR-I meltdown incident; and V. Fuel motion as a shutdown mechanism. Unfortunately, however, the AEC comments on I. and IV. are incorrect and unfounded; and those on III. and V. are based on inconclusive analyses and inadequate and questionable experiments. The AEC's comment on II. supports my Statement. It is extremely important to examine these specifical comments because, though they may appear to report settled areas of safety research, they in fact reveal the crucial inadequacies which I am most concerned when examined in the light of documented facts.

I. As to core disassembly analysis codes. The AEC states in regards to autocatalytic reactivity possibilities in accident calculations:

> "In the area of calculational methods for determing the magnitude of disassembly accidents, Argonne National Laboratory has developed the two-dimensional VENUS reactor disassembly code. This code takes into consideration autocatalytic reactivity effects such as fuel motion. The main conclusion from this work so far is that it takes only a moderate pressure and a very small amount of material movement to cause the disassembly of a nuclear reactor. Thus, during a hypothetical nuclear excursion, the maximum energy and the generated pressures are limited by the early occurrence of disassembly." (Emphasis added.)

This statement stands in direct contradiction to my Statement on the LMFBR Demonstration Plant; namely that:

> "[T]he calculational methods for determining the maximum explosion possible in an LMFBR [which I later identified VENUS as 'the more advanced explosion codes'] have not been developed to include all possibilities, and their combinations, for autocatalytic phenomena during and after an initial nuclear runaway. That is, there are conceivable mechanisms by which 'reactivity' can or might be rapidly 'inserted' due to the motion of fuel material resulting from an initial core explosion or meltdown event." (Emphasis added.)

The AEC's assertion, as it was to answer my conern, is simply not true, since VENUS only considers one or two kinds of auto-

catalytic effects, and cannot be used to assess others which are the more worrisome ones. The AEC evidently did not heed the basis for my Statement--i.e., the dissertation by Dr. J. Boudreau that I cited as Reference No. 22, and my dissertation (p.15), which point out the specific shortcomings of the VENUS code regarding autocatalytic reactivity effects. Briefly, the major shortcomings which the AEC ignored are:

A. VENUS is not capable of predicting whether nuclear excursions will occur as a result of all of the various conceivable kinds of fuel motion that might or will be caused by the initial nuclear excursion or runaway--specifically, explosive compaction and implosion of fuel for large fuel movement. In order to understand the matter, the following brief description of VENUS is necessary: The VENUS code[13] simulates an LMFBR nuclear runaway accident by making a series of successive calculations that represent the stepwise time progression of the fuel motion or core behavior during the accident. That is, the code takes small "time steps," and basically makes two interconnected calculations for each time step. These are: (1) compute the fuel motion (fuel movement) during a time-step given the buildup of explosive energy and pressure which a nuclear excursion causes; and (2) compute the reactivity as it is changed by the fuel movement that occurs in the time-step in order to calculate the course of the nuclear excursion for the next time step, afterwhich computation (1) is repeated. The cycle is repeated until the fuel motion is calculated to reduce the reactivity to below zero (subcritical). The nuclear excursion then ceases to generate substantial energy very quickly, as the power level quickly decays to a feeble level. The final, total energy generated by the runaway is then used to

determine the force of the explosion.

The specific inability of VENUS is as follows: VENUS has been developed to predict fuel motion for small to moderate amounts of fuel movement; but the code has not been developed to predict the reactivity for moderate and large fuel movement. This is because VENUS uses a reactivity theory known as "perturbation theory," which holds for only small movement of fuel materials under certain mathematical assumptions, which are not precisely met in actuality. Moreover, "small" is not numerically defined by the theory, except that it means next to zero fuel movement. VENUS thus takes advantage of the fact that small, expansive movement of fuel (about 1% core volume expansion) can reduce the reactivity enough during a runaway to stop it, and thereby limit the energy yield, at least for the initial runaway. The AEC's comment on VENUS verifies this point:

> "The main conclusion . . . is that it takes only a . . . very small amount of material movement to cause the disassembly of a nuclear reactor."

If only small fuel movement is needed to stop the excursion, there would be no point in extending the VENUS code capability to large amounts of fuel movement. One might then use the final energy buildup as calculated by VENUS to estimate the final explosive force of the accident, assuming no additional nuclear runaways occur later on when the fuel movement is large. The VENUS code makes this assumption and, therefore, ends with a small amount of calculated material movement.

Thus, VENUS does not, and cannot, follow the course of core disassembly or explosion for the subsequent large material movements to predictably determine whether the reactor explosion itself will result in compression or implosion of parts of

the core in an autocatalytic manner which would amplify the explosion. The point here is that such autocatalysis may be possible, and VENUS cannot consider them, contrary to the AEC's claim.

Dr. Boudreau investigated this shortcoming numerically by extending the VENUS calculation to moderately large fuel movement and comparing VENUS's <u>reactivity</u> prediction, despite its perturbation theory limitation, with a separate, more rigorous, reactivity calculation using a code called "TWOTRAN." The VENUS-computed fuel movement data was used as input data for TWOTRAN (i.e., both reactivity predictions used the same fuel movement history of the VENUS nuclear runaway-core disassembly calculation). He found the two reactivity predictions <u>diverging</u>: VENUE predicted a strong shutdown of the nuclear reaction (strongly subcritical), while the other, more rigorous reactivity calculation of TWOTRAN hovered relatively near prompt critical (the threshold for nuclear runaway).[163] However, the more rigorous method could not be used to follow the explosion throughout the remainder of the core disassembly process to determine whether the reactivity would eventually rise above prompt critical to trigger a second nuclear runaway. This is because the VENUS calculation of fuel movement brokedown due to its apparent limited ability to predict fuel movement or motion beyond a moderate amount. This shows up another VENUS limitation. Boudreau concluded:

> "The potential for added energy release in the second and third excursion warrants further study."[42]

(Boudreau added that "autocatalysis <u>can</u> occur." However, upon a review of his dissertation, I have concluded that he hasn't proved that autocatalysis definitely can occur; but that he has shown only that the autocatalysis may be possible.[42(n)])

The VENUS code does include a method for predicting autocatalytic reactivity effects that are associated with implosion of fuel toward the center of the core before overall outward fuel motion stops the nuclear excursion. But, again, only small fuel movement is valid, which is not defined, since VENUS employs the perturbation theory. That is, the VENUS method for predicting implosion autocatalysis has not been theoretically justified with more rigorous theory to my knowledge, even for small fuel movement, and certainly has not been verified by full-scale excursion experiments. Nor does the VENUS code hold for large fuel movement occuring with implosion, again because of the perturbation theory limitation. Also, autocatalytic reactivity phenomena due to implosion are not necessarily limited to those considered in VENUS, as my dissertation asserts and discusses--specifically, the implosion of coolant passages when fuel rods burst to fill up the voided coolant passages with fuel. (This is discussed in B. below.) The AEC ignored these points in its staff review.

Therefore, the AEC comment that the VENUS code considers autocatalytic reactivity effects associated with fuel motion is grossly deceptive to the layman, since it clearly implies that VENUS applies to any size fuel movements, which VENUS does not handle, and since the AEC's comment was to answer my allegation and supporting references that the VENUS-type core disassembly codes are not adequate from an autocatalysis standpoint.

As further support for my assertions regarding VENUS, I turn to one of the foremost analyst of LMFBR core

disassembly accidents, Dr. Richard B. Nicholson, who is the author of the classic work in this area, entitled "Methods for Determining the Energy Release in Hypothetical Reactor Meltdown Accidents,"[7] and who is a co-author of "Safety Problems of the Liquid Metal Cooled Fast Breeder Reactor," the before-mentioned ANL-7657 document which the AEC referenced in its Environmental Statement for the LMFBR Demonstration Plant. Commenting on the conclusion I drew from Dr. J. Boudreau's dissertation, Dr. Nicholson stated:

> "I am fairly well acquainted with Jay Boudreau and his work and have discussed it with him. You say his work indicates that the VENUS code is inadequate from the standpoint of predicting autocatalytic reactivity effects that result from large displacements following an excursion. This statement can be and has been made without the need to refer to Jay's, or anybody's work. It was never intended that VENUS should be applied to that problem, and to my knowledge no one has ever attempted to apply it to that problem."[43]

Therefore, the AEC's comment does not reveal the fundamental inadequacy of VENUS to predict the autocatalytic reactivity effects that I am concerned about. Indeed, the published technical document which presents the VENUS code (ANL-7701) commits the same error of omission committed by the AEC with its flat statement:

> "The reactivity feedbacks due to Doppler Broadening and material motion [fuel motion] are explicitly taken into account." (Emphasis added.)[44]

Moreover, nowhere within this document (ANL-7701) is there a

clear flag to the non-expert of the shortcoming relative to a capability for investigating all conceivable kinds of autocatalytic reactivity feedback effects, such as those due to large material movement.

This VENUS description document (ANL-7701), as with other LMFBR supporting technical documents, contains the disclaimer notice that its authors assume no responsibility for the "accuracy, completeness or usefulness of any information . . . disclosed" in the document. The above-mentioned omission of the whole truth about autocatalysis again shows up the limited value of LMFBR safety documents containing such a disclaimer. Perhaps even the AEC staff, which reviewed my Statement, relied on this VENUS document (ANL-7701) for its exaggerated claim of VENUS's capability to predict autocatalytic reactivity effects.

B. As mentioned in A. above, there is another kind of fuel implosion which is not included in VENUS, and which I investigated for my dissertation; i.e., coolant channel implosion. I concluded that it may be a very serious source of autocatalysis.[213] (It implies a 9000 lb. TNT nuclear explosion versus a 1000 lb. TNT limit.) Specifically, the effects I studied involved the fuel from the individual fuel rods exploding into the coolant passage spaces between the rods, which were assumed to be emptied of coolant, and the reactivity change resulting therefrom. (If the reactivity change is positive and substantial, the effect might very well produce an autocatalytic nuclear runaway.) I calculated for the Fermi LMFBR a strong positive reactivity change, which under plausible assumptions, transformed a mild nuclear excursion into an explosion exceeding the Fermi containment design limit of 1000 lb. TNT by eight times. However, as I cautioned, my method needs further critical evaluation and verification. (I mentioned this finding at the

end of my Statement.)

It has been claimed recently by Dr. R.B. Nicholson[45] that a reactor experiment had been conducted which tends to discount coolant-channel-implosion as a serious autocatalytic phenomena. I am presently investigating this encouraging claim, since Dr. Nicholson does not know whether the experiment was ever formally reported.* However, Dr. Nicholson did state that "you can argue that it [the experiment] is not definite proof that you have grossly overestimated the [reactivity] effect", and that the theory I used "would appear to be reasonable," if there are no mistakes in it, and that it "might prove to be applicable to . . .fast reactors," although he brought up some serious shortcomings and uncertainties of the theory. He concluded that:

> "one should not trust it until it has been checked against either experiment or detailed transport calculation [i.e., more rigorous theory]."[45]

This verification is precisely what my dissertation recommends, and which the AEC ignored in its staff review. It would be proper, therefore, to investigate the matter fully in view of its serious implication. VENUS cannot be said to be adequate until this matter, and the others I mention herein, are resolved.

C. As an example of another shortcoming of VENUS, neither it nor other codes sanctioned by the AEC include or investigate the possibility of a core crashdown event. This situation involves pieces of the core that were thrown upwards by the initial excursion and then subsequently fall back down onto the remaining parts of the core,

* I've written ANL for the information over a month ago on the alleged experiment, but have not as yet received a reply.[64]

triggering a potentially drastic explosion. (Recall that fuel coming together in sufficient amounts in an LMFBR increases the reactivity and can produce a nuclear runaway.) For this crashdown accident, possible autocatalytic reactivity effects would again have to be investigated as well--not only implosion into the gap that separates the pieces of the core that come close together during the crashdown; but explosive compaction of the core materials during and after the second runaway.*

D. Finally, the VENUS code would still require full-scale experimental confirmation even if the above called-for improvements are made and the uncertainties are resolved, as I stressed in my Statement and which the AEC totally ignored in its staff review.

When commenting on the results of using the VENUS code, the AEC staff review states:

> "The <u>main</u> conclusion from this work so far is that . . . the maximum energy . . . are limited by the early occurrence of disassembly." (Emphasis added.)

One can only wonder what are the other conclusions, <u>apart</u> from the <u>main</u> conclusion. In view of this vague and misleading staff review, I hereby urge that the Argonne National Laboratory issue for public examination a complete and detailed status report of all work in the area of core disassembly codes (explosive or otherwise) and associated investigations of autocatalysis, including all initial or preliminary findings or results whatsoever, whether or not the Laboratory or the AEC would rather investigate matters further before divulging such findings or results, and all draft reports, limited distribution

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* Boudreau points out other shortcomings of the VENUS code as well, such as the "extrusion" type of fuel motion disallowed in VENUS.[46]

reports, internal and external memoranda, and all other papers and write-ups on the subject. (Incidentally, the monthly progress reports for Argonne's reactor development program, which includes the LMFBR nuclear safety program, through the January, 1973, issue (the latest available) do not divulge any findings concerning the autocatalytic reactivity potential of LMFBRs; yet work in this area is evidently taking place.)

I have a specific example of a draft report in mind--a lengthy internal ANL memorandum alleged to have been sent to George Fischer, who was a manager of LMFBR accident analysis development at ANL, from Drs. J.F. Jackson and J. Boudreau, dated December 20, 1972. The memorandum, entitled "Draft Report" allegedly discloses a very serious autocatalytic reactivity potential in LMFBRs, not previously known, or at least the possibility for such potential, and recommends research work to pursue the subject. My source for this allegation is one of the co-authors of the memorandum, Dr. J. Boudreau, who upon my prodding, told me of its existence, and who said also that all of the work in the area of autocatalysis at ANL "looks bad."[47] *

I was not able to obtain a copy of this draft report for evaluation; but I do have the documented proof of its existence.[48] However, because the subject has extremely important public safety implications, and in view of the AEC's unfounded and deceptive staff review of my Statement, and because of the unconstitutionality of the AEC's civilian nuclear power program, and my other unfavorable experiences in dealing with the AEC on nuclear safety issues,[149]

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* Dr. Boudreau has subsequently emphasized that the said memo is a "preliminary study," which needs "refined, checked, and reviewed." He further stated that he is "not sure of the results myself, yet."[48]

which force me not to respect the privacy of internal AEC-ANL matters, I believe it is my moral duty to divulge what I have been informed of. If the memorandum (Draft Report) is not at all how I describe it, or if it cannot standup to critical review, then that would be fine. However, I urge that the public, including myself, be allowed to evaluate it along with any critical review of it. My aim is not to embarrass certain persons, or harm their careers, but rather to promote the health and safety of the public by inducing free inquiry and exchange of scientific and technical R&D information among scientists, and, thereby, further an adequate understanding of the LMFBR explosion potential.

II. <u>As to the close coupling of potential safety problems to a particular design.</u> The AEC's staff review states:

> "Because of the close coupling of potential safety problems to a particular design, a specific design (the demonstration plant for example) will be used to bring into sharp focus the LMFBR safety program, including work in the area of disassembly accidents of concern to Dr. Webb."

This AEC comment tends to support my Statement on this point, to wit:

> "the 300-500 MWe LMFBR Demo <u>cannot</u> demonstrate the safety of the larger 1000 MWe LMFBR that the AEC plans . . ."

I substantiated this statement by pointing out that the larger the reactor core is, the greater potential for autocatalysis there is.[49(n)] I added that the LMFBR R&D program contemplates an even larger plant size--3880 MWe. (The unit "MWe" means one million watts of electricity generating capacity.) I should now add further that one need not speculate the eventual use of the

3880 MWe size LMFBR, since the AEC's "Updated Cost-Benefit Analysis of the U.S. Breeder Reactor Program" assumes that the "average size of new nuclear units" would grow steady from 1000 MWe to 3000 MWe by the year 2006.[50]

Incidentally, I agree that a design of a Demonstration Plant must be attempted before one can rationally investigate the explosion potential. However, I would expect that the design work is sufficiently well along to turn now to the full investigation of the explosion potential. If not, then by all means the design should be sufficiently established. But this does not mean that a commitment to build the plant has to be made. It should not be forgotten, however, that the explosion potential of the target 1000-3000 Mwe LMFBRs (3880 MWe?) are our ultimate concern. Therefore, the design of these target LMFBRs must be fully investigated for their explosion potential, before the AEC can argue the merits of building a demonstration plant and before the risks of operating a demonstration plant should be incurred.

III. As to in-pile meltdown tests. The AEC staff review states optimistically that:

> "The in-pile meltdown tests performed to date in the TREAT reactor indicate that the mechanical damage potential is less than that which is thermodynamically possible by two or more orders of magnitude."

This reference to "meltdown tests" could easily be interpreted by the layman as a counter to my contention given in my Statement that "full-scale reactor meltdown tests" involving nuclear runaways are needed to experimentally check the methods for calculating

the magnitude of LMFBR explosion accidents (i.e., the accident analysis codes). That is, the AEC's statement might be taken as assurance that such full-scale tests, or even less than full-scale tests, have been performed, and that the results show that actual explosions are much less than the theoretical calculations. However, this is not the case. Furthermore, the specific phenomenon investigated by the TREAT tests has not been shown to be the major source or mode of the explosion potential; rather, the tests involved only one of the two modes of core explosion. Also, it would be premature to draw conclusions based on these tests relative to the explosion mode tested in TREAT. In this regard the AEC covered itself by use of the word "indicate." In short, the above AEC statement has nothing to do with experimentally investigating the potential for autocatalytic nuclear runaway--my main concern.

Specifically, the TREAT tests involved only several LMFBR fuel rods (one to seven) in a test hole inside a non-LMFBR reactor.[15] These fuel rods by themselves are not enough to sustain a fission chain reaction; i.e., a super-prompt-critical, nuclear runaway.* Whereas, a typical LMFBR design contains over 30,000 such fuel rods in the core.[16] Since the study of autocatalytic reactivity effects in LMFBR accidents requires full-scale reactor meltdown/explosion experiments, the TREAT meltdown tests can provide no experimental confirmation of LMFBR explosion predictions. This is because a sustained fission chain reaction (criticality), and the full potential for autocatalysis, require the same core loading of reactor fuel as would exist in an accident,

* TREAT is made to undergo limited, nuclear runaways which are designed to overheat the LMFBR test fuel specimens, while not producing damage to the TREAT reactor.

which does not exists in a scaled-down test. The TREAT in-pile tests are not even scaled-down tests of an LMFBR, and no one pretends them to be either; although the layman would not know this.

Furthermore, these TREAT tests do not test the "mechanical damage potential" for the mode of explosion which my Statement mainly addresses (as mentioned above)--i.e., very severe nuclear excursions or nuclear explosions due to fuel vapor explosions. The AEC was referring only to the "molten fuel/coolant interaction" experiments in TREAT, which measure the severity of possible sodium vapor explosions when molten fuel contacts liquid sodium coolant. (A sodium vapor explosion is the same phenomenon that could occur in a water-cooled reactor when molten fuel contacts water and causes a "steam explosion.") The sodium vapor explosion can occur when the molten fuel mixes rapidly with liquid metal (sodium) coolant. This mixing can boil the sodium extremely rapidly, generating an explosive sodium vapor pressure wave. The "mechanical damage potential" that is discussed vaguely in the staff review is simply the fraction of the heat or thermal energy of the molten fuel that is converted into mechanical or pressure energy of sodium vapor which then expands to cause the explosive damage to the core and its surroundings. Thus, a low mechanical damage potential for molten fuel/coolant interaction would mean that the heat of the molten fuel is dissipated without thoroughly mixing with the sodium, so that the sodium vapor explosion would be less than that which would occur if the molten fuel were dispersed instantly and thoroughly into the sodium coolant causing the "thermodynamic" maximum explosion.

The aforesaid annual report of the LMFBR Nuclear Safety Program (ANL-7800) reports the first results of these molten

fuel/coolant interaction experiments in TREAT in which the measured mechanical energy was found to be below the estimated thermodynamic maximum by two or more orders of magnitude (i.e., less than 1%).[15] Thus, ANL-7800 confirms that the AEC's comment refers only to sodium vapor explosions. (I reference ANL-7800 for the benefit of the layman, inasmuch as the AEC staff review does not reference a document to elaborate on its claim.)

As before mentioned, the phenomenon of severe autocatalytic nuclear excursions of which I am concerned involves another means or mode for producing mechancial or explosive damage, which is equally as important as sodium vapor explosions, or more so, and which the TREAT experiments do not measure--i.e., high pressure, fuel vapor explosions, as distinguished from sodium vapor explosions. If the nuclear excursion is strong enough, the fuel can turn into high pressure vapor which can cause mechanical blast and shock damage without having to mix or interact with the sodium coolant. (Any such mixing would presumably add to the force of the explosion.) In the said TREAT tests the energy content in the fuel was not high enough, and was not generated fast enough, to cause high fuel vapor pressures. The fuel vapor pressures which may be attainable in a LMFBR nuclear runaway, if the autocatalytic reactivity effects of which I am concerned should prove to be present in LMFBR nuclear runaways, are 100,000 psi, or more,[51] contrasted with the maximum pressure pulse of about 2000 psi observed in the TREAT experiments as reported in ANL-7800. The theoretical mechanical damage potential of such fuel vapor pressure waves would be severe--the order of 1000 lb. of TNT equivalent explosion or more, and therefore may be unacceptable from the standpoint of economical containment

structures. In contrast, the fuel/coolant interaction tests results in TREAT referred to by the AEC staff review implies an equivalent reactor explosion of about 5 lb. of TNT. (If fuel/coolant interactions or sodium vapor explosions can cause mechanical damage close to the thermodynamic limit, then the 5 lb. TNT figure would be raised to 500 lbs. of TNT equivalent explosion, which shows the importance of investigating the mechanical energy conversion or mechanical damage potential for this mode of explosion.)

Although the TREAT tests indicate that under certain conditions the <u>sodium vapor explosion</u> potential is far below the thermodynamic limit, there is no reason at this time not to believe the theoretically high mechanical damage potential of high pressure <u>fuel vapor</u>, should a disastrous autocatalytic nuclear explosion be found to be theoretically possible. In order to verify the theory of the damage potential of fuel vapor in a severe LMFBR nuclear explosion, which is referred to as the "equation-of-state" theory for fuel materials, severe nuclear excursion experiments in the beforementioned Excursion Test Facility (ETF) would be necessary. The TREAT reactor will not do. This "equation-of-state" theory of fuel vapor has not been firmly established, neither theoretically nor experimentally. Therefore, the mechanical damage potential of <u>fuel vapor explosions</u>, given the energy content in the fuel generated by a severe autocatalytic nuclear runaway, has not been fixed;[52(n)] whereas the theormodynamic limit of the mechanical damage potential of the <u>sodium vapor explosion</u> is well established. Refer now to Note 52.

The <u>LMFBR Program Plan</u> discusses the uncertainty of the fuel equation-of-state theory and the difficulty in confirming the theory short of nuclear excursion tests in an ETF:

"Many methods have been considered for the development of experimental equation-of-state data (exploding wires, laser beams, shock waves, Plowshare experiments, etc.), but nothing really suitable has been found. Theoretical studies of the equation of state of fuel materials are known to have deficiencies. One important goal of an ETF would be experiments which could produce useful equation-of-state data." (Emphasis added.)[53]

Moreover, it is not evident at this time that a smaller mechanical damage potential of sodium vapor explosions following molten fuel/coolant interation in an LMFBR accident necessarily means a lower overall LMFBR explosion. One might argue that a first nuclear excursion with mild mechanical effects due to a weak sodium vapor explosion may be more prone to undergo a severe second excursion due to re-compaction of the core and auto-catalytic effects, since the core would more likely be left basically intact for re-criticality (fuel re-assembly) following a mild "core disruption," than the case with an initially stronger sodium-vapor-explosion and the resultant disassembly of the core.

Also, if we ignore fuel vapor explosions for the moment and consider only the sodium vapor explosion, it should be pointed out that the other important safety quantity is the total energy generated by one or more nuclear excursions during an LMFBR accident, not just the ratio of mechanical damage energy to the total energy, which the AEC referred to. That is, the product of the two quantities determines the strength of the explosion, not just the said ratio.. Further, the ratio for sodium vapor explosions depends on the total energy, and may increase with increasing total energy, which is the case for fuel vapor explosions.[173] Concerning this

point, the AEC staff review does not assert that the "two orders of magnitude" factor (i.e., a factor of 100) below the thermodynamic limit for sodium vapor explosions that it mentioned applies to the total energy generated in the worst possible LMFBR accident.

Regarding the TREAT-measured mechanical damage potential of sodium vapor explosions, I should add that it is not conclusive that the TREAT in-pile meltdown tests performed so far demonstrate low values of efficiency in converting thermal energy to (explosive) mechanical damage energy for LMFBR accident conditions. This is partly because of the difference between the TREAT reactor and an LMFBR in something called the reactor "period" of the nuclear runaways during the fuel/coolant interaction TREAT tests and an LMFBR accident, respectively. This reactor "period" is a nuclear term that measures inversely the rate of energy generation in a nuclear runaway--in other words, a shorter period means a more rapid nuclear runaway. The minimum "period" in the TREAT reactor tests was 23 milliseconds (.023 seconds),[54] whereas an LMFBR period under nuclear runaway conditions can be ½ millisecond (.0005 sec), which means that an LMFBR nuclear runaway accident can generate energy in the fuel about 50 times faster than the TREAT reactor. Consequently, the TREAT in-pile meltdown tests are much slower, and therefore could be suspected to yield less violent sodium vapor explosions--i.e., a lower mechanical damage potential.

For example, ANL-7800 reported a TREAT test of 720 cal/gm of total energy deposition in the fuel and an associated low heat to mechanical damage [continue on next page]

conversion efficiency of .025% (compared with the thermodynamic maximum of about 10%). But the first pressure pulse was observed when the energy level in the fuel was 480 cal/gm, indicating that the fuel/coolant interaction began to dissipate the fuel energy before the 720 cal/gram could be generated and present in the fuel at anyone time. Now 720 cal/gram is a much more severe fuel energy level than 480 cal/gram for two reasons: (1) more fuel energy means more energy is availbale for the sodium vaporization process, and the greater sodium vapor explosion; and (2) more energy in the fuel means that the fuel pressure is greater for dispersing the fuel into the sodium, which in turn means conceptually finer fuel dispersal and a more rapid heating of the sodium coolant with a resultant greater sodium vapor explosion. The second reasons is especially important since the difference in fuel vapor pressure between a 720 cal/gram level and a 480 cal/gram level is great (I estimate about five times greater.). Therefore, the 720 cal/gram level could be expected to produce a much worse sodium vapor explosion if that level could be reached before the fuel dissipated its energy into the sodium. It appears that the fuel tested in the TREAT reactor cannot reach that 720 cal/gram level before energy dissipation because of the longer "period" of TREAT; whereas the faster heat generation in a real LMFBR runaway situation (the shorter "period") would seem to be capable of reaching the higher level of 720 cal/gram.

The above uncertainty cannot be confidently resolved, except by LMFBR nuclear runaway experiments, which are not planned. Thus, the rate of energy generation in the TREAT in-pile tests has not been established to be sufficiently high to simulate the effects of the much higher rates of energy generation that could occur in a severe LMFBR

nuclear excursion. In this regard an Argonne National Laboratory "limited distribution" report presumably sent to the AEC, entitled "LMFBR Accident Delineation and Recommended Program of In-Pile Safety Experiments" (May 1971), states that:

> "Very rapid transients are required for the excursion energy release experiments, although the quantity of fuel involved is small. Candidate facilities include PBF, SEFOR, and TREAT although the transient periods potentially available may not be sufficiently short to achieve an effective simulation of severe excursion conditions." (Emphasis added.)[55]

This ANL statement means that ANL has admitted that the TREAT in-pile meltdown (fuel coolant/interaction) tests may not be satisfactory for simulation of mechanical damage energy conversion in severe LMFBR nuclear runaway accidents.* This uncertainty should have been addressed in the AEC's staff review of my Statement, instead of mentioning only the optimistic aspects.

Recently, ANL conducted additional experiments in TREAT (the S11 and S12 tests) which were designed to reach greater fuel energy levels before the fuel interacted with the sodium coolant, as an attempt to minimize the effect of the difference between the long TREAT "period" and the short LMFBR "period".[150] The fuel energy level reached before fuel/coolant interaction was 540 cal/gram, which is higher than the 480 cal/gram level attained in the earlier tests mentioned above. The thermal to mechanical energy conversion (mechanical damage potential) was found to be higher than the earlier test, but still low compared to the thermodynamic maximum, which still supports the AEC's claim and is encouraging. However, no justification has been presented as to whether 540 cal/gram is the highest possible

*Due to this "period" difference alone.

level that the fuel rod can attain in an LMFBR accident before interacting with the sodium. I have estimated an upper bound between 700 and 900 cal/gram, excluding autocatalytic reactivity effects. As discussed earlier in connection with the 720 cal/gram value, energy levels in the range of 700 cal/gram could conceivable produce a drastic sodium vapor explosion. Clearly, the maximum energy level in the fuel/coolant interaction in-pile tests should be justified. It would seem that such a level could not be justified until the worst possible initial nuclear runaway is scientifically established; but the tests needed to determine the worst possible initial nuclear runaway would have to be full-scale LMFBR excursion experiments, which would at the same time provide the fuel/coolant interaction data that is sought by the TREAT tests.

Also, there are serious shortcoming with the S11 and S12 tests as with the other, earlier TREAT tests. These latest tests contained only one fuel rod surrounded by a thin annulus of sodium and then a thick, cold molybdenum wall, which raises the legitimate question whether much of the fuel energy was dissipated in the molybdenum so as to greatly lessen the sodium vapor explosion. In a real LMFBR accident situation, exploding fuel rods would not meet a cold molybdenum wall, but rather other hot, exploding fuel, so that the sodium would have no choice but to absorb the fuel energy. It appears, therefore, that the short period of LMFBR nuclear runaways cannot be conclusively simulated for fuel/coolant interaction tests except by actual LMFBR nuclear excursion experiments, such as in an Excursion Test Facility (ETF) that was previously mentioned.

There are other critical comments I wish to make about the said TREAT tests. The TREAT reactor test device for measuring the mechanical energy generated in the molten fuel/coolant interaction experiments could measure only a part of the mechanical energy--that being the kinetic energy of the slug of sodium that is ejected by the molten fuel-coolant interactions. That is, the TREAT tests were designed to measure the damage potential of a slug of sodium ejected from the core of an LMFBR by a nuclear excursion. The concern is that such a slug could impinge on the reactor lid or cover and propel the concrete and steel structure upwards, threatening the reactor containment structure, and eventually allowing radioactivity into the environement. Thus, the "mechanical damage potential" which the AEC said was measured by the TREAT meltdown tests is only concerned about this kinetic energy of the sodium coolant slug motion. However, molten fuel/coolant interaction in one region of an LMFBR core can cause mechanical damage to the rest of the core, as well as producing sodium slug motion. The potential for this type of mechanical damage (damage to the core of an LMFBR) was <u>not</u> included in the low values of "mechanical damage potential" referred to by the AEC.

The TREAT tests contained several hollow, dummy fuel rods and other materials which could absorb mechanical energy as well as a slug of sodium. A co-author of the TREAT tests, R.W. Wright, stated that no estimates were made of the magnitudes of this type of mechanical energy absorption (damage) that occurred in these tests.[56] The pressure-time data were recorded, but the full significance of the data obtained so far in terms of core damage in an actual LMFBR accident, and what it could lead to by way

of coolant blockage, core meltdown propagation, and then a core compaction induced nuclear excursion, or a directly produced core-compaction induced nuclear excursion, both with possible autocatalytic reactivity effects, has not been revealed or calculated, and certainly has not been confirmed by full-scale reactor tests.

Furthermore, the TREAT tests performed to date involve only one type of geometry or mode in which the molten fuel could interact with the sodium coolant--i.e., a bundle of several (one to seven) fuel rods immersed in liquid sodium. However, there are other possible modes of sodium/ fuel interaction, such as a volume of liquid sodium dropping onto a pool of molten fuel, as could occur with sodium coolant re-entering the core following its expulsion by core overheating, or such as a glob of molten fuel falling into a pool of liquid sodium. These modes have been observed to produce violent vapor explosions.[200] ANL stated that such modes "might be more energetic."[57] Such tests were planned for TREAT ("Sodium Impacting on Molten UO_2");[57] but Wright (ANL) stated that the tests have not been performed as yet.[58]

In the above mentioned "limited distribution" report[19] ANL discussed the fact that the few fuel rods involved in the TREAT fuel/coolant interaction tests do not truly mock-up an LMFBR environment, and proposed 19 to 37 fuel rods per test in order to make the tests more representative of LMFBR conditions.* (This ANL report will be discussed at length later under the topic of "fuel motion.") Supporting this opinion, Simpson, et al., stated:

* There are other shortcomings as well, which are discussed later.

> "[I]t is not possible to rule out a substantial difference in energy conversion efficiency [mechanical damage potential of fuel/coolant interaction] because the TREAT tests to date are not prototypic of FTR [i.e., LMFBR] hypothetical accident conditions in several respects, . . ."[59]

Even the AEC's regulatory division stated:

> "The Regulatory staff and its consultants believe that it is premature to use, as a basis for evaluation, the low experimental values [of mechanical energy conversion] indicated for the following reasons. First, the test results are not well understood and little analysis of them has been published. Second, the experiments do not mock up the real reactor accident environment--hence, analysis is particularly important in order to use the results. Only one or a few fuel pins were used in the tests. The TREAT period is slow relative to the transient period in the FFTF HCDA [Fast Flux Test Facility Hypothetical Core Disruptive Accident--another term for the core disassembly accident]."[60] (The FFTF is essentially an LMFBR for accident analysis purposes, only much smaller than a target LMFBR.)*

Moreover, while the TREAT tests provide some knowledge of fuel/coolant interaction, they are no substitute for full-scale tests for verifying accident analysis codes. Indeed, Kelber, et al., stated in regards to the in-pile tests:

> "When TREAT is used in this way, no attempt is being made to simulate a reactor accident."[61]

*FTF and FFTF are synonymous terms.

The fact is that a coolant vapor explosion which approached the "thermodynamic limit" of the mechanical damage potential has already been observed. According to Rees[191] one such explosion attained a heat-to-mechanical damage energy conversion efficiency of 86% versus the less-than-1% observed in the deficient TREAT test data. It is also evident that there is an element of chance in producing high efficiency coolant vapor explosions, since the knowledge of the required conditions for their occurrence seems to be elusive.[207] This means that a high efficiency coolant vapor explosion may be, and probably is, possible in an LMFBR accident; i.e., the fact that some TREAT data tend to indicate otherwise does not prove that they are not impossible.

The implication of such high efficiency vapor explosions resulting from molten fuel-coolant interaction in an LMFBR accident are very serious, since the concern for a breach of the reactor containment is heightened. Furthermore, a strong coolant vapor explosion could crush or compact a region of the core, which might thereby cause a very severe secondary nuclear runaway and a disastrous explosion. Certainly, such an event is plausible and has not been ruled out as impossible.*

In conclusion, the AEC can state that the

> "in-pile meltdown tests performed to date in the TREAT reactor indicate that the mechanical damage potential is less than that which is thermodynamically possible . . .",

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* This is discussed further in a postscript to this rebuttal, pp. 213-221.

which by itself is encouraging;* but what it all means in terms of the maximum explosion potential of the LMFBR is not known. To the layman the AEC's assertion regarding the TREAT in-pile meltdown tests might connote an all-is-progressing-well notion, when in fact the R&D work alluded to establishes nothing in terms of a bound on the LMFBR explosion potential.

IV. As to the EBR-I meltdown incident. The AEC staff review asserts:

> "Dr. Webb uses the EBR-I incident as a strong justification for his argument of the autocatalytic nature of fuel element melting."

This is not true. In my Statement I used the EBR-I meltdown incident to argue against lack of plans for a back-up, fast-acting reactor shutdown (SCRAM) system of diverse design in the LMFBR Demonstration Plant. I mentioned as an incidental that the EBR-I core meltdown was "caused by an autocatalytic power excursion." I did not say that the autocatalytic reactivity effect was due to fuel element melting. As this confusion draws a question as to my credibility, it would be proper to review the matter. It will be shown afterwards that the AEC compounded its error by drawing an admittedly tempting, but still unfounded conclusion from the EBR-I incident, which is/seriously misleading.

The AEC states that the incident was caused by "fuel element bowing." I knew full well that the autocatalysis in the EBR-I power excursion was attributed to fuel element bowing. My purpose of mentioning the autocatalytic nature of the EBR-I power excursion was to call the Joint Committee's attention to the fact that

* Actually, the AEC overstated the matter, since the tests so far indicate a low damage potential only for the conditions tested.

autocatalytic reactivity effects per se in LMFBRs are not impossible, since one had already occurred in an LMFBR (i.e., the EBR-I incident). (McCarthy, et al., characterized the EBR-I behavior that led to gross core meltdown as "autocatalytic";[62] so I was not using the term "autocatalytic" out of common context.) In my Statement I referenced Thompson's account of the EBR-I incident (Reference No. 16), which explains the cause as due to fuel rod bowing. Moreover, my dissertation, which I cited for the basis of my statement and which I suggested that the Joint Committee could borrow from the AEC, expressly mentioned this fuel rod bowing, and only fuel rod bowing, as having been determined to be at least partly the cause of the autocatalytic power excursion that led to the meltdown of the core. (See p. 23 of dissertation.) My dissertation does not assert that there were any other causes, such as fuel melting. Rather, it reports the only cause that was definitely determined--fuel rod bowing. If the AEC staff had read my dissertation and checked my reference in my Statement, they would have known that I was not implying that fuel-melting caused the power excursion and the meltdown.

More importantly, the AEC concluded without basis that the EBR-I incident is a demonstration of LMFBR safety even when core melting occurs. After briefly describing the "postmortem examination of EBR-I" and the displacement by melting of core material to "near the edge of the core," the AEC concluded:

> "Therefore, the EBR-I meltdown incident demonstrated that this phenomenon [fuel redistribution by melting] contributed to the shutdown of the reactor instead of leading the reactor into a 'runaway' condition as asserted by Dr. Webb."

This AEC statement is unfounded. Firstly, I made no such assertion. I asserted only that the activation of the back-up scram system (the dropping away of the core blanket from around the core, called the "cup") averted a "superprompt critical power excursion" (nuclear runaway).* I cited Brittan's "Analysis of the EBR-I Core Meltdown" and Thompson's review of the incident as my sources. (See my Reference No. 16) Brittan's paper shows that the reactivity was calculated to have been near prompt critical when the "cup started down" and was still increasing at a rate of about .3% reactivity per second at that point in time. Since the data indicate that the reactivity of the reactor was about .6% supercritical at that instant and since .7% reactivity was the threshold for super-prompt-critical (nuclear runaway) for EBR-I, a nuclear runaway would have occurred about one-half second later, if the blanket cup had not been scrammed when it was.** Brittan assumed that the reactor would have gone prompt critical (i.e., undergone a nuclear runaway) if the blanket cup had not scrammed. Thus, the shutdown was effected by scramming the blanket cup; i.e., dropping the blanket.

Secondly, there is no conclusive evidence that the core melting "contributed to the shutdown," as the AEC claims.*** Brittan

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* In my Statement I distinguished between a "power excursion" and a "superprompt critical power excursion"--the former being any strong rise in the power level, including nuclear runaway; and the latter being a nuclear runaway.

** Incidentally, if the EBR-I had been fueled with Plutonium instead of Uranium, then the incident would have triggered a nuclear runaway for certain. This is because the threshold reactivity for a Plutonium fueled core would have been about .3%, well below the peak value of reativity attain before the reactor was scrammed, which was .6%.

*** AEC also characterized the EBR-I overpower transient as a "short period transient," which to the layman might mean that it was short lasting, and thus not serious. But the opposite is true--a shorter period means a more serious transient, because of how the term "period" is defined in reactor theory.

considered such a possibility, and rejected it:

> "The most significant question requiring answers, however, is one posed regarding the shutdown mechanism: was the reactor shutdown by dropping the outer blanket or was it shut down because of change in reactivity due to expansion of the core materials as discovered after the core was removed for examination? This is rather an important point since, if the latter were the case, it would appear that the reactor had a sort of a natural fuse which would prevent a really bad accident from happening. An auxiliary question which arose, because <u>it finally develops that dropping the [outer blanket] cup had really shut the reactor down</u>, is: supposing the cup had not been dropped, would the core expansion then have shut it off and if so, how much worse would the accident have been?" (Emphasis added.)[63]

Brittan calculated that the meltdown incident would have been much worse than it actually was if the shutdown mechanism had been due to core melting and subsequent fuel motion. Brittan, therefore, concluded:

> "If the above shutdown mechanism [molten fuel motion] did not operate, it must be assumed that the shutdown was effected by dropping the cup."[64]

Brittan's conclusion is consistent with his scram time data.[63] (See Reference 16 of my Statement.) The late Theos Thompson, the former MIT nuclear engineering professor and AEC Commissioner, reaffirmed Brittan's conclusion:

> "This same study also investigated the possibility that the expansion of core materials observed in post-irradiation examinations of the core might have caused sufficient loss of reactivity to have caused the shutdown prior to the time that the outer blanket cup was dropped. It was concluded that the core damage was less than that

> to be expected if shutdown was by the mechanism of core expansion. Thus, the shutdown was almost certainly due to the dropping of the outer blanket cup. <u>The experiment therefore did not give any information either way as to whether core expansion of the type observed was by itself a sufficient mechanism to shut off a fast reactor during a transient of this type</u>."[65] *

So did McCarthy, <u>et al.</u>, confirm Brittan's account:

> "The best evidence suggests that the incident was shut down by motion of the controls [the blanket cup] and that the distortion and rearrangment of core material occurred following the peak power achieved."[66]

One reason why it wan't readily obvious that the blanket cup SCRAM had caused the shutdown (just in time to avert a nuclear runaway) is that the plotting instrument for the power level went off-scale during the power excursion, and the peak power level had to be extrapolated (estimated) from the plot made before and after the lost peak. During the time the power trace reappeared, the power level was rapidly decaying, indicating reactor shutdown. By this time fuel melting could have occurred. Soon afterwards, the reactor coolant pumps were started in an effort to cool the fuel, since the pumps were turned off prior to the incident. It was immediately observed that there was high resistance to coolant flow through the core, which "indicated extensive core damage."[67] This coolant flow may have assisted the fuel redistribution. Only after the core was removed and examined was the extent of the fuel redistribution (core disassembly) learned. The <u>final</u> state of the core as it was examined was <u>calculated</u> to have been strongly disassembled or subcritical (shutdown), even if the blanket

* Emphasis added.

cup would have been reinstalled next to the core. (Although, the cup was never reinstalled to verify this conclusion.*) This fact, however, does not support the AEC's conclusion that the EBR-I incident demonstrated that the fuel melting phenomenon contributed to the shutdown of that reactor during the incident. All that is known for certain is that the final configuration of the core as examined was calculated to be subcritical. What isn't known for certain is what happened in the period between the time when the power trace began to go off-scale and when the core was examined. The best estimate by those who analyzed the incident is that the blanket cup SCRAM stopped the power excursion, thereby averting a nuclear runaway; and that fuel melting alone would not have averted a nuclear runaway.

If the blanket cup had not been scrammed when it was, the course of the incident would have been much worse, according to Brittan, and might even have been drastically different. For example, a nuclear runaway would probably have occurred, or a so-called meltdown/crashdown event might have followed. This meltdown/crashdown event has been described as a situation where the middle of the core melts, then runs down and freezes in the lower region of the core, followed by the crashing down of the remaining upper piece of the core. By the free fall of the upper piece, it gains speed as the two pieces come together. The result would be a nuclear runaway, only with a high rate of reactivity insertion and the potential for a severe nuclear explosion. McCarthy, *et al.*, said that a meltdown/crashdown event "represents a far more dangerous possibility" for a nuclear runaway.[70] The final appearance of the EBR-I core and blanket

* Reinstalling the blanket would normally tend to make the reactor critical again.

somewhat resembled a condition prior to the crashdown phase.[71] Since the blanket cup scram had shutdown the reactor, however, the core evidently cooled long enough to freeze in place, avoiding such a crashdown event. (Could the turning-on of the coolant pumps after the power excursion have significantly influenced the fuel motion?) Whether the fuel melting was about to make the power excursion worse, or to help stop it, before the blanket cup SCRAM had its shutdown effect, is a question that will never by known, unless we repeat the experiment without scramming the blanket cup; but then it would be difficult or impossible to duplicate the exact sequence of events.

Therefore, the AEC's assertion that fuel melting phenomenon in the EBR-I core meltdown incident contributed to the shutdown of the reactor is, in the light of the published analyses of that incident, unfounded. If the AEC can substantiate their statement with new detailed, documented information beyond that given by Brittan and Thompson,[63,65] then the AEC should come forth with it. Moreover, the AEC should have pointed out that the EBR-I reactor was very, very small compared to the LMFBR Demonstration Plant and the larger 1000 MWe - 3880 MWe target plants.* Larger reactors have greatly different reactivity, thermal, and mechanical characteristics than the small EBR-I reactor, which makes it impossible to infer from the EBR-I meltdown behavior that the larger LMFBRs have a "natural fuse" due to fuel motion which prevents disastrous explosions, even if the EBR-I core meltdown behavior were well established.

* The following table shows the comparison:

Reactor	Reactor Heat Output	Core Volume
EBR-I	1.4 MWt	7 liters
1000 MWe LMFBR	2,500 "	3,450 "
3880 MWe LMFBR	10,000 "	16,700 "

MWt denotes the heat generation of the reactor; and MWe denotes the electrical power output from the plant.

V. As to fuel motion being a shutdown mechanism in large LMFBRs. In their final comment on the safety issues, the AEC staff asserts that it is now evident that the same shutdown effect of fuel motion that they alleged, without foundation, to have occurred during the EBR-I core meltdown incident will also occur in meltdown accidents in large LMFBRs. The AEC staff stated:

> "In fact, the importance of fuel motion as a shutdown mechanism is also evident from recent analyses (ANL's SAS and HEDL's MELT Accident Analysis Codes) and the results from the in-pile testing in the TREAT reactor."

Did the AEC want to imply that the "recent analyses" with the SAS and MELT codes, and the results from the TREAT in-pile tests, conclusively establish that the fuel motion under all possible accident conditions and core behavior will lead to reactor shutdown instead of an explosive nuclear runaway? I am almost sure the AEC did not want to imply such. However, it is not clear just what the AEC staff wanted to convey by their comment; nor did they provide any substantiation or reference any documentation. The before-mentioned LMFBR Nuclear Safety Program report, ANL-7800, which was issued in July 1971, contains no overall conclusions about fuel motion being a safety shutdown mechanism that averts nuclear runaway in LMFBR accidents. Nor do the subsequent monthly progress reports contain any such conclusion. (Incidentally, since ANL-7800 is the last annual report, which was for the period July 1969-June 1970, why are the annual reports for the subsequent periods July 1970-June 1971 and July 1971-June 1972 delayed so long? These reports are needed to fully scrutinize this vague AEC claim about the shutdown effectiveness of fuel motion.)

Strictly interpreted, however, the AEC's comment does not refute my Statement, since no definite conclusions are drawn to discount my basis for urging against the Demonstration Plants.

What the AEC is specifically alluding to are recently proposed fuel motion models for the HEDL's* MELT accident analysis code, which is used for predicting the course of fuel motion during the initial stages of an assumed accident when the fuel rods still retain their shape, as distinguished from gross core meltdown** conditions. (A "model" is a theoretical representation or description of some real, physical phenomenon or system which is used to predict the response of the real system to conditions imposed on it. The model is always simplified in order to make calculations practical.) These recent MELT calculations predict for some accident situations that some of the fuel is propelled or expanded outward from the center of the core due to the initial overheating and melting so as to reduce the reactivity and make the reactor subcritical, which causes the power level to fall to nill, thereby allowing the core to cool and freeze in place and avoid gross core meltdown and a nuclear runaway that earlier models had predicted for the same accident situations. Also, the AEC staff implies that these recent analyses are supported by conclusive experimental results.

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* HEDL denotes the Hanford Engineering Development Laboratory, a prime contractor for the Fast Flux Test Facility (FFTF).

** My use of the term "gross core meltdown" refers to the core condition in which the fuel meltdown is so extensive that it is no longer valid to model the fuel motion in the core as a composite of separate fuel motions associated with the individual fuel rods, since the fuel rods no longer retain their shape; but rather, the core behaves as an entity in itself, which is much more complicated to predict, as will be explained later on.

If no nuclear runaway can occur in any possible LMFBR accident, then no violent core disassembly or nuclear explosion can occur either, except perhaps a sodium vapor explosion when molten fuel interacts with sodium coolant. With no possibility for nuclear runaway there would be no need to investigate the possibility for autocatalytic reactivity effects during and following nuclear runaways, and the associated concern for disastrous nuclear explosions. There would be no need for the VENUS disassembly code for that matter. However, I will show that:

(1) the proponents of these recent analysis models have not proved that a nuclear runaway will be averted by fuel motion for the selected accidents which were analyzed (indeed, these models under different plausible assumptions predict the reverse, a severe nuclear excursion);

(2) the models have not been applied to all possible accident situations and core conditions for the LMFBR Demonstration Plant and the larger LMFBRs planned for the future (to my knowledge at least);

(3) the models, even if they are valid, have not been extended and verified to follow the core accident behavior beyond the initial fuel movement (core expansion) to determine whether core compaction, and nuclear runaway, can occur later in the accident, after the predicted shutdown occurs;

(4) the models have not been confirmed experimentally, contrary to what the AEC's comment about the TREAT in-pile tests might imply to the layman; and

(5) these models are merely unverified predictions based on a relatively simplified picture of core melting phenomena and other subjective assumptions.

Before proceeding with an examination of the recent analyses and TREAT results alluded to by the AEC staff, let me give some background information and comment.

V.A. Background on Fuel Motion Theory Development:

The purpose of the SAS and MELT codes should be distinguished from the VENUS nuclear explosion (core disassembly) code, which was critically evaluated earlier. In order to do so, let us divide the LMFBR accident up into two parts--the pre-disassembly or melting phase, and the disassembly phase. The phase of a severe accident beginning with the initial mal-function and ending essentially when the reactivity rises above prompt critical (the threshold for nuclear runaway) is commonly referred to as the "pre-disassembly" phase.* The objective of the LMFBR safety program is (or at least was) to calculate the complicated core behavior during the pre-disassembly phase with the presumption that should the calculation lead into a nuclear runaway and core disassembly, the conditions at the onset of the runaway would be much less severe (e.g., much smaller rates of reactivity build up) than if one merely assumed the highest conceivable rate of reactivity insertion and then calculated only the disassembly phase. The SAS and MELT codes are being developed for predicting the pre-disassembly phase, and VENUS for the disassembly phase.[72] The recent analyses using the MELT code predicts that an accident will not even enter the disassembly phase, at least for the accidents analyzed, and therefore will result in no nuclear explosion.

* The runaway and explosion is the "disassembly phase."

The difficulties with accepting the MELT approach are that: (1) there are no full-scale LMFBR experiments to confirm the total accident predictions; (2) there is a myraid of different and interrelated core phenomena which dictate the course of the LMFBR meltdown accident (i.e., the fuel motion) and which, therefore, must be accounted for in the calculation, making the problem extremely complicated and sensitive to assumptions; and (3) the recent fuel motion models incorporated in the MELT code for the pre-disassembly calculation are based on TREAT type in-pile tests which are of questionable value in themselves. Chapter One of my dissertation partly describes in some detail and in somewhat layman terms the staggering complexity of the LMFBR core accident phenomena, which the Joint Committee should study. Regarding attempts to calculate the complex core meltdown behavior, I quoted in my Statement and in my dissertation an authority on the LMFBR:

> "[W]e don't know very much about what the meltdown accident is going to be, and though one can indeed make calculations about it, one would be naive to really believe them." [73]

This statement was made in 1965. Now, the SAS and the MELT codes referred to by the AEC staff for their "recent analyses" are attempts to do just that; i.e., to calculationally simulate the core meltdown phenomena during the pre-disassembly phase by computing the course which an LMFBR core might take during an over-power or under-cooled core accident up to the time when, and if, nuclear runaway **is calculated to occur.**

The point to keep in mind about predicting the course of LMFBR core meltdown accidents is that once gross core meltdown occurs, or a nuclear runaway occurs, the SAS and MELT pre-disassembly codes (as well as the VENUS disassembly code) cease to have any real credibility or applicability because of the complexity of core meltdown. It would require full-scale core meltdown experiments in order to develop and verify the SAS and MELT codes for ~~gross~~ core meltdown condition. For once gross core meltdown occurs, there is the valid concern that the event would lead to autocatalytic nuclear runaway behavior and severe core disassembly --i.e., a disastrous nuclear explosion. (A nuclear runaway, which could occur before gross core meltdown, could either lead directly to an autocatalytic nuclear explosion, or to gross core meltdown and then autocatalytic runaway.) It is advantageous, therefore, to investigate the motion of the fuel during the very initial stages of an LMFBR accident to determine whether there is a sound basis for concluding that initial fuel motion (IFM) will shut down the reactor and avert Gross Core Meltdown and/or Nuclear Runaway (GCM/NR)--i.e., whether core disassembly or nuclear explosion can be averted by negative reactivity insertion due to initial fuel movement away from the core center. This IFM approach to predicting the likelihood of nuclear runaway is appealing because during the initial stage of the core accident, much or most of the 50,000 or so fuel rods retain their relatively well-defined shapes, and their behavior is a less complicated problem to solve than the GCM/NR situation.

This IFM approach is what has been adopted for the recent MELT analyses. But whether one can use this approach to establish an upper bound for the severity of LMFBR accidents hinges on whether one can predict using

the MELT or SAS codes that GCM/NR cannot occur for all possible accidents, and whether the predictions need and can be experimentally confirmed by full-scale, core accident tests.

In order to show that the trend of the MELT development is toward this IFM approach, except for full-scale, experimental verification, let us review briefly the history of MELT development. The first MELT calculations reported by Sha and Waltar in 1971 for the over-power accident and the loss-of-coolant-flow accident ended in nuclear runaway or disassembly. (They integrated the VENUS code with the MELT code to follow the calculations through the disassembly phase.) Sha and Waltar then noted:

> "It should be noted that within the gamut of accidents of interest, many terminate without leading to the disassembly phase." [74]

My dissertation commented critically on the MELT-II/VENUS method used by Sha and Waltar by pointing out specific shortcomings. I asserted that although the method is impressive, the MELT code was crude relative to the myraid of different phenomena that can occur in the core during an accident. That is, the code did not include many types of forces that could drastically alter the course of fuel motion. In my Statement on the LMFBR Demonstration Plant I attempted to summarize the reliability of the MELT-II/VENUS method by quoting Sha and Waltar:

> "a substantial amount of effort is yet required." [75]

Concerning <u>fuel motion</u>, which is now implied by the AEC as a reliable shutdown mechanism, Sha and Waltar had this to say:

> "Fuel motion prior to disassembly continues to be a matter of concern, particularly because fast reactor

> cores, characteristically, are not arranged in their most reactive configuration during normal operation. Although most large accident analyses have been associated with gross movement of molten fuel, reactivity effects of fuel motion prior to the time of cladding failure may also be significant. Neither mode of fuel motion is very well understood at present. (Emphasis added.)[76]

As for in-pile testing in the TREAT reactor which the AEC now cites for support, Sha and Waltar added:

> "The limited number of TREAT and Capsule Driver Core tests to date have been instructive but difficult to interpret regarding the motion of fuel during the transient." (Emphasis added.)[77]

Now, just two years later, the AEC implies that the MELT code has been developed to the point that even for the more crucial accidents (the over-power and loss-of-coolant-flow accidents) the code predicts or establishes, when applied to the FFTF reactor,* that the fuel motion during initial core melting (IFM) results in partial core expansion, which reduces the reactivity sufficiently so as to preclude the reactivity from rising above prompt critical and triggering a nuclear runaway. TREAT in-pile test results are now alleged for support of such implied conclusions. Thus, what was not "very well understood" and "difficult to interpret" two years ago suddenly is understood enough to enable the AEC to see no basis for yielding to my Statement--something to be doubted inasmuch as two years work is a short period compared to twenty years of LMFBR R&D.

It therefore appears (or at least the AEC seems to imply) that the trend in LMFBR accident analysis code development is toward

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* A Liquid-Metal-Cooled Fast Reactor presently under construction.

justifying a conclusion that a nuclear runaway won't even occur for the maximum "credible" LMFBR accidents--i.e., the initial fuel motion may be relied on as a dependable shutdown mechanism for avoiding nuclear runaway, as the AEC comment asserts is "evident." These are the "recent" developments referred to optimistically by the AEC. Let us now examine the MELT fuel motion model in some detail. Contrary to the AEC optimism, however, I will show that GCM/NR cannot now be ruled out as impossible, and most probably never will be. (Despite the AEC's implication to the contrary, I doubt too the AEC would disagree with me.) Afterwards, I will show that the accident analysis codes have not been developed to rule out rapid, autocatalytic core compaction or implosion events that could produce disastrous nuclear explosions should GCM/NR occur. Finally, I will show that an experimental program to validate the accident analysis codes (SAS and MELT) is essentially non-existent for the pre-disassembly phase, let alone for the disassembly phase.

V.B. Critical Assessment of Recent Fuel Motion Theories:

The specific analyses which the AEC probably has most in mind are those contained in the recent report by the Hanford Engineering Development Laboratory (HEDL), entitled "Fast Flux Test Facility (FFTF) Design Safety Assessment," HEDL-TME-72-92, July 1972, which the AEC's Directorate of Licensing reviewed in its "Safety Evaluation of the Fast Flux Test Facility", Project No. 448, October 31, 1972. The FFTF is an LMFBR, except that it contains no breeder material that blankets the core. Otherwise the FFTF is much the same as an LMFBR, although it is much smaller than a large "commercial" LMFBR.* (Its purpose is to test LMFBR fuels and other core materials to high exposures that are characteristic of

* The power rating for the FFTF is 400 MWt vs. 10,000 MWt for the 3880 MWe LMFBR.

LMFBR conditions, such as high fuel burn-up, radiation damage, high temperature. This is done by placing LMFBR test specimens inside the FFTF core.) Therefore, accident analyses for the FFTF are basically the same as for LMFBRs. However, the LMFBR has a greater potential for nuclear runaway because the core is larger, which means that any conclusions from the recent FFTF accident analyses regarding fuel motion as a shutdown mechanism are not necessarily applicable to the LMFBR Demonstration Plant or the larger 1000 MWe to 3880 MWe size plants. (There may be other differences as well, besides the core size difference.) This difference raises the first question in regard to the AEC's claim of a fuel motion shutdown mechanism, since the "recent analyses" have evidently not been applied to the topical LMFBR accident analyses (the Demo and beyond), at least they are not a matter of public record.

In their report HEDL presented a model which was incorporated into the MELT code and which predicts one of the fuel motion shutdown mechanisms. The accident to which the model was applied was an "over-power transient" in which the reactor accidentally undergoes a rise in the reactivity at a rate of ½ $/second. (One dollar, $, is another unit of reactivity and corresponds to "prompt critical"--the threshold for nuclear runaway. Recall the other unit for quantifying reactivity, which is the "per cent" unit. I will have occasion to use both units. For the FFTF, 1$=.35% reactivity.) Recall that when the reactivity rises above zero (criticality), but not above prompt critical, the reactor power level will rise continually unless the reactivity is returned to zero or made negative. Such a power "excursion" will become fairly strong as the

reactivity rises near prompt critical, and can cause fuel melting, and then fuel motion, before the reactivity reaches prompt critical and triggers a nuclear runaway. Given the rate of reactivity rise of ½ $/sec in an over-power accident, it is clear that the reactor would undergo a nuclear runaway in two seconds if there is no shutdown mechanism. Hence, the initial fuel motion shutdown effect must act quickly if it is to prevent a nuclear runaway.

The exact sequence which the model predicts is:

(a) the vertical fuel rods heatup due to the strong power excursion that occurs below the prompt critical reactivity condition, assuming the control rods had failed to SCRAM;

(b) the thin tube wall of each fuel rod (called the fuel cladding) then fails or splits open at the top of the fuel rod;

(c) the gases inside the fuel expand when the fuel melts, quickly expelling the fuel/gas mixture (like foaming soda pop) upwards inside the fuel rod and then out through the opening in the fuel cladding at the top and into the sodium coolant stream; and

(d) the molten fuel and sodium mix to produce violent boiling and expulsion of the fuel-gas-sodium mixture upwards and out of the core.

Note that the fuel motion occurs when the fuel rods in the core still retain their shape. The fuel movement in (b), (c), and (d) above is outward from the core center in each case, producing a kind of core expansion. Since core expansion reduces

reactivity, the fuel motion tends to counteract the initial reactivity rise that brings on the accident, whatever may be the cause. The rate of reactivity reduction by this outward fuel motion was computed by MELT to be about -10 $/sec, compared to the initial reactivity rise that causes the accident of +.5 $/sec; so the predicted fuel motion dominates, and tends to terminate the power excursion and avoid a nuclear runaway. Assuming that this fuel motion persists for one second, the reactor could be about $10 subcritical (i.e., -$10) very quickly, which is strong enough so that in some cases at least the initial reactivity mechanism which causes the accident could be exhausted without triggering a nuclear runaway and/or gross core meltdown. (The fuel motion-induced shutdown could be assisted by a delayed control rod SCRAM.)

HEDL referred to a similar analysis for the other accident it studied--the loss-of-coolant flow accident, which too causes fuel melting. In this analysis the fuel motion too is due to gas formation ("fuel frothing") and the analysis predicts reactor shutdown similarly to the over-power transient. These gases, incidentally, are the "fission product gases" which build up within the fuel microstructure upon fissioning and are released upon fuel melting, causing the fuel to foam-up or squirt like soda pop.

While HEDL's recent analyses are encouraging, they are inconclusive. For example, if the fuel rods failed (split open) at or near their mid-height during the over-power transient accident, instead of at the tops of the fuel rods as the MELT code now predicts, the fuel motion would be the reverse. That is, the

fuel motion would be directed toward the middle of the core, producing dangerous core compaction, instead of core expansion; and would raise the reactivity further, instead of reducing it, and would therefore/lead strongly into a nuclear runaway condition. Furthermore, the fuel/coolant mixing in this reverse case causes coolant boiling and expulsion from the middle of the core instead of from the top, which has the nuclear effect of increasing the reactivity still further. (Recall that coolant voiding by itself can raise the reactivity, if it occurs near the center of the core.) An earlier HEDL-MELT analysis which assumed fuel rod failure at the mid-height and, thus, coolant voiding in the middle of the core, predicted nuclear runaway with a +500 $/sec rise in reactivity from the coolant voiding effect alone (neglecting the autocatalytic reactivity effects of the fuel motion toward the core center) versus the .5 $/sec initial causal mechanism.[78] (This is an example of one kind of autocatalytic reactivity effect that may be possible.) Thus, by using a different, but plausible assumption, the MELT code can be made to predict a definite nuclear runaway and gross core melting and disassembly (explosion), rather than a safe shutdown. (That is, the initial response to the over-power transient could produce a more rapid reactivity rise situation instead of shutdown. This autocatalytic response is similar to what actually occurred during the EBR-I core meltdown incident, only with the fuel rod bowing instead of fuel melting, which underscores the possibility for autocatalytic response to accident initiators, instead of a shutdown response.) Then, with gross core meltdown and/or nuclear runaway occurring, the condition of the core would be transformed into one which is even more complicated to analyze than the initial fuel motion that occurred when the shape of the fuel rods are still relatively intact.

Since the demands on fuel performance are generally more severe in the middle of the core than at the top, it is plausible to assume that the fuel rods would fail at the fuel rod mid-height location, rather than at the tops of the fuel rods. These fuel performance demands include fuel burn-up and swelling and neutron radiation damage to the fuel cladding. Nevertheless, HEDL's model for MELT predicts failure at the top of the fuel rods; although, it is not clear from the HEDL report whether the predicted failure location along the fuel rod length is strongly preferential or weakly so. But regardless, it can be presumed that the fuel failure phenomenon is not sufficiently understood to draw firm conclusions from the MELT fuel motion model. (There are other assumptions as well to be questioned.) For one thing, the purpose of the FFTF reactor, which is now under construction, is to expose LMFBR fuel rods to the normal LMFBR core environment for the burn-up and exposure times anticipated for the LMFBR Demonstration Plants and the larger plants beyond. Until such steady-state, fuel irradiation tests are completed, and then the irradiated fuel further tested under transient accident conditions, we cannot now be sure of the condition of the fuel and its accident behavior for predictions of the fuel failure location along the length of the rods. Even the AEC's Directorate of Licensing stated in its comment on HEDL's analyses:

> "The staff has not dismissed the possibility that cladding ruptures may propagate or occur axially over a major part of the core height during the predisassembly and disassembly phases of the accident so that fuel can be ejected at many axial locations simultaneously instead of just near the top. Neither has the staff dismissed the possible existence of forces *that might cause fuel motion into a more reactive configuration*." (Emphasis added.) [79]

To be sure, the MELT fuel motion model is just a prediction; despite the AEC reference to the TREAT experiments, which might connote verification of the model. For as the HEDL report states:

> "This experimental data [TREAT in-pile results] was used to predict the mode of fuel failures, location of fuel failure, and relative motion of the fuel during the analysis." (Emphasis added.)[80]

This HEDL statement falls short of an assurance that the experimental tests confirmed explicitly the actual predicted fuel motion; i.e., that the fuel motion was observed. (Incidentally, no reference was given for this HEDL statement, although the HEDL report does refer to another HEDL report to be published, which I have requested from the author, but have not received.) As we shall see later on, the experimental program underway for observing fuel rod behavior under transient conditions is questionable, as there are a number of important shortcomings. For one thing, the TREAT in-pile tests referred to by the AEC and HEDL do not truly mock up an LMFBR core environment. For example, there are "flux depression" effects across the diameters of the test fuel rods (non-uniform power generation within the fuel inside the fuel rod) which do not exist in an LMFBR. Does this flux-depression affect the validity of fuel failure data or predictions?

More fundamentally, we can never be sure of such predictions as HEDL reported, when they have not been verified by full-scale core-destruct tests. We can never be certain that the fuel rods will not fail preferentially at their mid-height location for the HEDL's assumed accident, and other possible accidents as well.

We can never be certain that the MELT model does not overlook other effects that force a nuclear runaway even if the location of fuel rod failure is as predicted.* Could molten fuel-coolant mixing occuring at the top of the core produce a sodium coolant vapor explosion which compacts the fuel downward enough to offset the predicted shutdown effect and trigger an nuclear excursion and gross core meltdown? Indeed, the AEC's Directorate of Licensing stated:

> "Experimental evidence has not yet been provided to permit prediction of fuel failure dynamics with the confidence needed to employ this model." [81]

These are a sample of the uncertainties associated with accident analysis codes. It must be emphasized that if the predictions are wrong, or don't apply to other possible accident situations, and an accident in which gross core meltdown occurs, either due to a nuclear excursion or coolant loss, then the fuel rod model of the core used by HEDL in the MELT code becomes meaningless. The core behavior then becomes much more difficult to predict, and the core condition becomes potentially more dangerous. Once the core suffers a major meltdown, then, fuel compaction and nuclear runaway and an explosion of unknown magnitude could occur, since the maximum explosion that can possibly result from such a happening has not been scientifically established. That is, the accident analysis codes have not been developed and verified by full-scale tests to confidently predict the course of GCM/NR for the LMFBR Demonstration Plants, nor for the larger LMFBRs, nor even for the FFTF for that matter. Nor do the AEC's plans as published include such development and <u>verification</u>. Without such, the only way one can establish

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* One factor overlooked in this Rebuttal so far is the fact that the subject fuel motion model of MELT does not hold for a fresh

an acceptable accident potential is to establish that under no circumstances (possible accident situations) can the core of an LMFBR melt in a gross fashion and/or undergo a nuclear runaway. The MELT code seems to be developing toward this goal of justifying that GCM/NR cannot occur; but the theory is unconvincing. Moreover, I doubt the AEC claims that it is impossible for the LMFBR to suffer GCM/NR. I have not seen any attempted set of analyses which predict the impossibility of GCM/NR. On the contrary, the aforesaid Argonne National Laboratory "limited distribution" report on "LMFBR Accident Delineation . . ."[19] describes numerous possibilities for GCM/MR, which depend on various assumptions of core behavior, as is always the case with accident analyses. This ANL document is replete with uncertainty as to the course of LMFBR accidents.

Examples of possible accidents for the LMFBRs of main interest--the LMFBR Demonstration Plants and the target 1000MWe LMFBRs (or larger), and not the FFTF--which may be capable of initiating a nuclear runaway despite the recent MELT code model of fuel motion are: (1) dropping a fuel rod bundle (core subassembly) into a just critical core during a refueling operation; and (2) a loss-of-coolant flow accident which could be caused by pump stoppage (either seizure or coastdown) or by a coolant pipe rupture. The former has been estimated to be capable of causing the reactivity to increase at a rate as high as 140 $/sec; and the latter has been calculated to result in a reactivity rate at least 5 $/sec due to the autocatalytic reactivity "feedback" of sodium coolant expulsion from the core (voiding). (Because the FFTF is smaller than the LMFBRs, the coolant voiding

core situation, when there is no "fission gas" present in the fuel to cause the predicted fuel motion. See note 209.

reactivity effect was not predicted by the MELT model to result in autocatalytic reactivity feedback during the loss-of-coolant flow accident in the FFTF.) The MELT fuel motion model evidently is not applicable for these strength of reactivity insertion rates, since the model was only applied to the range between .5 $/sec to 5 $/sec, and since HEDL stated that:

> "The applicability of the fuel failure and motion model used becomes less certain at the upper end of the range calculated [which was 5 $/sec]."[82]

(I wonder also what the model would predict for reactivity rates less than .5 $/sec.) Of course, one must keep an open mind, but presently I doubt seriously if nuclear technologists will ever be able to show that GCM/NR in an LMFBR is impossible. The EBR-I core meltdown incident underscores the possibility.

I should add that fuel motion models similar to HEDL's MELT model are discussed in my dissertation.[83] I mentioned the model used by Pate, which predicted a strong autocatalytic reactivity mechanism, and the model used by Lorenzini and Flanagan which predicted a strong shutdown mechanism similar to the MELT model. Inasmuch as the AEC cited the optimistic MELT type mode, one would expect the AEC to address the pessimistic Pate model as well in order to bring out the divergent results of different fuel motion models.

V.C. General Shortcomings of the TREAT In-Pile Tests; Necessity for Core-Destruct Tests:

Let us now examine the shortcomings of the experiments performed so far in support of LMFBR accident analysis code development in regard to both the predictions of fuel rod behavior (fuel motion) during the initial stages of an accident,

and the predictions of core behavior during the later stages, assuming that gross core meltdown and/or nuclear runaway (GCM/NR) can occur and the core ceases to behave as a collection of individual fuel rods. Namely, the TREAT in-pile tests referred to by the AEC will be critically reviewed here. It will become evident that the said fuel motion models used in the MELT code are not founded on conclusive experimental results. Because of the complexity of core behavior under accident conditions (to be discussed), and especially under GCM/NR conditions, it will be concluded that the codes will simply have to be verified in some measure at least by <u>full-scale</u> LMFBR accident tests in order that the accident analyses can be shown to have scientific validity. Full-scale tests are needed partly because of the all-important <u>reactivity</u> effects of fuel motion and coolant boiling, which cannot be duplicated except by full-scale tests, and also because of thermal and hydraulic effects and other nuclear effects, which cannot be exactly duplicated, except by full-scale tests, and which will be discussed.

The TREAT in-pile tests are small, involving only one to seven fuel rods (or fuel "pins" as they are more commonly called) and thus do not form an LMFBR reactor, which contains about 50,000 fuel rods. As discussed before, the TREAT tests, because they involve just a few fuel rods, cannot confirm full-scale core behavior as calculated (predicted) by accident analysis codes, especially the all-important reactivity effects, which determine whether the reactor shuts itself down by fuel motion caused by the accident, or whether the fuel motion produces GCM/NR and explosion. One may then ask: What is the purpose

of the in-pile testing, if it isn't to confirm or verify the LMFBR accident analysis codes? The answer is provided by Kelber, et al., :

> "[To d]efine an empirical model of fuel meltdown and coolant interaction." (Emphasis added.)[84]

That is, the few-fuel rod, in-pile tests are used to observe and study individual effects; such as fuel rod damage, fuel motion inside the fuel rods before and right after the fuel escapes the confines of the fuel rod tubing or cladding, and local molten fuel/coolant interaction and resultant sodium vapor explosions, and subsequent fuel motion, and damage to adjacent fuel. The knowledge gained by the in-pile tests of individual phenomena is then used to devise some of the components of the accident analysis codes. Hence, such models are called "emperical," as distinguished from "theoretical" models, which are derived, not from in-pile test observations, but from a combination of sound principles and unverified theories (assumptions). (See the said report by Kelber, et al., p. 67.) The accident analysis codes, then, are formed by connecting the empirical models with other, purely theoretical, models to calculate the net result of the interrelated effects, and thus predict fuel motion (explosive or not) throughout the core and possible autocatalytic nuclear excursions and explosion, if the codes are perfected to properly consider autocatalysis (which I claim is not the case). As to a purely theoretical approach, Kelber, et al., stated:

> "It is probably not possible, on purely theoretical grounds, to predict fuel motion under the complex conditions that exist in the meltdown. Therefore, an experimental approach is essential."[85]

This statement attests to the fact that fuel motion is so complicated that the in-pile tests are not used to verify pre-established, theoretical models, but rather to observe fuel conditions or motion and then select a relatively arbitrary and convenient model that will "fit" the in-pile data or observations. This means that the phenomena causing fuel motion in an accident situation will not be well understood theoretically; but rather, the emperical models would be valid for predicting fuel behavior only if we were given the exact conditions of the in-pile tests, and the tests were simply repeated (i.e., if we wanted to predict the trivial problem of what the fuel motion would be if we simply repeated the test), or if the in-pile test conditions could reasonably be assumed to exist in the core of an LMFBR during an accident situation, which is to be doubted. However, when an LMFBR accident progresses from the initial stages to when the separate, individual phenomena begin to interact, including whatever phenomena that may have been overlooked in the in-pile test program, or could not be re-produced in the tests, the configuration and other conditions of the fuel begin to deviate from the in-pile test conditions for which the empirical models hold true; and one begins the dangerous process of extrapolation--i.e., asking the empirical models to predict fuel motion for conditions and interactions which did not exist in the in-pile tests.

Finally, when the fuel rods in the core have totally lost their initial shape, and the core is largely or totally molten (gross core meltdown) and may have undergone a mild nuclear runaway and/or explosion, then the empirical models based on in-pile tests

of fuel rods are completely inapplicable. The course of the fuel motion in these later stages of the accident, then, will be predicted by unverified, theoretical methods, according to present AEC plans as published.

Furthermore, since the core behavior is more complicated in these later stages than in the initial stages of an accident, and since the empirical method was resorted to for the modeling of the simpler, but still too complicated, initial stages, one should suppose that the empirical method, instead of the theoretical method, would have to be resorted to for modeling the later, more complicated stages of gross core meltdown and/or nuclear runaway as well. But the empirical method applied to GCM/NR would require a countless number of full-scale, core-destruct tests in order to cover all possible conditions, which is obviously impractical. Therefore, we are simply forced to attempt to develop theoretical models as distinguished from emperical models for predicting the later stages of an accident. (But again, the theoretical models would require full-scale core-destruct tests to verify their validity.)

This limitation of in-pile tests and the complexity of gross core meltdown are so crucial to the assessment of LMFBR safety that these points deserve elaboration and re-emphasis.

In-pile tests can be helpful to investigate motion of fuel during the very initial stages of an accident, during and right after the time when the fuel rods have just begun to loose their shapes upon failure or melting, and to investigate the likelihood of damage to adjacent fuel by melt-through or sodium vapor

explosions to assess fuel failure propagation through the core should trouble first occur locally rather than core wide. But core behavior during possible LMFBR accidents is not limited to self-spreading failure propagation. For, as discussed earlier, we must assume that there are possible accidents in which all or a sizable fraction of the core can meltdown more or less all at once. (Examples of such accidents were previously discussed.) With the core heavily distorted by meltdown the problem of predicting fuel motion changes from one of a composite of predictions of individual fuel rods, or bundles of several fuel rods, to a prediction of the behavior of a mass of core material having no resemblance of a small bundle of seven or so fuel rods involved in the TREAT in-pile tests. This mass of core material can be composed of molten fuel, fuel vapor, frozen fuel, regions of damaged fuel rods, holes, cavities, porosity, and other core materials, which can arrange itself in a very distorted configuration. Molten fuel is inviscid (reference: ANL-7657, p.155); that is, it is very free flowing, not thick or even syrupy, but like water. This and the fact that the core is acted on by a myraid of forces and constraints (such as fission gas pressures, sodium vapor pressure, sodium liquid or hydraulic pressures, fuel vapor pressures, vapor explosions, and the constraint of core structures) makes a calculated prediction of fuel motion an extremely formidable task, especially so when the resultant fuel motion has the potential for triggering secondary nuclear runaways, which would add more energy to the core that would stir up and distort the core even more. Remember, about 2% core volume reduction is enough to generate nuclear runaway and the

intense heat associated with it.

Calculations of such core behavior are just now being attempted, to what extent it is not clear. But unless full-scale, core-destruct tests are run, the calculations will consist only of unverified, theoretical predictions based on numerous idealizations to simplify the problem so as to make a computer calculation practical. (Mind you, the problem is so complicated that the analysts might be tempted to be satisfied with a theoretical model, not because it is sufficiently rigorous, but because to make it more rigorous would prevent it from being solvable on the computer.) The TREAT in-pile tests mentioned by the AEC involving several fuel rods cannot verify theoretical predictions of fuel motion for a large, distorted core mass of frothing, inviscid, molten fuel and solid fuel that is being sloshed and blown around by a myraid of forces and constraints, complicated by the intense heating of autocatalyic nuclear runaway should the fuel move into a super-promt-critical configuration, since the in-pile tests bear no resemblance of such gross core behavior, including reactivity effects.

Because of the sensitivity of core-compaction-induced nuclear runaway (a 2% core volume reduction can trigger a runaway*), fuel motion must be accurately predicted in order to investigate the possibility for "re-assembly" of fuel into a super-prompt-critical mass, and associated autocatalytic reactivity effects, for all possible forms or configurations and compositions of the fuel material in order then to establish the maximum explosion potential. An example of a severe gross core meltdown and compaction event which should be evaluated has been suggested

* Similarly, slight compaction of a core region can cause a runaway.

by Daane for the Fermi LMFBR:

> "Assume the reactor power to increase suddenly, causing sodium to boil and be expelled. The fuel elements [rods] overheat and become plastic. A sudden return of sodium or the onrush of sodium from the pump is assumed to compress the core. If this compression is assumed to take place due to sodium rushing in at 30 ft/sec, a reactivity insertion rate of about 9 Δk/sec results from the ensuing calculation."[86]

Now, 9Δk/sec means 900 %/sec reactivity insertion rate when using the "per cent" unit of reactivity, or 1400 $/sec, which is much greater than than 5 $/sec upper limit value applicable for the MELT code fuel motion model.[166(n)] Applying this sodium re-entry accident to a large 1000 MWe LMFBR, I estimated a sodium re-entry velocity of 15 ft/sec, and a corresponding reactivity insertion rate of 150 %/sec (430 $/sec). Then by applying Meyer and Wolfe's value of 1,300 MW-sec of explosion energy (650 lb. of TNT equivalent) for a 100 $/sec reactivity insertion rate,[4] which factored in the mitigating effect of the negative Doppler reactivity feedback mechanism, I estimated that the 430 $/sec sodium re-entry accident produces an explosion of the size 5850 lb. TNT equivalent.* Such an explosion potential greatly exceeds the presumed 1000 lb. TNT limit for economical containment. Furthermore, this estimate excludes any subsequent autocatalytic reactivity effects, which could only worsen an already disastrous result. As the aforesaid "limited distribution report" from ANL states:

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* This estimate or extrapolation is based on the "3/2 power rule" of the classic Bethe-Tait theory, which relates the reactivity insertion rate with the resultant explosion energy:

$$[430/100]^{3/2} \times 650 \text{ lb. TNT} = 5850 \text{ lb. TNT.}$$ [167(n)]

> "It is extremely important to establish the nature and extent of molten fuel motion to determine whether reactivity is being inserted or removed and how rapidly."[87]

The fact that in-pile tests are judged necessary to determine fuel motion for early, more simplified stages of an accident, when fuel is just beginning to interact with neighboring fuel, shows that full-scale, core-destruct tests are surely needed to establish fuel motion in the much more complicated later stages of an accident when the core, or a large part of it, is molten, pulsing, erupting, frothing, sloshing, and exploding with the ever present possibilities for auto-catalytic nuclear runaway. In regard to full-scale,core-destruct test, the aforesaid ANL report states:

> "The need for integral core destruct tests will be examined in greater depth in a later phase of the safety test facilities study program."[88]

However, that "facilities study program" has been "terminated."[39] Presumably, this means that the question will never by formally examined and resolved in the LMFBR Nuclear Safety Program by the Laboratory scientists, unless the program is re-started.

The People should know that their safety relative to the LMFBR will be estimated, therefore, by unverified accident analyses. There is enough fuel in the core of a 1000 MWe LMFBR to make about ten, perhaps as many as 40, separate "critical" reactors, if compacted.[10] So, because of the sensitivity to nuclear runaway, there are practically an unlimited number of configurations the molten fuel could re-assemble into and trigger a nuclear explosion, or at least a mild power excursion that

could induce a sodium vapor explosion which in turn could act to compact the core or a region of it to trigger a nuclear runaway explosion. Predicting fuel motion under such circumstances (which includes decay heating from the intense radioactivity, by the way) borders on the impossibility. For a small error in the calculation could mean that the fuel motion is erroneously directed away from a nuclear runaway condition, which might involve autocatalysis as well, so as to hide a disastrous explosion possibility. Kelber, et al., acknowledged that a complete theoretical description for each nuclear runaway accident possibility will not be practical,[89] and that a "great deal of judgment is required in the choice of conditions to be covered in a particular [accident] study." (Emphasis added.)[90]

Therefore, core-destruct tests would be needed not only to confirm what analyses are made, but also to confirm the judgments of the analysts, as things now stand. However, we must perform a complete theoretical investigation of the LMFBR explosion potential, and avoid personal, subjective judgments. That is, the whole range of possible core behavior must be thoroughly explored. For it is conceivable that unacceptable explosions could be found which may be possible, and that it would be impractical to devise a rigorous theoretical model which could rule them out as impossible, or to conduct a series of costly and hazardous core-destruct tests just to confidently determine whether the reactor could create for itself such disastrous conditions.

V.D. Specific Shortcomings of the TREAT In-Pile Tests:

Turning now to the TREAT in-pile tests results alluded to by the AEC, there are valid grounds to suspect that these tests

are not now of sufficient value or/even applicable to the initial stages of LMFBR accident situations for which the tests are mainly intended to simulate. Even if the deficiencies of in-pile testing are corrected as best we can, there are still inherent limitations of the test facilities; which are further grounds for concluding that the in-pile derived empirical models, as well as the theoretical models, which are combined in an LMFBR accident analysis code, WOULD HAVE TO BE VERIFIED BY FULL-SCALE, CORE-DESTRUCT TESTS for their integrated ability to predict core behavior with safety margin during postulated accidents, in order to remove the uncertainties of the in-pile test results, as well as to verify the theoretical models.

Yet, the AEC places such an emphasis on the TREAT in-pile tests that it has apparently adopted the philosophy that full-scale, core-destruct tests are not necessary to verify or justify the accident analysis codes for the LMFBR Demonstration Plants, nor for the target 1000 MWe LMFBRs (and beyond). Thus, the few-rod, in-pile tests will comprise the only semblance of experimental verification of what would otherwise be completely unverified, theoretical methods for accident calculations. It is important, therefore, that we inquire into the status and value of the TREAT tests themselves in regards to making predictions of fuel motion as a shutdown mechanism.

To begin with Kelber, et al., cited some of the serious shortcomings of the TREAT in-pile tests in regards to the possibility for "large scale reactivity insertions":

> "Postfailure examination of TREAT tests shows dispersal of fuel with much fuel on the sides of the test section, and the possibility of extensive movement of molten fuel into blanket regions [which surround the core]. The absence of decay heat in TREAT, however, leads to chilling the molten fuel prematurely so that post-failure examination may give a misleading picture of the final disposition of the fuel. Molten UO_2 is inviscid, and decay-heat simulation is required, particularly with regard to the possibility of secondary criticality [i.e., nuclear runaway]. TREAT experiments also indicate strong wall effects. In the presence of proper [LMFBR core] environments, the fuel motion is expected to be even greater and perhaps more coherent. We need to determine wall effect and the effect of axial blankets on the flow of molten fuel." [91]

The "wall effect" has to do with the fact that the few fuel rods that are tested in TREAT are influenced by the relatively colder walls of the test container which surrounds the fuel rods. Whereas in an LMFBR accident, the fuel rods will be surrounded by more hot fuel rods, which means that more fuel energy will be available to produce vigorous fuel motion that may be in the autocatalytic direction.

The concern for "coherent" fuel motion is the crux of the question of whether the reactivity insertion rate caused by fuel re-assembly during a core meltdown accident will be disastrously high. (This is a separate question from the question of autocatalytic reactivity effects during nuclear runaway and core disassembly.) For example, if one assumes that the core could meltdown all at once and collapsed under gravity (that is to say that the core compacted "coherently"), one can compute a reactivity insertion rate of the order of about 100 %/second--a dangerous value.

However, the LMFBR promoters are not willing to concede that such coherent core collapse is "credible." Instead, they want (or are forced) to take advantage of the non-uniformity in the core collapse process--i.e., the hotter regions of the core will melt first, followed later by other regions in succession. The result is a bit-by-bit rise in the reactivity toward "prompt critical," and a slower reactivity insertion rate for producing a nuclear runaway. This slower, more "realistic" meltdown process has been computed to yield a reactivity insertion rate of 5 %/sec, instead of 200 %/sec for a simple, coherent core collapse model. This slower process is admittedly more realistic for the initial stage of an accident, at least for some types of LMFBR accidents. But the later stages of an accident are of concern as well. For what if the initial nuclear runaway were mild due to the slower, incoherent meltdown process. Such a mild runaway could conceivably heat the entire core to melting very rapidly; so that the rest of the core might collapse all at once, or be compressed by a sodium re-entry event before-mentioned, in a coherent fashion and thereby producing the dangerously high reactivity insertion rates of the order of 200 %/sec. Then, any additional auto-catalytic reactivity effects, such as implosion or core compaction, would worsen the accident. Such is the significance of the concern for fuel motion coherency expressed by Kelber, et al. It should be questioned whether the shortcomings of the TREAT tests mentioned by Kelber, et al., still apply to the results referred to by the AEC? And are there any other shortcomings associated with the few-rod, in-pile tests?

Coherency is, therefore, a region of the core moving as a unit, or a coherent mass, which requires core-destruct tests for investigation. The TREAT tests cannot investigate core-region coherency. Further, there are so many conceptual possibilities

for fuel motion leading to a severe nuclear excursion, such as compaction of a region of the core by coolant vapor explosion, and flow channel plugging due to fuel dispersal, then further meltdown, that it would be extremely difficult to gain confidence in prediction techniques even from full-scale, core-destruct tests, let alone from the few-rod TREAT tests, since so many of such costly and hazardous full-scale reactor destruct tests would have to be run to cover the variety of effects and initial conditions, and their combinations, and since the experimentalist cannot observe the motion of fuel in a core-destruct test in order to check for coherency or its potential. True, some important information is gained by the TREAT tests, but the data are unavoidably influenced by factors peculiar to the tests. Moreover, the above mentioned LMFBR Nuclear Safety Program Annual Report (ANL-7800) and the subsequent monthly progress reports, which report fuel motion experiments in TREAT, do not draw any conclusions as to how the accident potential of the LMFBR is affected overall by the TREAT results.

Let us refer again to the ANL "limited distribution" draft report, entitled "LMFBR Accident Delineation and Recommended Program of In-pile Safety Experiments" (May 1971), which was the Volume II of a two-volume report of the project "Studies of LMFBR Safety Test Facilities."[19] (The report by Kelber, et al., quoted from above is the final, published version of Volume I of the two-volume series.) Again, this is the project that has since been terminated without issuance of a final ANL document defining, and providing the rationale for, a program of in-pile safety experiments. Without such a document one must assume that the said draft report still represents the preferred experimental program of the LMFBR scientists (one group at least) who most

understand the LMFBR safety problems; or at least one must assume that the technical basis for the recommended program of experiments is still valid.

The specific, in-pile safety experiments in support of the Demonstration Plant(s) as recommended in the said report extend out through 1978 and beyond. But since the study project has been terminated, one could suppose that if it should be re-started, the in-pile experiments for support of the Demonstration Plants would not be completed until even later. Therefore, even if we use the AEC's criterion that in-pile safety experiments should provide an adequate experimental basis for LMFBR accident analysis codes, we must presume that the scheduled completion of the recommended program will occur after the scheduled date for operating the demonstration plants, and well beyond the irrevocable commitment of resources made for the design and construction of the plants. Now it is unrealistic to expect that a plant for which $700 million had been invested[92] will be abandoned, or even its operation delayed, if the in-pile test data prove negative. Rather, it would be prudent to assume that the risks of operating the plants will simply be taken. For just as the data will not be capable of establishing an acceptable maximum explosion potential, the data neither will be capable of proving an unacceptable accident potential; and it could then be expected that the Demonstration Plant promoters with their enormous investment, will find some technical argument (as distinguished from scientific argument) or rationale for discounting negative in-pile data.

That rationale might go something like this: Even if a nuclear runaway should occur, the theoretical disassembly codes predict a containable explosion. However, these disassembly codes (such as VENUS) will not have been proof tested by full-scale, nuclear runaway tests. Or, the rationale might be that accidents leading to nuclear runaway are "incredible"--i.e., the probability of nuclear runaways occuring will be so low as to justify operating the plant despite the negative in-pile data.

Therefore, if we put aside the question of full-scale, reactor destruct tests for the moment, it would still be prudent to defer the Demonstration Plant commitments until the ANL-recommended in-pile test program is completed; or to require the AEC to supply its detailed, scientific justification for proceeding with the Demonstration Plants despite the aforesaid recommended in-pile program.

Despite the lack of a formal, published, systematic, and justified in-pile program, the AEC staff review connotes to the layman that the in-pile test results to date have demonstrated that fuel motion occurs in a safe, non-autocatalytic direction during an LMFBR accident. (Although, the AEC's comment does not positively give such assurance.) But since the AEC did not supply references to the documentation supporting its claim, if it exists, one can only wonder, and doubt, whether even the essential tests of the ANL recommended in-pile test program have been carried out. For there is conclusive evidence that the tests considered essential by the LMFBR safety scientists at ANL have not been performed. Therefore, the AEC's optimistic comment about the TREAT in-pile tests appears to be premature on that standard alone. This lack

of "essential" tests is discussed specifically next.

There are many deficiencies associated with the in-pile tests performed so far, but perhaps the main one, aside from their not being full-scale, is the limited number of fuel rods in the fuel rod test bundle involved in each of the tests. The TREAT tests mentioned by the AEC contain only one to seven fuel rods at a time. In contrast, an LMFBR core is made up of about 200 bundles of fuel rods with about 200 fuel rods per bundle, not seven fuel rods per bundle. These fuel bundles (called core subassemblies) are each housed in a steel can which channels coolant flow through the bundle for normal heat removal and eventual electric power production. The/draft ANL report has pointed out, however, that none of the fuel rods in a seven-rod test bundle experience an "environment truly representing an operating LMFBR."[93] This is because all of the rods of a seven-rod bundle are exposed to the relatively cold walls of the test fixture, so that the heat transfer and other exchanges between fuel rods that would occur in an LMFBR accident are not duplicated in the tests. Test bundles with 19 fuel rods (almost triple the number) would provide only one fuel rod in a / "representative" environment. That is, only the central rod of a 19 rod bundle is not directly influenced by the colder test fixture walls. This is simply a consequence of the geometry of the fuel rod array in the bundle.

But one of the essential objectives of the in-pile tests is to observe how at least several ruel rods in an simulated LMFBR core environment interact with one another. Therefore, even a 19-fuel rod bundle is insufficient, since only one fuel rod is in

the "representative environment";* not several rods. But, the said ANL limited distribution report that recommended a program of safety experiments stated:

> "[I]t is considered essential to extend experimental capability to four rows of fuel elements, 37 elements, so that at least the central 7 elements will be in a representative environment." (Emphasis added.)[94]

Tests with a 37-fuel rod bundle provides seven rods in the desired environment, away from direct exposure to the cold walls of the test fixture. The ANL recommended in-pile test program includes 19 and 37-fuel rod tests, and even tests with bundles containing more than 91 fuel rods. Now it is doubtful that the recommended 19-fuel rod test have been performed, let alone the 37-rod tests, the latter having been scheduled for completion at 1979 or about.[95] (Upon reviewing the reactor development program progress reports emanating from ANL to date,[174] I could find no TREAT tests beyond the 7-rod number for studies of fuel motion effects or fuel/coolant interaction studies.) Even the adequacy of the 37-rod tests is questionable. For the said ANL report stated:

> "[I]t will be very desirable to conduct tests at large scale (greater than 91 fuel elements) to provide firm demonstrations that adequate safety margins have indeed been designed into LMFBR fuel assemblies planned for widespread use."[96]

Now extending the in-pile test capability from seven rods to 19 fuel rods and then to 37 rods and beyond is an expensive enterprise, since new facilities and modifications would be

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* Actually, a "true environment" is not established in the in-pile tests merely by increasing the number of fuel rods in the test bundles, since there are other shortcomings of the TREAT tests (as mentioned earlier and which will be discussed later) that

required, which could explain why they have not been performed. Furthermore, although the 37-rod tests provides the essential "representative" LMFBR accident environment for several fuel rods to interact in, the 37-rod tests are more difficult for observing fuel motion, since the fuel of interest is in the interior of the test bundle where the true LMFBR environment is supposed to be, and where fuel motion is harder to detect, which makes it unclear whether in-pile tests of any size number of fuel rods, short of full-scale, core-destruct tests, can provide any conclusive information. (Furthermore, I doubt whether the environment is <u>truly</u> representative in a 37-rod test. See footnote on pp.121-122.) But <u>assuming</u> the 37-rod tests would provide the essential experiments, they have not been performed. In fact such tests are just now being designed. As late as April 1972 ANL reported design work to improve the TREAT reactor:

> "to provide the capability of testing LMFBR fuel-pin clusters of 37 to 91 pins at normal LMFBR power densities in both the power-burst mode and the constant-power (flattop) mode."[97]

The improvements are being made because, according to ANL:

> "There are strong incentives for transient tests with larger clusters of fuel pins, because the clusters would provide a better simulation of the thermal and hydrodynamic environment of the fuel pins in fast-reactor fuel subassemblies . . . the present TREAT reactor would not be suited for these experiments . . ."[98]

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prevent duplication of a <u>true</u> environment. Perhaps the authors of the draft ANL report meant to cover themselves by the use of the word "representative" and the phrase "environment truly representing an operating LMFBR."

As of January, 1973 the TREAT reactor improvement/design work is still in progress.[99] If, therefore, the 37-rod tests are not performed by the time the demonstration plants are committed, and most probably won't be, then the accident analysis codes used to justify the safety of the plants beforehand will not be based on any essential experimentation whatsoever in regards to fuel motion.

In view of the foregoing, it is extremely important to obtain from the AEC a list of the in-pile tests that have been performed to date for comparison with the set of in-pile tests that were recommended by ANL in the aforesaid draft report; and the detailed justification, along with ANL's comments, for the AEC's reference to the in-pile tests and its optimistic statement about "fuel motion as a shutdown mechanism."

There are a variety of accident situations and concerns for which the said recommended in-pile test program was designed to investigate. These include (a) "fuel element failure propagation," in which a fuel element or fuel rod fails and spews fuel and fission product materials onto adjacent fuel rods, causing them to fail, and so on, spreading the failure condition throughout the core, possibly causing meltdown and eventually a nuclear runaway; (b) fuel rod bundle coolant flow blockage; (c) total core coolant flow stoppage; and (d) core power excursion, which affects the whole core all at once as does total core coolant flow stoppage. These recommened tests were to include the effects of expulsion and re-entry of sodium coolant on the motion of molten fuel (sodium vapor explosions, for example) and

propagation of damage to adjacent fuel rod subassemblies or bundles.[95] These tests would require at least 37-rod tests, and very probably, tests with greater than 91 fuel rods, just to at least have some confidence that a bundle of fuel rods and their interaction with sodium coolant were tested under a variety of accident conditions in an environment that is representative of an LMFBR accident, not the environment of a test fixture.*

According to ANL, a proper simulation of fuel rod interaction or behavior requires at least a full-scale fuel rod bundle in order to investigate, among other things, the "coherence" of fuel motion. Recall that the severity of an LMFBR nuclear runaway depends in some circumstances on whether the fuel from the individual fuel rods moves as a coherent unit during a melting situation toward a more reactive, runaway condition (coherent fuel movement), or whether the fuel motion during core meltdown is intermittent enough (the incoherency of fuel rods failing one at a time, for example) to bring about a slower rate of reactivity insertion and a less severe nuclear runaway--at least a less severe initial runaway. Regarding in-pile tests to investigate the coherency of fuel motion, Kelber, <u>et al.</u>, in ANL-7657 stated:

> "The issue of coherence is important, because it indicates a need for full-scale subassembly size tests."[100]

A full-scale subassembly (fuel rod bundle) typically contains about 200 fuel rods, which is far from the seven fuel rods in the TREAT tests cited by the AEC.** This shows up another deficiency in the TREAT tests.# (Incidentally, I have seen no analyses which prove that incoherency would mean a less severe,

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* Although, I asserted that full-scale, core-destruct tests are necessary.

** A co-author of ANL-7657 wrote to me recently that the method under development for observing fuel motion in subassembly size tests (hodoscope) "is even now far from being a proven technique."[108]

See footnote on next page.

incoherent fuel motion could mean ultimate accident, since initial/less core disruption should a nuclear runaway occur, and a better chance for the grossly molten core to remain near the dangerous, prompt-critical state for much more coherent fuel re-assembly later on.)

Earler, I discussed accident possibilities which involve total or near total core meltdown, and the problem of predicting and verifying experimentally the course of fuel motion and the severity of nuclear explosions resulting therefrom. These accidents usually assume the reactor SCRAM system fails to work. There may, however, be more probable accidents situations in which the SCRAM system is operable, but which core meltdown and runaway still occur because the core meltdown proceeds too fast for the SCRAM system to respond. Consider an accident in which the coolant flow to one of the 250 or so fuel bundles in the core is suddenly blocked. Such a mal-function could, of course, lead to enough fuel meltdown so as to trigger a mild power excursion which, if not stopped by the reactor protection system with a SCRAM, could bring on the total core meltdown. (The FERMI meltdown accident resulted from such flow blockage, and the SCRAM was delayed, as mentioned in my Statement; indeed, the operator withdrew the control rods further before SCRAM.) There is, however, the additional concern that the damage resulting from such a single core subassembly (fuel bundle) mal-function, such as local flow blockage, might spread throughout the core too rapidly for the reactor protection system to detect and respond with an automatic, emergency SCRAM in time to avert core-wide meltdown and a nuclear excursion. For this "failure propagation" concern, small-scale, few-rod tests are being conducted. But, as with the

Kelber, et al., stated that failure propagation studies may even require an "extensive in-pile test program of multiple subassemblies"--i.e., more than one fuel rod bundle. (ANL-7657, p.153.)

other shortcomings mentioned before, these tests evidently cannot be conclusive. For as Kelber, et al., put it:

> "We do expect small-scale tests, similar to those involving loops in TREAT which would simulate channel geometry, to yield valuable data on regimes of mixing and vapor generation, the relative explosive energy efficiency for each regime, and some indication of system scaling laws. However, we have reservations about extrapolating those data to real subassemblies, since the tests in most cases do not include realistic sodium heads [pressures], representative ratios of wall area to coolant volume, coolant volume to fuel volume, etc." (Emphasis added.)[101]

It is concluded that contrary to the impression given by the AEC, an experimental basis for the LMFBR accident analysis codes to be used in support of the demonstration plants will be lacking both from the standpoint of essential in-pile experiments for developing predictions of core accident behavior, and from the standpoint of full-scale, core-destruct tests for verification of accident analyses, when the commitments are made for these demonstration plants, and when the plants are ready for operation as well.

V.E. Autocatalytic Fuel Motion and Major R&D That Remains:

Turning again now to the "recent analyses" using the SAS and MELT accident analysis codes referred to optimistically by the AEC, we can now appreciate their shortcomings. For they are partly composed of empirical models that are questionable extrapolations from deficient in-pile tests, and partly composed of unverified, theoretical models. I have discussed the inadequacy of the accident analysis codes relative to a capability to confidently predict the course of the extremely complicated fuel motion under severe core meltdown conditions, and whether severe autocatalytic reactivity excursions can ensue, as well as the fuel motion during the initial stages

of an accident. I have discussed earlier in regards to the VENUS code the inadequacies of core disassembly codes from an autocatalytic reactivity standpoint; i.e., during and following severe nuclear excursions. But I should again emphasize that besides the VENUS shortcomings, we need to focus on the milder excursions or meltdown conditions, and the subsequent core behavior for which the predictive calculation must continue to follow with necessary precision in order to determine whether a rapid re-assembly of fuel can take place later on to set off a disastrous nuclear explosion. I doubt that a theoretical prediction, however crude, exists for this problem, or that one is even claimed. Predicting fuel motion is difficult enough when the fuel rods are initially intact; so much so that ANL has resorted to making empirical models based on in-pile TREAT type tests, rather than attempting a purely theoretical model from basic principles, which could then be checked with the in-pile test results. But the predictions of core behavior under gross core meltdown is even more complicated than predicting initial fuel motion, which, in the absence of core-destruct tests, should give the layman an appreciation of the crude state of the accident analysis codes relative to the complexity of the LMFBR accident prediction problem.

Therefore, although some accident situations have been calculated (predicted) using the recent analyses of MELT to stop short of a gross core meltdown and nuclear runaway, or explosive pressures, there would still be at least four important questions that would need justified answers in regards to LMFBR accident analyses:

1. Are there plans to verify the analyses by full-scale LMFBR tests?

2. Did the analyses include all possible sources of pressure and resistance to fuel motion and all possible reactivity effects, including autacatalysis?

3. Did the calculations end with the occurrence of shutdown with the fuel in a frozen state, without pieces of the core precariously separated from each other which could by some later action, such as clean-up tampering, or decay heat-induced melting, come together and trigger a nuclear runaway?

4. Will analyses be extended to cover all accident possibilities, including those involving gross core meltdown and nuclear excursions?

From the preceeding discussion, it should now be evident that the maximum explosion potential of the LMFBR has not been scientifically established, nor is there a prospect for establishing such by the time the LMFBR demonstration plant is committed and built. Consider the statement by HEDL which accompanies the recent MELT code analyses regarding the fuel motion shutdown effects:

> "Since the results reported here represent a current assessment of on-going work, a complete case for a single upper limited energy value is not made." 102

Consider too the comments on HEDL's analyses by the AEC's Directorate of Licensing, which apply to the FFTF reactor safety analyses:

> "The analytical approach to evaluating both accidents assumes that the core behaves in a prescribed manner and that a sequence of events occurs which can be described in a mathematical model. The modeled events are then expected to be verified by experimental programs. The

Regulatory staff is of the opinion that the experimental work completed thus far has not established an indisputable position for verifying the modeling and results of the accident analytical models that are now coming into use. The experimental work completed thus far provides encouragement that the future accident evaluations may result in less energetic accidents; but confirmatory experimental work is required to prove this expectation." 103

Specifically, the Directorate of Licensing stated:

"More work is also required to establish limits on the rates of sodium voiding and fuel motion during accident conditions . . .

"More adequate modeling in the disassembly phase of the analyses is required to include such factors as heat transfer, fuel-coolant interactions, improved calculation of reactivity effects, the effects of fission gas and improvements in the equation of state modeling used to predict hydrodynamic behavior of the core materials [e.g., fuel motion]. . .

"The adequacy of perturbation theory treatment of reactivity effects due to material motions when substantial distortions are involved should be evaluated. . .

"Analyses of HCDAs [Hypothetical Core Disruptive Accidents, which is another name for core explosion] should be completed in that the evaluations of the consequences of these excursions must be carried through to the point where a final, stable and subcritical configuration has been obtained regardless of the magnitude of the energy yield developed from the initial excursion." 104

These comments support my claims. For example, the comment on perturbation theory supports my allegation that the VENUS disassembly code has limitations regarding autocatalytic reactivity effects; and the comment about stable subcritical configuration supports my claim, stated in my dissertation (p. 17) and earlier

in this rebuttal (pp. 63,128) that the accident analysis codes will have to be extended to follow core behavior to its complete end to ensure that re-assembly of fuel into a critical mass cannot occur to start a whole new chain of potentially dangerous events.

Incidentally despite these serious questions posed by the Directorate of Licensing, the Directorate concluded that the explosion potential for the FFTF is limited to about 500 MW-sec of explosion energy (250 lb. TNT equivalent), which the containment is designed to withstand.[105] In other words, the Directorate concluded that the FFTF explosion potential is safely bounded, despite their admission of serious questions or uncertainties. But because of the fundamental uncertainty which these questions reveal, the Directorate has no sound basis for its overall conclusion.

I should re-emphasize again that regardless of the level of sophistication of the accident analysis codes, such as SAS, MELT, and VENUS, there still will be the need to verify them by full-scale, core-destruct experiments, and somehow cover all accident possibilities, if this is practical. As mentioned before, TREAT cannot do this. This is the lesson learned from the EBR-I core meltdown incident, according to the late AEC commissioner, Theos Thompson:

> "Experiments must be carried out to explore the limits of reactor safety, and from time to time these will (and should) involve [core] destructive tests. Such tests can be carried out at appropriate sites without endangering the general public as was the case here [with EBR-I]."[106]

In contrast, some reactor destructive tests have been performed for the water-cooled reactors, although to a limited extent. But nevertheless, they have been performed--viz., the BORAX and the SPERT tests.[107] These tests involved small, but <u>whole</u>, reactors that were caused to undergo severe nuclear runaways. (No LMFBR has ever been tested under a nuclear runaway state.*) The experiments verified that the water-cooled reactors have an effective inherent shutdown mechanism which self-terminates nuclear runaways, and thereby limits the explosion force. This inherent shutdown mechanism is the boiling and expulsion of the water coolant from the core due to the rapid, core heating of the nuclear runaway. Because of the low fuel concentration in water-cooled reactors, the water is needed not only as a coolant, but also to enable the reactor to sustain a fission chain reaction. Therefore, expelling water from the core or compacting the core, which squeezes water out of the core, tends to shutdown the reactor and terminate or preclude a nuclear runaway. Thus, barring other effects, the shutdown mechanism is dependent on water heat transfer characteristics, which does not require a full-scale reactor to duplicate. That is, the small-scale SPERT type data can be justification for an inherent safety mechanism in the much larger, commercial water-cooled reactors, at least to the first approximation.[108(n)] However,

small-scale reactor testing is insufficient for LMFBRs because the LMFBR fuel concentration is much greater, so that fuel meltdown, and indeed coolant expulsion, can trigger nuclear runaway; and even the fuel motion in response could worsen the runaway by providing autocatalytic reactivity effects. In order to verify a limited explosion potential, or investigate autocatalysis ex-

* Except with the LMFBR-like SEFOR; but these tests were very limited as my Statement on the LMFBR Demo discusses--i.e., no fuel motion or core explosion was involved.

perimentally for the LMFBR, full-scale reactors need to be tested because autocatalytic reactivity effects will <u>depend</u> on the presence of the total mass and distribution of fuel assumed to be present initially in an LMFBR accident. Thus, a large 3800 MWe LMFBR with its 11 tons of Plutonium would have to be tested, since this is the ultimate size contemplated for the LMFBR. There is no way around it, since this constraint arises due to the nature of the LMFBR.*

I should emphasize also that my Statement and this Rebuttal are not a recommendation to proceed with core-destruct experiments, which may in themselves be too hazardous (and too costly); but rather, I am contending that <u>if</u> the nation through constitutional procedures decides to proceed with developing the LMFBR, then the steps I recommend should be taken. These steps are:

1. Investigate fully the theoretical potential for explosion, including autocatalytic reactivity effects--i.e., the maximum possible explosion, and the maximum conceivable explosion which cannot be ruled out as impossible;

2. Establish and justify a systematic program of in-pile tests which eliminate the shortcomings of the in-pile tests performed so far as best we can; and

3. If the additional theoretical and experimental work allows a preliminary conclusion that the LMFBR is feasible from a safety standpoint, than determine whether

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* Even for establishing the design reactivity effects or characteristics of reactors for <u>normal</u> operation, before building the reactor, including the <u>LMFBR, full-scale</u> assemblies of the fuel mass, composition, and distribution are tested. These tests are called "zero power, physics critical experiments," as distinguished from "super-prompt-critical (nuclear runaway) experiments."

a practical full-scale, core-destruct test program can be carried out to verify the accident analysis predictions. If not, then LMFBR development should be terminated, in order to avoid basing assurances of public safety on unverified estimates of accident potential.

The complexity and uncertainties of calculating core behavior during an LMFBR accident is attested in the Argonne National Laboratory report, entitled "Safety Problems of Liquid-Metal-Cooled Fast Breeder Reactor," ANL-7657, by Kelber, et al. I have supplied examples from this report in the course of this rebuttal. Because the report is extremely important, the AEC should be required to comment on each and every paragraph and justify for each paragraph why the demonstration plant program should proceed if the AEC believes that any uncertainty expressed in each of the paragraphs is not important enough to defer the projects. This author believes that the report raises very serious questions. For example, it reveals the concern for the need for "integral core-destruct tests," and does not rule out their necessity. However, this report should not be taken as necessarily defining the complete scope of the LMFBR safety problems and uncertainties. In this regard I have some criticisms of the Kelber report.

Firstly, the report does not attempt or claim to describe all possible accident situations and associated safety problems, although it touches on many important ones. Secondly, the report is replete with examples of concern for dangerous reactivity

situations; but does not give the reader an appreciation for the maximum conceivable explosion that might be possible with each of the examples. For instance, the report states:

> "In addition to the insertion of reactivity through fuel meltdown and collapse, another potential source of rapid insertion of positive reactivity is the motion of solid fuel into a region of higher reactivity worth. Such motion might, for example, be induced by a vapor explosion in a portion of the core." [109]

Unfortunately, no analyses were referenced or summarized in the report to provide an upper bound for the nuclear explosion force that might be caused by such an reactivity insertion event. I have attempted to supply such omission by assuming a relatively small 5 lb. TNT(equivalent) sodium vapor explosion which acts to rapidly drive a group of nine fuel bundles* (still solid) into a previously expanded core and toward a nuclear runaway condition. I estimated a reactivity insertion rate of about $3000 per second, which corresponds to a nuclear explosion of about 100,000 lb. TNT (equivalent). (Recall that 1,000 lb. TNT is about the upper limit for econcomical containment.) With such an explosion force, I do not know whether autocatalysis that might result from such a huge explosion would not be radically different (and horrendously worse) than that associated with less stronger nuclear runaway; but the radioactivity release would be full. Perhaps conceivable nuclear explosions of the order of, or in excess of, 10,000 lb. TNT (equivalent)** is what Murphy, et al., had in mind when asserting their view that it is unlikely that the worst accident permitted by the laws of nature can be economically contained. (See p. 2 herein.)

* Out of about 200 bundles in the core.

** See note 176 concerning the uncertainty of explosion estimates.

Inasmuch as Kelber, et al., supplied no upper bound estimate for the sodium vapor explosion-induced-solid fuel motion accident, I wrote to Kelber with my 3000 $/sec example. (I had then crudely estimated a 15,000 lb. TNT explosion based on a proportional rule for adjusting energy yield values for a greater reactivity insertion rate. Actually, a 3/2 power rule* is more appropriate, according to the Bethe-Tait theory,[167(M)] which yields an explosion of the order of 100,000 lb. TNT.) Kelber replied by implying that he did not understand the "rationale" for my accident. He then stated:

> "In the classic paper on upper energy bounds by Hicks and Menzies (in ANL-7120) their Table I, on p. 659, shows the largest entry as 2470 pounds of TNT equivalent, for an insertion rate of 200 %/sec. (About 600 $/sec.) and a zero Doppler constant. This is so much less than your estimate that I strongly urge you to reconsider your bases. Note that the Hick-Menzies approach is exceedingly conservative. For your case [i.e., a typical Doppler constant = -.3%] they might estimate of the order of 300 pounds of TNT."[110]

I responded to Kelber's reply by citing the above quotation from his report (ANL-7657) about solid fuel motion induced by a sodium vapor explosion as the "rationale" for my accident. Then, I noted that the Hicks and Menzies paper[3] did not attempt to justify the 600 $/sec reactivity insertion rate as an upper bound, nor associate it with the vapor-explosion-induced fuel motion accident. Then I noted that the Hicks and Menzies explosion values in ANL-7120 are about 100 times lower than Meyer and Wolfes data[4] for the same reactivity insertion rate, which indicates that the Hicks and Menzies data cited by Kelber may be too low. With these responsive comments, I asked

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* Energy Yield = Factor x (Reactivity Insertion Rate)$^{3/2}$

Kelber again if he knew of any ANL crude estimates of maximum conceivable accidents of the sort I described which yield an explosion of the order of 10,000 lb. TNT. In reply, Kelber gave no comment except to refer my questions to the "Reactor Analysis and Safety Division" of ANL.[#2] That was on March 8, 1973. I have yet to receive an answer.

As a follow-up, B. Wolfe (general manager of General Electric Co.'s breeder reactor department) has informed me that Hicks and Menzies have since "revised" their ANL-7120 values, which are now "in general agreement" with the Meyer and Wolfe's data.[#3] If true, this would suggest that Kelber has been prejudiced by erroneous, low estimates of the "upper energy bounds" for the LMFBR explosion potential in his reply to me and in the preparation of ANL-7657, "Safety Problems of the LMFBR," which the AEC cited as a key reference in the LMFBR Demonstration Plant Environmental Statement. I have written to Hicks and Menzies (Dounreay Experimental Reactor Establishment, Scotland) on May 4, 1973 for confirmation of their revised estimates, which, according to Wolfe, are "published in a restricted distribution report."[208] (Emphasis added.)* (Incidentally, my maximum conceivable explosion estimates are inferred from the Meyer and Wolfe data, not from the original Hicks and Menzies data.)

Another example of a conceivable mechanism by which the reactor might be made to undergo a strong nuclear runaway involves the rebound of the slug of sodium coolant that had been ejected upwards by an initial reactor explosion. The massive reactor vessel cover is designed to withstand the impact of the sodium slug. This reactor cover, then, is part of the explosion containment system. Conceivably, the massive sodium coolant slug

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* As of July 23, 1973 I have not received a reply, nor a copy

could rebound off the vessel cover and travel back downwards to crash into the core debris, compacting it (the fuel) rapidly to set off a second nuclear runaway, which conceivably could be worse than the first. Using data from HEDL's analysis of sodium slug ejection and impact on the reactor vessel cover for the FFTF[114], and Meyer and Wolfe's nuclear explosion calculations in ANL-7120,[4] I estimate, as an upper bound only, that a secondary nuclear runaway might yield an explosion of the force of 17,000 lb. TNT (equivalent), barring autocatalytic reactivity effects. R.W. Wright of ANL, who is conducting the TREAT experiments for measuring or observing slug motion, stated that this slug-rebound-induced core compaction accident is a "good question" and that the reactor analysis section at ANL "worry about it."[115]

It would be helpful, therefore, if ANL would compile all such analyses of maximum conceivable accidents associated with their stated concern for rapid reactivity accidents in ANL-7657, and issue them in a report in order that the layman as well as scientists can better appreciate the importance of the hazard uncertainties associated with the LMFBR.[162(n)]

It should be pointed out that the above ANL-7657 report by Kelber, et al., falls short of claiming that the LMFBR can be made safe. The report, which reflects the views of its 13 authors, who are central figures in the LMFBR safety program, conveys the notion that its authors are researchers who objectively tried to assess the accident potential of the LMFBR, and could not bring themselves to the conclusion based on a scientific foundation that the LMFBR is safe--i.e., that the upper bound of the explosion potential is economically contain-

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of their report, which I requested. P.S. Confirmation obtained.[215(u)]

able. So how could the AEC assert that the objective of the LMFBR Demonstration Plant(s) is to "demonstrate safety," as it did scarcely a year after the ANL-7657 report was issued, when the scientists working directly in the field of LMFBR safety concluded that serious uncertainties and other problems remain. This is another indication that safety has not been established for which to demonstrate.

There are other concerns for possible accidents which I will mention in order to show by way of example another class of accidents which are possible, and therefore should be analyzed. These concern the strength of the Doppler feedback effect. Recall that the LMFBRs are being designed so that should a nuclear runaway occur, the rapid fuel heating will subtract the reactivity which tends to shutdown the excursion, and thereby mitigate the accident. Without this negative Doppler feedback, the LMFBR explosion potential would be unquestionably unacceptable. But suppose the special material inserted into the LMFBR core to bring about the desired Doppler strength (BeO) were left out. This would constitute a possibility which should be evaluated for its consequence on the LMFBR nuclear runaway accident when LMFBR safety analysis reports are issued, as leaving out the BeO would mean a smaller, mitigating Doppler feedback.

Another concern is the degree of mixing of the Plutonium-Oxide (PuO_2) fuel with the Uranium-Oxide (UO_2), non-fissionable (non-fuel) filler material during the fuel manufacturing process. If the Plutonium-Oxide is not well mixed, there is the valid concern that during the nuclear runaway, only the fissionable Plutonium-Oxide particles will heat

up, and not the Uranium-Oxide filler material in which the Plutonium particles are embedded, due to the lag time for heat transfer from the PuO_2 to the UO_2. Since it is the heating of the UO_2 which gives rise to the negative Doppler feedback (indeed, the PuO_2 heating alone would cause a positive, autocatalytic Doppler feedback), a lack of thorough mixing of the PuO_2 and UO_2 in the fuel manufacturing stage could conceivably have a disastrous effect on the explosion potential of an LMFBR. Golden stated:

> "It is noteworthy that for the U-238 Doppler to be as prompt-acting as possible, the U-238 must be thermally closely coupled to the primary heat-producing Pu-239. That is, significant segregation of the fuel species caused by fabrication or thermal migration during operation is undesirable." 116

These two example about Doppler, as well as all other possible accidents should be evaluated and publicly disclosed for their effect on the maximum explosion potential of the LMFBR.

In conclusion, the AEC's comment about fuel motion as a shutdown mechanism is no ground for <u>not</u> "reversing the AEC's current plans for designing, constructing and operating the LMFBR Demonstration Plant," as Deputy General Manager John O. Erlewine of the AEC had concluded in the AEC's letter forwarding the Staff Review to the JCAE.

Practicality of an LMFBR Safety R&D Program

It can be doubted that a research program to determine the maximum explosion potential for the LMFBR is even practical. The calculational methods for predicting the course of accidents must include a myraid of phenomena, varying initial conditions, and uncertainties, all of which are interrelated in such a complex way that defies calculation. These include: motion of molten and solid fuel; sodium boiling and expulsion; sodium vapor explosions; fuel vapor explosions; fission gas release from the fuel; core materials composition and distribution; equations-of-state uncertainties; restraining effects of reactor internal structures and blanket fuel-breeding material; azimuthal effects; heterogeneous effects; shock and blast waves; sodium re-entry pressures and effects; initial configuration of the core, which may involve fuel loading errors, and the position of the control rods; unintended gaps or cavities; operation of coolant pumps; state of the core materials at the onset of a super-promt-critical power excursion (nuclear runaways); the predictability of the reactivity during the course of the accident (autocatalytic reactivity effects); irradiation of fuel (fuel burn-up) and structual materials; and so on.

Then, assuming that the calculational methods could be devised to simulate "in the computer" ~~all of~~ these effects, and their interaction, there would have to be full-scale, integral core-destruct tests of such a number to ensure that all important combinations of effects are tested to confirm the validity ~~validy~~ of the accident analysis codes. In view of the extreme costs for such integral core-destruct tests and the hazards as well, it is conceivable or even probable that the LMFBR accident analysis codes

will never be fully verified experimentally. As an indication of this, the LMFBR Program Plan stated:

> "it is not now apparent that such experiments can be devised for the Excursion Test Facility for code verification at large scale." 117

That is, if the LMFBR is adopted, we should understand that the magnitude of the associated risks to the health and safety of the People will probably never be known.

The ANL-7657 report by Kelber, et al., "Safety Problems of the LMFBR," discusses some of the difficulties with "integral core destruct tests." The report states in part:

> "a. The cost would be exceedingly high, even if some scheme is devised for recovering most of the large amount of fuel required.
>
> "b. The hazards would be difficult to cope with, especially if it is necessary to use plutonium fuel . . .
>
> "c. It would be difficult to extract information on individual phenomena from an integral proof test. Thus, if good agreement is obtained between predicted and experimental gross behavior, one may be satisfied that the individual processes are well enough understood. But if there are significant differences, it may not be possible to pin down the source of the differences. [This is because the detailed fuel motion inside the reactor and core will not be observable or measurable.]
>
> "d. If there is not good agreement between theory and experiment, a large number of tests would be required to evaluate reproducibility and the influence of small changes in initial conditions . . ." 118

The ANL-7657 report added:

> "There are also judgments to be made here on accident initial conditions and calculational models. . .The energy release in super-prompt-critical excursions is most sensitive, however, to the initial conditions . . . An experimental program cannot possibly cover the complete range of conditions." [119]

Yet, the ANL-7657 report admitted that an integral core-destruct test could be beneficial, such as to verify whether serious autocatalytic reactivity effects attend a nuclear runaway due to large fuel movement:

> "This is an area that conceivably could benefit from a proof test of a complete whole-core destructive-excursion experiment. A great deal more investigation would be required to determine the full benefit of such an experiment." [120]

Regarding the advantages of integral core-destruct tests, the Kelber report said:

> "The tests of heat exchange; mixing; equation of state and heat capacity; material-displacement feedback [reactivity effects]; sodium voiding; fuel-coolant interaction; mechanical restraints; response of surrounding structures; buildup, propagation, and dissipation of shock waves; and perhaps even missile production would be checked simultaneously in total core-destruct tests." [121]

Furthermore, the mitigating effect of Doppler in nuclear excursions needs to be fully tested as well. In my Statement I said that:

> "although the SEFOR tests were very useful in demonstrating the Doppler mitigating mechanism, and were evidently successful in that regard, they provide no

confirmation of explosion calculational methods."

I neglected to point out, however, although one could have surmized it from the data I provided, that the SEFOR test confirmed the Doppler mitigating action only for mild excursions; i.e., small changes in core temperature (10% temperature rise). The tests did not confirm the mitigating potential of Doppler in the explosive range of temperatures. Kelber, et al., stated that this also would be an advantage of integral core-destruct tests:

> "[T]he SEFOR program is directed toward verifying the effectiveness of the Doppler effect in terminating excursions. But if further demonstration is needed, the integral proof tests would provide it and extend the SEFOR results to much higher destructive temperatures." 119

In my opinion, the People, should not be expected to accept the risks associated with operating LMFBRs based on extremely complex, incomplete, theoretical accident analyses that have not been verified to any extent by full-scale,* core-destruct tests, especially since the codes will contain many judgment factors, assumptions, approximations, and possibly some overlooked phenomena and errors. 214(n) The potential for disaster is simply too awesome to ask the People to take that chance.

But then, is an adequate test program practical? To answer this question, there should be commissioned a committee of objective scientists for the purpose of determining the theoretical maximum explosion potential and then, if such is acceptably low, to determine whether a program of full-scale, core-destruct tests

* Or any size core-destruct test for that matter.

to adequately verify the LMFBR accident analysis codes for all important conditions is even practical; that is, to determine whether the LMFBR is a machine that is simply incapable of establishing by confirmatory experiments a bound on the explosion potential which is economically acceptable. This committee of scientists should not be commissioned by the unconstitutional agency of the AEC or the nuclear industry with its natural, vested interest, but by the People through their representatives in constitutional processes.

For example, Congress should review the state of nuclear development in order to determine whether to repeal the civilian nuclear promotion program on the ground that it is unsafe, or to propose to the States a constitutional amendment which request authority to proceed with the civilian nuclear power development. To facilitate this review, Congress can constitutionally pass a Nuclear Safety Assessment Act, which while in force would nullify the promotional provisions in the 1954 Atomic Energy Act and subsequent amendments.* This Act could provide, among other things, for the establishment of the said committee of objective scientists. The States, however, would not be bound by the final report of this committee, should it conclude that the explosion potential is acceptable. For the report, and a necessary constitutional amendment proposition of Congress to proceed with the LMFBR that might be based on the report, would be advisory only. The States themselves in their individual capacities can establish whatever additional advisory committees they would judge necessary to aid in their individual decisions on whether to ratify a proposed amdendment.

* This would, for example, remove the Price-Anderson liability immunity, and thereby have the practical effect of shutting down all civilian nuclear power plants in the United States.

The reason why no full-scale, core-destruct verification tests are planned, so one argument goes, is that the tests are so expensive that they would be very limited in number such that only a "few data points" would be obtained, and that what tests are performed would quickly use up the available funds for LMFBR R&D. Therefore, it is argued that it is far more efficient to spend the money developing theoretical methods with the aid of cheaper, auxiliary, non-integral experiments, such as the TREAT in-pile tests. In this way one could at least hope to investigate the entire accident spectrum, including combinations of initial conditions, and so forth. There is some merit to this argument, except that it is not being lived up to, since commitments are being made to build the Demonstration Plants without the full theoretical research and associated non-integral experiments. Indeed, there are reports that the R&D funding for theoretical studies at Argonne National Laboratory have been cut back.[168] But regardless, the argument is not of sufficient merit, since it is simply not wise to depart from the scientific method, which has been found so useful in arriving at truthful knowledge, by not verifying the theoretical accident analysis codes by full-scale reactor destruct tests--especially, in light of the immense complexity of the problem of predicting core behavior under accident conditions.

Assuming that a full-scale test program would cost $2 billion, that is a small percentage of the cost of the expected number of LMFBRs to be built (less than ½%). It is a small price to pay to ensure the health and safety of the People and the protection of the Environment from ruinous radioactivity contamination. But I must emphasize

however, that an adequate full-scale, verification program may be impractical; too costly and-or too hazardous in itself; in which case the LMFBR development should be terminated.

The cynic might believe that the LMFBR promoters do not want to conduct core-destruct tests for fear that the explosion potential would be proven unacceptably too large. There is some ground to suspect such a motive for not performing core-destruct tests. For I have personally witnessed this kind of thinking in high circles within the AEC. Specifically, a high AEC official for the Shippingport Pressurized Water Reactor project decided not to test the reactor at full, design power for fear of causing fuel rod failures which would politically jeopardize a nuclear reactor project for the Navy's super-aircraft carriers, despite the fact that fuel rod failures were not even predicted to occur.* (The official, however, was overruled by his superior--Admiral H.G. Rickover.)

In order to perceive better the ground for the cynic's view, consider the fact that the LMFBR Demonstration Plant will be designed, constructed, operated, and maintained with near infinite care by no less than eight major organizations:

AEC's Division of Reactor Development,
Breeder Reactor Development Corporation,
Project Management Corporation,
Advisory Committee on Reactor Safequards,
AEC's Division of Regulation,
Westinghouse Electric Corporation,
Tennessee Valley Authority,
Commonwealth Edison,
plus architect firms and construction companies.[122]

With such close supervision, and large funds spent on the project,

* A similar episode was reported involving the Navy's F-14 fight-plane contract qualification tests in which a crucial test was not performed.[123]

the chance for serious malfunction occurring leading to a core meltdown and/or nuclear runaway condition would indeed seem small. I suspect also that a lot more safety margin will be designed into the reactor, since the plant is not designed to be economical. By "safety margin" I mean the margin between normal operation and fault conditions--for example, a stronger Doppler strength than what is being planned for target commercial plants, more instrumentation for detecting trouble, and so forth. This close supervision, and the probable added safety margin, could ensure that the Demonstration Plant will accumulate years of successful experience, which would then be cited in assuring the public on the safety of larger, and potentially more dangerous, LMFBRs, and large numbers of such plants, while the maximum explosion potential remains unknown because the full-scale, core-destruct tests will not have been performed to verify accident predictions--a false assurance indeed, but an effective one according to the art of <u>public relations</u>.

But even if the Demonstration Plant runs without mishap, this would not <u>guarantee</u> that a thousand larger LMFBRs, whose operations become routine and mundane and not nearly as much supervised, and susceptible to possible mismanagement and other human fallibility factors, will not suffer mishaps leading to dangerous, nuclear runaway conditions. Clearly, we must know the explosion potential of the LMFBR before commiting ourselves to the LMFBR.

(Incidentally, we should solicit the views of Admiral H.G. Rickover on the safety of the LMFBR since he elected to pursue development of a non-LMFBR breeder (civilian) reactor, which is cooled by water, and which does not make nor use the highly toxic Plutonium,

the Light Water Breeder Reactor, or LWBR.[211] The Navy's nuclear propulsion division, which Admiral Rickover heads, tested a liquid-metal-cooled nuclear reactor; but because of unfavorable experience with it, the Navy terminated the use of such a reactor.[212] Perhaps this unfavorable experience factored in the decision to adopt a LWBR over a LMFBR.)

Finally, the AEC staff review in a footnote stated that the LMFBR Program Plan is presently being updated. This by itself is a reason to postpone consideration and action on a LMFBR Demonstration Plant on the ground that the public should at least have the complete, updated Program Plan before passing judgment on the most important element of it--Safety. Presumably, the up-dated Program Plan addresses the above matters by providing the plans for the theoretical and experimental research along with the rationale and, hopefully, but doubtfully, the justification. Moreover, AEC stated that the safety issues contained in my dissertation "continue to be addressed," which is a ground for a full investigation into the "safety issues" I raise by the Joint Committee.

Fission Products and Their Possible Mitigating Effect on Nuclear Runaways

Recently, attention has been focused on the by-products of atomic fissioning that build up within the fuel as a result of normal use in the reactor, and the possible mitigating effect these "fission products" have on the nuclear runaway. Some of these fission products produce higher pressures at lower temperatures than the fuel material itself (i.e., the PuO_2-UO_2), which could mean that reactor shutdown due to core expansion (core

disassembly) will occur earlier in a nuclear runaway (i.e., at lower energy levels) so as to reduce the total energy yield of the runaway and the force of the resultant explosion. Indeed, the effect of the fission products was estimated by A.J. Brook to reduce a 600 lb. TNT equivalent nuclear explosion (1200 Mega-joules of explosion energy) to a negligible level with the assistance of the negative Doppler feedback.[124] Since this recent finding is obviously crucial to LMFBR safety assessment, it would be appropriate to address this development in this Rebuttal, especially since the Brook paper was published in the AEC's journal Nuclear Safety after my Statement, and the AEC' staff review of it, were published in the JCAE Hearings.

While the findings by Brook appear to be encouraging, we must be cautious in drawing conclusions for the following reasons:

1. There is an indication in the Brook data that the fission product pressure contributing to shutdown was practically due to the gaseous fission products (fission gases) retained in the fuel. Yet under core meltdown conditions, all of the fission gases could be released from the fuel (bubble-out like soda pop) and leave the core, which would render the fission products practically useless in mitigating the nuclear runaway, contrary to the thrust of Brook's article. In order that the layman will be able to follow my justification, I need first to explain the difference between "released" fission gas and "retained" fission gas.

For the used-fuel assumed by Brook, about 56% of the fission gas diffuses through the solid fuel material and collects in the thin spaces within the fuel rod, ready to be released when the fuel

rod cladding ruptures during an accident. Brook assumed that this "released" gas will "leave the core" as a result of core crumbling prior to the nuclear runaway. The remaining 44% of the fission gas is still trapped or "retained" in the solid fuel material in the form of microscopic bubbles. However, even this retained fission gas would presumably be released from the core should the fuel melt and become liquid, since the gas could bubble-out. Brook stated that:

> "it is <u>assumed</u> that all such retained gas can be released on fuel melting." 125

Despite this, Brook assumed:

> "for purposes of calculation, all 'retained' gas was assumed to be present, but no alkali metals or released gas." 126

However, inasmuch as all of the fission gases could be released, and other fission products as well, according to Brook, he should have performed a calculation for this case as well. Based on the data Brook supplied, I suspect that this case would result in little mitigating effect on the nuclear runaway, if any.

2. The strong mitigating effect on the nuclear runaway due to the retained fission gases, if assumed to be present because the fuel is solid or just became molten before the nuclear runaway, would mean that the core would be left more or less intact, and therefore capable, presumably, of suffering additional nuclear runaways, either due to core meltdown caused by the heating of the initial runaway and/or the radioactivity "decay heat," or other effects such as sodium-coolant-reentry-induced-core compaction. With core meltdown due to heating, the retained

fission gases could escape the core, setting the stage for nuclear runaway <u>without</u> mitigation from the fission products.

3. So far, the subject of autocatalytic reactivity effects has not been mentioned in connection with the effects of fission products. In this regard Brook# used a "Bethe-Tait calculation" for calculating the energy yield of the nuclear runaways he studied, which is incapable of predicting the main, worrisome kinds of autocatalytic reactivity effects, as I discussed earlier in regard to the VENUS code and the perturbation reactivity theory. In addition Brook# assumed a <u>uniform</u> fission product distribution across the core, which, in conjunction with the Bethe-Tait theory, precludes a prediction of autocatalysis altogether, since the fission product pressure would always be directed outward to disassemble the core, instead of causing fuel compaction or implosion. Actually, however, the fission product distribution in the core will be the opposite of uniformity, not only because the fissioning process which generates the fission products is non-uniform, but because the several hundred fuel bundles in the core will be shuffled around,* such that new fuel having no fission products and semi-old and old fuel having fission products will each occupy different regions in the core as dictated by economic reasons (fuel management) and operational reasons (to avoid excessive power peaking or hot spots in the core during normal operation). Conceivably, this non-uniform fission product distribution could lead to undesirable pressure distributions during a nuclear runaway that could cause region-wise core compaction or inward implosion of fuel in an autocatalytic reactivity manner, just as one worries

* when the reactor is refueled,

about such autocatalytic possibilities for distorted cores with a non-uniform density. Alluding to this concern, Brook stated:

> "The effect of such features ["nonuniform distribution of fission products throughout the core"] on the pressure field within the core should be taken into account in calculations of prompt-critical excursions [i.e., nuclear runaways] . . .[T]he implications of the non-uniform distribution of fission products have yet to be fully examined." [127]

In this regard Brook stated that his analysis of the effect of fission products was "preliminary", and further, he drew no conclusions from it other than what the calculations "indicate" for the various assumptions made.[128] The theoretical studies needed to assess the effect of the fission gases on the autocatalytic potential is part of the effort I asserted that needs to be made when I urged a thorough theoretical investigation into autocatalysis. In my dissertation (p.15) I mentioned the "fission gas pressure" and other effects which "might change drastically the ultimate course of the motion of fuel and, thus, the accident."

Incidentally, why didn't Brook mention specifically what he means by his statement that the "implications of the non-uniform distribution of fission products have yet to be fully examined," instead of letting the public guess. A clue as to why he did not elaborate might be the fact that Brook's article was published in <u>Nuclear Safety</u>--an AEC publication that can be expected to avoid pessimistic comment if there is a chance that any pessimism will be found later to be unwarranted.

4. The Brook model is theoretical, of course, and its use in LMFBR accident analysis codes would still have to be verified by full-scale, core-destruct (nuclear runaway) tests, especially in view of the concern for autocatalysis due to non-uniform fission product distribution, and the possibility for fission gas release from the core. However, because of the added compexity of nonuniform fission product distributions, which will take many complex forms, the practicality of full-scale, core-destruct tests becomes even more suspect because of the many forms that may need to be checked out.

Finally, there is the case of a new LMFBR when little or no fission products are present to possibly mitigate a nuclear runaway. Although a nuclear explosion/breaching the containment would then release correspondingly little fission products, the Plutonium release would be maximum, which questions whether the maximum possible explosion (and the consequences) will be at all affected by any fission product mitigating effect, even if such an effect could be demonstrated scientifically by full-scale, core-destruct tests for all possible accidents.
It is pertinent that the partial core meltdown in the Fermi LMFBR occurred early during its life when the reactor was being tested before being taken up to full power. This incident, therefore, suggests that the probability of a serious core accident occuring when an LMFBR is new is not any less than after it is run for an extended period of time to build up the fission products.

In conclusion, there is no sufficient basis to assess the effect of fission products on the maximum explosion potential; nor is it established that fission products must be assumed to be present in all LMFBR accident.

Unconstitutionality of the Atomic Energy Acts

Before I answer the AEC's comment on this constitutional issue, let me first address the difficulty some people have in accepting any link between the LMFBR safety issue and the constitutional issue.

It is believed by some that to raise the constitutional issue along side the safety issue only serves to confuse the latter and to question my general credibility by my claiming expertise in both fields. As to my credibility on the constitutional claim,* I refer the Joint Committee to my treatises and memorandum filed with my law suit of Webb v. AEC,[129] and the fact that the AEC has now had two occasions to reply to these papers, but has not done so. Later, I will provide a glimpse of my constitutional argument and supporting evidence, and then reply to the AEC's comment.

I. Inseparability of the LMFBR Safety Issues and the Constitutional Issue

As to joining the two issues, I view them as inseparable, because the safety issues boil down to the questions: When is something safe? And, who should decide when something is safe? The following is my argument:

The LMFBR safety issues I raise are basically twofold:

1. If LMFBRs should ever be built, should the reactor plant containment structures for withstanding explosions be designed to withstand (a) the maximum credible accident; or (b) the maximum possible accident; or (c) the maximum conceivable accident? By "withstand" I mean that the containment will absorb the explosion and contain all of the radioactivity except for a minor, harmless release. These accident categories were explained earlier (pp. 36, 36a-e). Their definitions are summarized as follows:

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* I should add that I have published a lead article in a major university law journal on another constitutional issue.[151]

Maximum Credible Accident--A possible accident which has a judged probability that, in the opinion of the decision authority, is high enough to warrant protection, and is the worst such accident in this category.

Maximum Possible Accident--The worst possible explosion accident predicted by rigorous, theoretical analyses (that have been verified by experiment) to be capable of occuring in nature, allowing for the uncertainty factors. Of course, the verification explosion experiments would not be performed if the theoretical analyses predict an unacceptable explosion hazard. In which case, the LMFBR would be rejected under this criterion of containment of the maximum possible accident.

Maximum Conceivable Accident-- The worst accident condition which cannot be ruled out by theoretical and experimental research as physically impossible, and which is calculated by rigorous theoretical analyses for the course it will take, including the uncertainty factors, and verified by experiment where practical. By its definition, the maximum conceivable accident includes the maximum possible accident.

Again, this first safety issue is: Which of the above accident categories should be the basis for the design of the explosion containment structures. A corollary question is: What should be the maximum credible accident? (Note that the "burden of proof" is different among the three categories.)

2. Should the accident analysis techniques be verified by full-scale, core-destruct tests? That is, is it inade-

quate to base accident analyses on theoretical models and extrapolation from small-scale, or in-pile, tests?

As discussed earlier, deciding in favor of the maximum possible accident or the maximum conceivable accident, and/or full-scale, core-destruct tests, would mean the postponement of the LMFBR, and possibly its rejection altogether.

These questions or issues are philosophical, and cannot be resolved with mathematical logic by technologist or scientists. Rather, in view of the possible consequences to human life on Earth should the radioactivity escape from an LMFBR, especially the Plutonium, these two safety issues involve profound human thought and value judgment of the most fundamental kind. Consider the second safety issue: It is not a question of whether this or that theory is correct; it is a philosophical question of whether a theory can be accepted without experimental verification, as science implies such verification. So, the second safety issue is really whether to turn away from the scientific method in establishing "margins of safety" for the LMFBR (if any can exist at all), which is a philosophical issue affecting the health and safety of the People, since to reject the scientific method would involve risks that would not exists if the LMFBR accident analysis codes were verified to be conservative by a wide variety of full-scale, core-destruct tests. The first safety issue is also philosophical, which is obvious, since to resolve it depends on personal, subjective judgments as to what constitutes safety.

I have expressed my personal value judgments on these safety issues in favor of the maximum conceivable accident and full-scale tests. But of course, my judgments are not inherently

correct, for I have no special claim to infinite wisdom. Also, there are value judgments to be made and balanced concerning the alleged necessity for the LMFBR. Perhaps the health and safety of the public requires accepting the risks that would be incurred by rejecting my judgments, because of other factors I may have not weighed sufficiently. There should be no doubt, however, that the safety issues I raise are legitimate, and are profoundly important to the health and safety of the People.

Because of the extreme profoundness of the safety issues, and the implications to the health and safety to ourselves and our posterity, it is necessary, therefore, that we resolve them in the most careful manner. But because of their philosophical character, involving human value judgments as they do, we should refer to more than just the natural law, such as the laws of physics and chemistry, but the human law as well--specifically, the branch of human law defined by Blackstone as "civil law . . . a rule of civil conduct prescribed by the supreme power in a state, commanding what is right and prohibiting what is wrong." (Blackstone's Commentaries, Intro., p.44) The "supreme power" of making civil law is the "sovereignty," which in the United States under the State and Federal Constitutions rests ultimately with the People, as distinguished from a Parliament.* These Constitutions are the fundamental civil laws in the United States, and prescribe the powers of government and the rights of the People.

One of the fundamental rights of the People is "to pursue and obtain safety," which is expressly declared in the State Constitutions and ensured in the Federal jurisdiction by the Ninth

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* As with other nations.

Amendment of the U.S. Constitution. The People have provided for their safety and welfare by instituting government under a written constitution and vesting it with certain powers to act, and withholding from their government those powers not granted. (The Tenth Amendment of the U.S Constitution.) The civil law, therefore, tells us that the LMFBR safety issues should be resolved by the People, unless the People had delegated the decision power or authority to the federal government when establishing or amending the U.S. Constitution. By "the People" I mean the People acting through their representatives in each of the States, either in conventions, or state legislatures.

The profound philosophical nature and importance of the safety issues, therefore, demands that we carefully review constitutional procedures to ensure that the human law--i.e., the civil law--is abided by, else we risk chaos by violating well-established principles of social contract. Such is the link between the safety issues and the constitutional issue that I raise. Accordingly, we should review the Atomic Energy Act of 1954, and subsequent amendments, and the associated legislative history; and then review the Constitution, along with the recorded intentions of the Founding Fathers in the Federal Convention of 1787 and the States' Ratification Conventions, The Federalist, and other sources. Such review will show without doubt that the civilian nuclear power portion of the Atomic Energy Act violates the Constitution. That is, the LMFBR, and other civilian nuclear projects as well, are being promoted, and hence the safety issues are being decided, by the Federal Government without authority from the People, which our Founding Fathers would call "usurpation." This in turn means that the People are being denied their Right to pursue and obtain safety against the LMFBR and other nuclear hazards by deciding whether Congress should be granted such authority.

This right of the People includes the right to decide the fundamental safety issues, or to reject the LMFBR, or even the civilian nuclear power program as a whole, and thus to avoid the risks altogether, by rejecting a constitutional amendment that Congress must propose if Congress wants to proceed with civilian nuclear power.

Therefore, the safety issues I raise, which involves human value judgments, cannot be resolved by Congress and/or the AEC in favor of proceeding with the LMFBR Demonstration Plant program without violating human law. To decide human values (safety) in a way which violates human law is contradictory, and would therefore mean that the safety issues would not be resolved at all. It follows, then, that the said safety issues and the constitutional issue are inseparable.

Another reason for my linking the two issues is grounded on probability. George Washington in his Farewell Adress said of usurpation that "it is the customary weapon by which free governments are destroyed." Usurpation implies "special interests," and powerful interests as well. Therefore, for me to raise these LMFBR safety issues without raising the constitutional issue as well would mean that in all probability the safety issues, which have arisen because of usurpation, would be quashed by that same usurpation, since it would only be my value judgment in competition with those judgments of the usurpers, who simply have the power by the very fact of their usurpation. Specifically, if I were to raise only the safety issues before a body in any legal forum outside the AEC, that body would plead "lack of jurisdiction" and I would be referred to the AEC or to the Congress, both whom are the usurpers in regards to civilian nuclear power. The usurpers would then politely listen to my claims, or merely receive them,

and then quietly reject them with some brief, subjective argument, such as the claim that the probability of the accidents are too low to warrant analysis, or that the issues are beyond the scope of the proceedings, or that the AEC is adequately investigating the matter. Such as been my experience in raising these and other nuclear safety issues. In other words, for me to raise the safety issues without raising the constitutional issue would in all probability, be a futile exercise, having the same effect as if I had not raised them at all.

Moreover, besides the welfare of the People in general, my interests are personal, involving my constitutional right to pursue and obtain safety for my family and the rest of my posterity relative to the LMFBR. It is necessary and proper that I assert my constitutional rights, and seek their enforcement, when questioning my family's safety relative to civilian nuclear energy.

To see the inseparability of the LMFBR safety issues and the constitutional issue in another light, let me add that public safety issues, which involve human value judgments, cannot be adequately resolved by usurpers with their special interest, since such judgments would constitute only what the usurpers judge <u>their</u> safety to depend on, no matter how they argue or might believe that their interest is the welfare of the People. But for the People's welfare to be truly arrived at, the People should resolve the fundamental safety issues, through their constitutional representatives. Specifically, Congress should review the wisdom of civilian nuclear power. If Congress should decide that it would be desirable to proceed with civilian nuclear power development (the LMFBR, for example), then Congress

should so propose to the States a constitutional amendment proposition and thereby request from the People the constitutional authority. The People, through their representatives in each of the States' conventions, will then consider the matter. In the course of these proceedings, the LMFBR safety issues will be resolved.

A final reason for why the safety issues are inseparable from the Constitutional issue is that Article VI of the U.S. Constitution declares that all executive officers and members of the legislature are bound to support the Constitution. Since the AEC and the JCAE cannot resolve the safety issues in favor of proceeding with the LMFBR Demonstration Plants without violating the Constitution, it follows, then, that the issues are inseparable.

II. Short Proof of My Constitutional Claim

The following is a glimpse of my proof that the civilian nuclear power program under the 1954 Atomic Energy Act, and subsequent amendments, is unconstitutional.

A review of the said Act and its legislative history reveals that the civilian nuclear power portion is based on the explicit assumption that Congress has the power "to provide for the general welfare" and the implicit assumption that Congress has the power "to promote manufactures." These assumptions are allegedly grounded on the taxation clause, with its welfare clause, and the commerce clause in the U.S. Constitution, to wit:

> "The Congress shall have Power To lay and collect Taxes, Duties, Imposts and Excises, to pay the Debts and provide for the common Defence and general Welfare of the United States; . . .
>
> "To regulate Commerce with foreign Nations, and among the several States, . . ." 130

However, the records of the Federal Constitutional Convention and the States' Ratification Conventions; The Federalist, which was a collection of 85 essays written by advocates of the Constitution during the Ratification Debates to explain the Constitution; the transcripts of the early proceedings in Congress; early Presidential messages, and early Supreme Court opinions; which together record and affirm the intentions of the Founding Fathers, reveal that:

(1) The taxation clause is no grant of power to provide for the general welfare, nor a power to spend money from the Federal Treasury for the broad and undefined objects of the general welfare; but merely a power to raise money--a power that the Continental Congress lacked under the previous Articles of Confederation, which was one of the deficiencies that led to the convening the Federal Constitutional Convention.[131] The spending power (i.e., the appropriations power) was to be confined to the limited, enumerated powers that followed the taxation clause (except to pay the expenses incidental to the laying and collecting taxes, duties, etc.), such as the regulation of commerce power and the powers "To raise and support Armies . . ," and "To constitute Tribunals inferior to the supreme Court." (See Article I, Section 8 of the U.S. Constitution.)

(2) The welfare clause was affixed to the taxation power merely to limit the purposes for which taxes could be layed and collected.* Originally, during the Constitutional Convention the clause "to lay and collect taxes, duties, imposts and excises" stood alone. But, the Framers wanted the People to understand that the tax revenues would be used to repay the debts incurred during the Revolutionary War--hence, the clause "to pay the Debts"

* To ensure against Congressional exercise of the taxation power to the detriment of a minority.[132]

was affixed. But to leave it at that would have meant that taxes could only be laid and collected to pay debts; so the clause "and the necessary expenses of the United States" was added. But even this was thought not to be sufficiently broad, since "Duties" on imports, for example, might need to be collected, not so much to raise money to pay expenses of government, but for regulation-of-commerce purposes. For fear of using phraseology that could render the taxation power impotent if allowed a strict definition of the purposes for raising money, the Framers simply fell back on the Eighth Article of Confederation for the "common defence and general welfare" phraseology, to wit:

> "All charges of war, and all other expenses that shall be incurred for the common defence or general welfare, and allowed by the united states in congress assembled, shall be defrayed out of a common treasury which shall be supplied by the several states, . . ."[133]

This article of the Confederation contained no grant of power to spend money; rather, it merely established a treasury and how it was to be plenished. Thus, just as the welfare clause in the Eighth Article of the Confederation was well understood by the Framers of the Constitution to be no grant of power to spend money for the indefinite, general welfare; so too, the welfare clause in the Constitution was to be no such grant of power. (See, for example, The Federalist, No. 41; and letters from Madison.[132])

(3) The words "Commerce" and "Manufactures" were to denote separate and coordinate fields of human industry; and, thus, a power to regulate one field (commerce) does not imply a power to regulate the other (manufactures), nor a power to promote the other by spending from the federal treasury, such as promoting the

manufacturing of electricity by atomic energy by a deliberate federal program of spending and regulation. The phrase "Commerce among the several States" was simply to denote that activity that took place at ports--the coming and going of merchandise.

In order to show that in the Federal Constitutional Convention of 1787 understood the difference between commerce and manufactures, it was proposed, but rejected, to grant Congress the power:

> "To establish public institutions, rewards and immunities for the promotion of agriculture, commerce, trades and manufactures."[134]

Also, the Supreme Court in Kidd v. Pearson, 128 U.S. 20,21 (1888) ruled that "commerce" does not imply "manufactures", and that a power to regulate commerce does not confer power to regulate manufactures.

(4) No sophistry was to be used to infer incidental powers from the commerce clause or other clauses of the Constitution--i.e., only those incidental powers that are plainly implied by the enumerated powers of Article I, Section 8, and which are necessary and proper for carrying into execution the enumerated powers, can Congress exercise. For example, the power to regulate commerce among the States implies a power to pass a law for paying the salaries of the executive officers who are [illegible] to inspect the trade, and lay and collect the duties according to the schedule established by Congress. (However, the promotion of nuclear manufactures is based on the sophisticated argument that unless the federal government provides abundant energy, commerce will suffer, and, therefore, to regulate commerce supposes a power to bring about the flow of goods by directly causing their manufacture in order to then in turn regulate that flow. With such sophistry, one could use the commerce clause as an argument for making practically any law.) Therefore, Congress has the power to

regulate commerce among the States, not a substantive power to promote commerce, nor a substantive power to promote manufactures. The interstate commerce power is a power to only legislate on the articles of interstate commerce. 177 (n)

The principle which is fundamental to the Constitution is that the Government derives its powers from the Consent of the People, which was ascertained by the Tenth Amendment:

> "The powers not delegated to the United States by the Constitution, nor prohibited by it to the States, are reserved to the States respectively, or to the people."

The Federalist explained the limited powers of Congress:

> "In the first place it is to be remembered that the general [federal] government is not to be charged with the whole power of making and administering laws. Its jurisdiction is limited to certain enumerated objects . . . .
>
> "The powers delegated by the proposed Constitution to the federal government are few and defined. Those which are to remain in the State governments are numerous and indefinite. The former will be exercised principally on external objects, as war, peace, negotiation, and foreign commerce; with which last the power of taxation will, for the most part, be connected. The powers reserved to the several States will extend to all the objects which, in the ordinary course of affairs, concern the lives, liberties, and properties of the people, and the internal order, improvement, and prosperity of the States.: (Nos. 14 and 45.)

This principle of limited, enumerated powers would be non-existent if the People had granted Congress the indefinite (and therefore unlimited) power of providing for the general

welfare, or if the power to regulate commerce among the States was to include a power to legislate on any activity, just so long as it affects commerce, which again is an unlimited power, since everything affects commerce in one way or another.

Recent Supreme Court opinions, such as U.S. v. Darby, 312 U.S. 100 (1940), and U.S. v. Gerlach Live Stock Co., 339 U.S. 738 (1949), however, contended in effect that Congress has the power to spend money for the indefinite, general welfare, and to regulate manufactures; i.e., the power to make "internal improvements." These unfounded opinions, thus, overturned previous Supreme Court opinions and well established, constitutional history, and thus sanctioned the initial precedents of unconstitutional programs in the 1930s and 1940s. This process of usurpation was gradual at first; but the precedents soon gave way to massive programs of the federal government such as the civilian nuclear power program, and more recently the "peaceful uses" of nuclear explosives, as the Congress used and continues to use these recent Supreme Court opinions as if they are the Constitution--i.e., as if the government derives its powers from the unfounded dicta and opinions of the Supreme Court instead of from the consent of the People. But our Founding Fathers understood that:

> "the law, and the opinion of the judge, are not always convertible terms, or one and the same thing; since it sometimes may happen that the judge may mistake the law."[135]

The judges in these recent cases mistook the fundamental law. Their sole offer of proof amounts to a reference to Justice Story's Commentaries on the Constitution; an erroneous, theoretical inference made from the earlier, and famous, Supreme Court opinion delivered by Chief Justice John Marshall in McCullough

v. Maryland, 4 Wheat. 316,421; and an unsupported comment by Alexander Hamilton. Story's basic references were James Monroe's Message on Internal Improvements, and Hamilton's comment on the welfare clause. However, Monroe's Message on Internal Improvements was misrepresented by Story, since President Monroe specifically contended that Congress does not have the power to make internal improvements based on the welfare and commerce clauses, or any other clauses in the Constitution.[136] The theoretical inference from the opinion in McCullough v. Maryland was simply a unfounded play-on-words, and contained no supporting, historical information. The baseless inference was essentially as follows:

The court opinion in McCullough v. Maryland asserted in regard to the "implied powers" of Congress that if the "end is legitimate," then those means which are "appropriate" (i.e., "plainly adapted" to the legitimate end, and in the "spirit and letter" of the Constitution) are constitutional. From this opinion, however, the supreme court in U.S. v. Darby erroneously inferred, without any offer of historical support, that the means are automatically "appropriate" if taken to attain a legitimate end, which is a version of the dangerous rule that the "end justifies the means." Thus, Darby switched the criterion for appropriateness from those means which are plainly adapted and in the letter and spirit of the Constitution (the Darby opinion neglects these terms) to any means, just so long as they are taken to attain a legitimate end, no matter how indirect the path. The Darby opinion offered no proof and even supplied its own contradiction:

> "The power of Congress over interstate commerce is not confined to the regulation of commerce among the states."
> 312 U.S. 118

The Hamilton quotation is as follows:

> "It is, therefore, of necessity, left to the discretion of the National Legislature to pronouce upon the objects which concern the general welfare, and for which, under that description, an appropriation of money is requisite and proper. And there seems to be no room for a doubt, that whatever concerns the general interests of learning, of agriculture, of manufactures, and of commerce, are within the sphere of the national councils, as far as regards an application of money." [137]

Hamilton asserted this power of appropriating for the general welfare in his 1792 Report on Manufactures.* He offered no supporting historical information for his claim. Moreover, The Federalist, which he co-authored by writing fifty-one of the eighty-five essays, asserts the opposite (No. 41). (The Federalist was written to explain the Constitution during the Ratification Debates.) In the fifty-one essays written by Hamilton, nowhere did Hamilton make the claim that he later asserted in his Report on Manufactures after the Constitution was adopted and the federal government came into operation.** And neither when he addressed the New York Convention which ratified the U.S. Constitution, did he assert his later claim.[138] If he had, the Convention would have rejected the Constitution, since the States were keenly intent on limiting the powers of Congress and were repeatedly assured that this was precisely what the Constitution does, and that the welfare clause was no grant of power.

Let us consider a typical excerpt from the transcripts of the State conventions which ratified the Constitution, specifically the Virginia Convention. There, the opponents led by Patrick Henry

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* As Secretary of the Treasury

** Nor did Hamilton even mention the welfare clause in his essays in The Federalist.

feared that the <u>welfare</u> clauses would eventually be contrued by Congress as a grant of power. One of the leading advocates of the Constitution, Governor Randolph, assured the convention delegates that this could not happen:

> "But the rhetoric of the gentleman has highly colored the dangers of giving the general government an indefinite power of providing for the general welfare. I contend that no such power is given. They [Congress] have power 'to lay and collect taxes, duties, imposts, and excises, to pay the debts and provide for the common defence and general welfare of the United States.' Is this an independent, separate, substantive power, to provide for the general welfare of the United States? No, sir. They can lay and collect taxes, &c. For what? To pay the debts and provide for the general welfare. Were not this the case, the following part of the clause would be absurd [i.e., 'but all duties, imposts, and excises shall be uniform throught the United States']. It would have been treason against common language. Take it altogether, and let me ask if the plain interpretation be not this--a power to lay and collect taxes, &c., in order to provide for the general welfare and pay debts. (<u>Elliot's</u> <u>Debates</u>, III, 466.)

Near the end of the Virginia Convention when the opponents of the Constitution sensed defeat, they reverted back to worrying about the <u>welfare</u> clause. To this Randolph laid the issue to rest when he said that they were:

> "back to the clause giving that dreadful power, for the general welfare. Pardon me, if I remind you of the true state of that business. I appeal to the candor of the honorable gentleman, and if he thinks it an improper appeal, I ask the gentleman here, whether there be a general, indefinite power of providing for the

> general welfare? The power is, 'to lay and collect taxes, duties, imposts, and excises, to pay the debts, and provide for the common defence and general welfare;' so that they [Congress] can only raise money by these means, in order to provide for the general welfare. No man who reads it can say it is general, as the honorable gentleman represents it. You must violate every rule of construction and common sense, if you sever it from the power of raising money, and annex it to any thing else, in order to make it that formidable power which it is represented to be." (Elliot's Debates, III, 599)

(Contrary to such assurances given to the delegates of the People in 1788 when the Constitution was established, the Congress declared in the 1954 Atomic Energy Act, Chapter 1. "Declaration, Findings, and Purpose," Section 2.g. and 2.i., that:

> "Funds of the United States may be provided for the development and use of atomic energy under conditions which will provide for the common defense and security and promote the general welfare.
>
> "In order to protect the public and to encourage the development of the atomic energy industry, in the interest of the general welfare and of the common defense and security, the United States may make funds available for a portion of the damages suffered by the public from nuclear incidents, and may limit the liability of those persons liable for such losses.")

Indeed, very early in the Federal Constitutional Convention Hamilton suggested a plan of Government which would give Congress the unlimited power: "to pass all laws whatsoever. . ," as he suggested the dissolution of the States and replacing them with one general government for the country.[139] Specifically, Article VII of his plan stated:

> "The Legislature of the United States shall have power to pass all laws which they shall judge necessary to the common defence and general welfare of the Union . . ."[140]

However, Hamilton's plan received no support in the Convention. For as Hamilton himself said:

> "He was aware that it went beyond the ideas of most members."[141]

It thus appears that Hamilton as Secretary of the Treasury attempted after the Constitution was adopted by the People, and after the federal government began operation, to effectuate broad, unlimited power for the federal government which he could not gain approval of when the federal government was established.

Thus, the Supreme Court in the Darby and Gerlach opinions misinterpreted the meaning of the welfare and commerce clauses. Their interpretations are nothing but unfounded opinions. For surely, the only equitable way by which the Judiciary should interpret the Constitution is to examine the intentions of the People of 1787-1788 who, through their duly appointed representatives, ordained and established--i.e., legislated-- the Constitution or the fundamental law. As Blackstone asserted:

> "The fairest and most rational method to interpret the will of the legislator is by exploring his intentions at the time when the law was made, . . ." (Commentaries, Intro., 59.)

By "will of the legislator" Blackstone meant "the true meaning of a law." (Id., 61) This "fairest and most rational method" was not used by the Supreme Court in Darby and Gerlach; rather the court substituted its unfounded opinion over the recorded

intentions of the Founding Fathers.

Moreover, these court opinions are not the Constitution, since the judicial power extends only to settling specific controversies between litigants,* and does/ not extend to resolving Constitutional questions for the license of Congress. As John Marshall said:

> "By the Constitution, the Judicial Power of the United States is extended to all cases in law and equity, arising under the Constitution, laws, . . .[but is not] to extend to all questions arising under the Constitution, . . . A case in law or equity was a term well understood, and of limited signification. It was a controversy between parties which had taken a shape for judicial decision. If the Judicial Power extended to every question under the Constitution, it would involve almost every subject proper for Legislative discussion and decision; . . .The division of power . . .could exist no longer, and the other departments would be swallowed by the Judiciary." (Annals of Congress, 6th Cong., 606)

The Supreme Court opinions in Darby and Gerlach on the welfare and commerce clauses, therefore, have no force of law or reason. 178(h)

Besides the promotion of civilian nuclear power by the unconstitutional Federal spending programs of research and development, and other subsidies, another unconstitutional manifestation of the Atomic Energy Act is the 1957 Amendment (The Price-Anderson Act), which limits the legal liability of the nuclear industry for redressing injuries / due to nuclear accidents by granting immunity from such responsibility. (Recall that this immunity shows up in the published technical reports on LMFBR safety in the form of the disturbing disclaimer-of-responsibility for the

* A judicial decision applies only to the specific case for which the decision was made; and the associated opinion on the meaning of the Constitution is not binding on any future decision of any department of government, but has only such influence as the force of its reasoning may deserve. Furthermore, the present

"accuracy, completeness or usefulness" of the information contained in the reports.) Since the legal liability problem was a major roadblock to the growth of nuclear power back in 1957, Congress passed the 1957 amendment to clear this obstacle by the simple expediency of granting immunity from liability in order to promote nuclear manufactures--the manufacture of electricity using nuclear power plants. That Congress lacks constitutional authority to vest the AEC with the power to promote the LMFBR, for example, by Federal spending and the granting of immunities from legal liability is shown by the compelling evidence in the records of the Federal Constitutional Convention of 1787 that "ordained" (prepared) the Constitution; viz., the before-mentioned proposition to include among the powers of Congress the clause:

> "To establish public institutions, rewards and immunities for the promotion of agriculture, commerce, trades and manufactures." [134]

But, this clause was rejected by the Federal Convention. Yet, this power, despite its rejection by the Federal Constitutional Convention, has been assumed or usurped by Congress for the civilian nuclear power program. Observe: (a) public institutions--the Atomic Energy Commission and its "national laboratories;" (b) rewards--federal contracts, grants, graduate fellowships, etc.; and (c) immunities--the Price-Anderson amendment.

Incidentally, this rejected clause was proposed after the existing commerce clause (the power to regulate commerce with foreign nations and among the states) was adopted by the Convention,

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issue of the welfare clause has never been squarely before the Supreme Court for a settlement, notwithstanding Gerlach. See Note No. 178 in the back.

which signifies that the delegates of the Convention who proposed that Congress be vested with the power to promote manufactures (indeed to promote commerce as well) understood that a power to regulate commerce among the states was not sufficient to reach the object of promoting manufactures or commerce.

Furthermore, another clause that was rejected by the Federal Constitutional Convention was:

> "[Congress shall have Power] to encourage, by premiums and provisions, the advancement of useful knowledge and discoveries." [134]

This too would have provided a power to promote an LMFBR, but it too was rejected. Note that Article I, Section 8 of the Constitution includes the power:

> "To promote the Progress of Science and useful Arts, by securing for limited Times to Authors and Inventors the exclusive Right to their respective Writings and Discoveries; . . ."

Now, if the Founding Fathers wanted Congress to have the power to promote science and the useful arts (technology, for example), then surely they would have left off the qualifier "by securing for limited Times . . . the exclusive Right . . ," which limits such power to promote science and technology to the providing for patents and copyrights.

Characteristic of the recent assumption by Congress of the unconstitutional powers to provide for the general welfare and promote manufactures and civilian technology is the total lack of historical justification, nor any attempt at such. From the legislative history of the Atomic Energy Act we learn that Congress simply claimed such power without offering any historical proof.[152] Presumably, Congress

relied on the aforesaid supreme court opinions, which too are unfounded and void of historical evidence of the intentions of the Founding Fathers, or evidence of Congressional practice for the period of 1787-1920.

Of course, this revelation of the limited, enumerated powers of Congress has profound implications on most other federal programs of today as well, such as social security, aid to education, super-highways, civilian space programs, foreign aid, airport subsidies, and so forth. But then the civilian nuclear program with its LMFBR has extreme implications for the health and safety of the People and their Posterity that overweighs any reasons for "winking" at the Constitution, which some might suppose is proper. I am not proposing that we repeal all such unconstitutional federal programs. Rather, I call for separating out which powers that Congress usurped that we the People want Congress to exercise, and which powers we still want to withhold.

This concludes the glimpse of my constitutional proof, which is no substitute for the complete proof contained in my law suit materials in <u>Webb</u> v. <u>AEC</u>, which I referred the JCAE to.*

III. <u>Reply to the AEC's Comment on the Constitution Issue</u>:

Let me now turn to the AEC's comment on this constitutional issue that is contained in the AEC's staff review. The AEC in their letter forwarding the staff review concluded that the staff review <u>indicates</u> that my Statement offers no justification for reversing the AEC's current plans for the LMFBR Demonstration Plant, either from technical or <u>legal</u> standpoints. The AEC's comments on the technical aspect have already been treated.

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* I hope to publish my treatises in book form under the title "The Limited, Enumerated Powers of Congress." The book will also include an exhaustive analysis of the Government's Brief in <u>U.S.</u> v. <u>Butler</u>. (See note 178.)

The legal aspect, of course, refers to this constitutional issue. However, on this legal issue the AEC's staff review provides no legal or historical justification for the Joint Committee to dismiss my allegation, nor does the staff review even offer any.

The AEC's staff review correctly reports that the U.S. District Court in Webb v. AEC ruled only that I lacked standing* to challenge the constitutionality of the Atomic Energy Acts. Concerning the constitutional issue, however, the Court did not express an opinion, despite the fact that the AEC's memorandum in support of its Motion to Dismiss argued at some length that the civilian nuclear program is constitutional,** and that in response to the AEC's memorandum I submitted my complete proof, which was in the form of thoroughly researched treatises of the intentions of our Founding Fathers and early interpretations of the welfare and commerce clauses, including an exhaustive analysis of the records of the Federal Constitutional Convention of 1787 and the States' Ratification Conventions, and an analysis of Supreme Court opinions on the matter, including all of those cited by the AEC in their memorandum. (The AEC even had an opportunity to reply to my response, but chose not to.)

In a somewhat similar case, Pauling v. McElroy, 278 F.2d. 252 (C.A.D.C. 1960), Pauling alleged that the Atomic Energy Act was unconstitutional in regards to the AEC's military nuclear weapons test program; but both the district court and the court of appeals in that case ruled that the weapons test program was constitutional,

* Standing refers to the fact that the complaintiff bringing the suit has alleged a sufficient personal stake to require the court to take up the case.

** By citing only recent Supreme Court opinions on the welfare and commerce clauses.

despite their added rulings that Pauling lacked standing to sue. Therefore, the fact that the present constitutional issue was debated in the pleadings, coupled with the fact that the district court did not express an opinion on this issue, indicate, in light of Pauling v. McElroy, that the AEC's contention that Congress is empowered to provide by statute for a civilian nuclear power development program is not "well settled," as the AEC asserted in Webb v. AEC.

Thus, the AEC's staff review contains absolutely no information (court opinions or historical evidence) which even indicates that my Statement offers no legal justification for "reversing" the AEC plans for the LMFBR demonstration plants, contrary to what the AEC concluded in their forwarding letter. That is, by merely reporting that the district court ruled that I lacked standing does not shed any light on the constitutionality of the civilian nuclear power program whatsoever.

Regarding standing, I continue to believe that I do have standing to sue, since the AEC is working to build about 1000 nuclear reactors by the year 2000, which in fact will represent a real hazard to me and my family. I seek to enjoin the AEC from carrying out the civilian nuclear power program in order to be able to fully assess the associated hazards, which I believe and alleged are unacceptable as things now stand at least, and to exercise my share of the People's right to decide whether to vests Congress with the power to carryout a civilian nuclear power program, and, thereby, to make the judgment as to the necessity for and safety of such a program. Thus, I am seeking an enforcement of my constitutional right to "pursue and obtain safety," which is expressly protected in the Ohio and Indiana Constitutions, for example, and the

Ninth Amendment of the U.S. Constitution. The recent Supreme Court in Laird v. Tatum, 408 U.S. 1,13, held that in order to have standing to sue one must allege a "threat of specific future harm." In my Complaint, I alleged partly that "civilian nuclear power (fission) is not safe based on what is known and unknown today," which denotes an alleged threat of specific future harm, and which I ought to be allowed to amplify. In my memorandum in opposition to the AEC's motion to dismiss I so amplified my complaint by showing specifically how the civilian nuclear power program of the AEC is detracting from my safety. (Incidentally, the AEC did not deny my allegations of fact.) But in ruling that I lacked standing, the district court referred only to part of my complaint in which I alleged that my right to assess and provide for my family's safety as it relates to civilian nuclear power is being abridged. (The court said that this claim is insufficient for standing.) However, the Court ignored the fact that my complaint further alleged that the said program is not safe based on what is known and unknown today; and the district court ignored also my subsequent amplification. I attempted to appeal the district court's judgment about my standing to sue on the ground that both my amplification of my complaint and my "not safe" allegation, which I supported in my complaint with a list of nuclear safety questions, must be addressed by the court; but the court of appeals for the sixth circuit denied my motion to proceed on appeal in forma pauperis.* Because of my poverty I could not continue with the suit; and now the time for appeal has passed. I plan to make out a new complaint later.

My resorting to the judiciary would not be necessary if the members of Congress would discharge their responsibility of Article VI of the U.S. Constitution to support the Constitution. Now, I am not claiming that Congress must abide by my interpretation; but I ask that Congress ascertain for themselves (individually) the

* Without paying fees and giving security and printing numerous copies of briefs in book form, because of reason of poverty.

true meaning of the Constitution in the light of my challenges, and supporting treatises and citations, in order to <u>ensure</u> that Congress does indeed support the Constitution.

The AEC in its staff review and associated forwarding letter seems to be contending that unless a federal court declares the AEC's civilian nuclear power program unconstitutional, the JCAE and the rest of Congress need not or cannot question the constitutionality of the program. This is not so, however, since Article VI of the U.S. Constitution declares:

> "The Senators and Representatives before mentioned, . . .shall be bound by Oath or Affirmation, to support this Constitution; . . ."

There are no qualifiers, such as, "as interpreted by the Supreme Court in it latest opinions." I prove this point in my law suit memoranda and attachments, which I referred the JCAE to, by drawing on the theory of the "judicial Power" as understood by the Founding Fathers.

The evidence revealed in my law suit materials proves the unconstitutionality of the said nuclear program, and these materials are what I stand on. It should be noted that the AEC has yet to respond to this proof, although the AEC has had two occasions now to do so. I again urge the Joint Committee on Atomic Energy to study my law suit materials and not rely on soothing assurances from the AEC that the constitutionality of the civilian nuclear program is "well settled." If the AEC will not loan the Committee my law suit materials, which I cannot imagine, I shall be happy to provide the committee with a set if I knew that the JCAE would seriously review the matter. Significantly, the AEC staff review does not re-affirm the AEC's court pleading that the civilian nuclear program is constitutional, now that the AEC has my disproof.

Availability of AEC-Contractor Reports

The AEC's comment about the availability of AEC-Contractor reports assures the Joint Committee that published AEC research and development reports are available to the public. However, the AEC neglected to address my comment about internal distribution R&D reports. I would like, therefore, to re-emphasize that there are unpublished R&D reports emanating from AEC contractors which are not available to the public. These come under the classification of "limited distribution reports." (Even ANL "internal memoranda" are availble to selected persons outside of the Argonne National Laboratory.)[153] Examples of such reports which have come to my recent attention are:

(1) ANL Reactor Development Program monthly progress reports, bearing the ANL-RDP serial prefix, which reports the safety R&D;

(2) Volumes I and II of the "Fast Reactor Safety Test Facility Study," which was an ANL LMFBR Nuclear Safety Program project. Volume I was entitled "Program"; and Volume II was entitled: "LMFBR Accident Delineation and Recommended Program of In-Pile Safety Experiments."

(3) Four (4) "limited distribution reports" on the subject of "Fuel Dynamics Studies in TREAT," mentioned in ANL-7765, December 1970, which discussed the all-important fuel motion during an LMFBR accident.

The RDP reports mentioned above bear the following notice:

> "Any holder of this document is prohibited from making any further distribution to third parties representing foreign interests, foreign governments, foreign companies, and foreign subsidiaries of foreign divisions of U.S. companies, without the prior approval of the Director, Division of Reactor Development and Technology, U.S. Atomic Energy Commission."

It is difficult to see how such a restriction could be enforced, except by selecting recipients. But in all fairness I should add that I was able to get the ANL-RDPs, but only after considerable pleading and negotiation, as the AEC now demands $7.60 per copy, which makes the RDP reports practically unavailable to the public. Furthermore, there is evidence that the RDP reports are first reviewed by the AEC before being released to or made available to the public. For one such RDP report that I received bears the following additional notices:

> "NOTICE--This report contains information of a preliminary nature and was prepared primarily for internal use at the originating installation. It is subject to revision or correction and therefore does not represent a final report. It is pass to the recipient in confidence and should not be abstracted or further disclosed without the approval of the orginating installation or USAEC Technical Information Center, Oak Ridge, TN 37830."
>
> "Distribution of this Document is Limited To Government Agencies and Their Contractor & CAR."

The Volume I report mentioned in (2) above was submitted to the AEC and the nuclear industry for review and comment, and "was revised to take account of the specific comments of the reviewers,"[38] and was finally published as ANL-7657, "Safety Problems of the LMFBR," by C.N. Kelber, et al., which was referenced in the LMFBR Demonstration Plant Environmental Statement. Volume II

was never published. The copy which I was able to obtain has the following notice attached:

> "NOTE: This is a limited-distribution report for the use of the recipients. It is not intended for and has not been reviewed for publication, and should not be given broader distribution without permission of the author, or be referenced in publication."

The report too was "submitted for review and comment," presumably to the AEC and to industry as the report "presents the recommended program of in-pile experiments," and mentions that the Volume I report "was submitted to the AEC and to industry for review and comment in June, 1969."

I recently have been told by a source I wish to keep anomonous that a new classification of ANL reports is being promulgated with the following two separate categories: "base technology" and "applied technology," where reports under the latter category would <u>not</u> be available to the public. 205(n)

The point I wish to make here is that there are crucial R&D reports on LMFBR safety emanating from Argonne National Laboratory which are <u>not</u> available to the public,* except in selected cases, and then <u>after</u> the AEC and "industry" review and comment on them before being put into the "final" form. This practice prohibits the public and Congress from receiving uncensored information of the progress of the LMFBR safety R&D work, and in some cases prevents the public's access to R&D reports altogether. Under such policy, the Congress and the People will stand the risk of not being fully informed on what the LMFBR safety researchers are finding out on this profoundly important subject. In my opinion

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* Not even to the nuclear engineering departments of the universities affliated with ANL. See Appendix D.

all LMFBR R&D reports emanating from ANL, and other AEC contractors, in any way whatsoever, whether they be draft reports, final reports, or internal distribution reports, internal memoranda, or limited distribution reports, just so long as they issue forth from Argonne National Laboratory, or other contractors, to persons or organizations outside, should be made available to the public without prior review by the AEC, or the nuclear industry, or anyone else, including those documents which are submitted for review and comment by the nuclear industry and/or the AEC. If the AEC disagrees with any conclusions, findings, quality of the reported work, or recommendations, the AEC can issue their own report or have ANL issue a supplemental report where the points of disagreement are openly discussed.

Therefore, I call on the Joint Committee to require the AEC to make cheaply available all LMFBR R&D reports that have emanated and will emanate from ANL and other AEC contractors, and make public a list of such reports.

What reports that are available are costly, from $3 to $7.60 per copy. This simply is not reasonable, especially for poor persons, such as myself, who have families to support on an annual income of less than $5000, and who are trying hard to assess their safety in relation to the LMFBR, which requires study of numerous R&D reports. For example, since the last annual report was issued for the LMFBR Nuclear Safety Program at Argonne National Laboratory, which was for the annual period

ending June 1970, over thirty-one (31) monthly progress reports must be obtained in order to determine the R&D "progress" for the LMFBR. The AEC's Technical Information Center (TIC) has told me that the RDPs (the monthly progress reports for ANL) costs $7.60 per copy. Thus, in order to learn the progress being made at ANL the citizen must now pay over $150, whereas these reports up until this AEC policy was announced (which was about the time my Statement on the LMFBR Demonstration Plant was submitted) use to be free upon request at ANL. Argonne long had this policy of supplying R&D reports on the LMFBR free upon request, which I found essential for my graduate studies. But now, the AEC has stopped this practice. According to ANL:

> "Recently, the U.S.A.E.C. revised its policy regarding the distribution of reports on LMFBR. Any future reports on the LMFBR safety program will be distributed according to this revised policy which precludes distribution of these reports by the Argonne National Laboratory except as directed by the U.S.A.E.C." [142]

The AEC staff review states that it has long been the policy of the government to attempt to recover the costs of printing R&D reports.[156(n)] However, this statement contradicts the previous long standing policy of ANL. Furthermore, U.S. Senator Edmund Muskie recently stated in a Senate committee hearing[143] that the intent of Congress in passing the Freedom of Information Act was that the "cost recover" principle or rule was not to be the policy; rather, the government was to adopt only such a policy as would discourage wasteful orders. The benefit to the public by encouraging critical review of LMFBR R&D reports under a "free on request" policy surely outweights the trifling expense of printing extra copies when compared to the costs of the nuclear projects, or the cost of a disaster averted because of such review.

The AEC staff review suggests that I travel long distances to a central library to read microfilm copies of the R&D reports. (The AEC failed to notice that I reside in Bloomington, Indiana, which is far away from one of the central libraries.) I simply cannot afford such travel and the lengthy stays that would be required to study the reports, and neither can most people; nor is it practical to read extensively off a micro-film reader, because of eye fatigue for one thing.

These are but other examples of how AEC policy tends to thwart critical inquiry about the civilian nuclear power program.

Personal Philosophy and Motivation

I realize that my Statement and this Rebuttal are discouraging to those who look upon the LMFBR as providing abundant, pollution-free energy for "modern society." I for one would like to be able to state that the maximum accident potential of the LMFBR is scientifically well established, and that it is economically practical to guarantee containment of the worst possible explosion by the use of passive concrete shielding and steel containers and blast shields, so that should the worst accident occur, there will be no injury to People and their health, and no serious, widespread radioactivity contamination of the Environment. But in all honesty to myself, my posterity, and my fellow citizen, I cannot give such an opinion, at least not at this time.

The JCAE and the AEC, and the rest of the nuclear community should be assured that by my criticisms I seek only the truth, and not personal aggrandizement, as one eminent LMFBR scientist has suggested. I have no vested interest to work against the LMFBR. On the contrary, I know full well its potential for solving our nation's air pollution

problem. Before I embarked on my LMFBR safety studies, I had stated in a published article in January, 1969 that we should:

> "[i]ncrease substantially the effort to develop breeder nuclear power reactors which permit the extraction of over 50% and up to 80% of the energy available in our nuclear fuel resources. This compares with a 2% maximum for today's non-breeder plants. Thus, the breeder will ensure electric power for transportation, factory use, and home use, including heating, for centuries. It holds the main hope for reducing air pollution." 144

However, the health and safety of the People are overriding; and the hazards and pollution potential of the LMFBR must be dealt with just as we must deal with the traditional forms of pollution. (Also, I am very much disturbed about the long term nuclear waste disposal or waste storage problem and the problems of accountability of Plutonium fissile material, and the apparent fact that nuclear power is not being used to replace fossile power in order to reduce fossil fuel usage, and thereby reduce air pollution in our cities.) My intensive studies into the state of Man's knowledge of the LMFBR explosion potential have led me to conclude with objectivity that LMFBR safety R&D has not sufficiently progressed to conclude that the potential and propensity for explosion are acceptable. Although I have not proved that the worst possible explosion is unacceptably high; neither have the promoters of the LMFBR Demonstration Plant, nor the LMFBR Nuclear Safety Program at ANL, proved that it is acceptably limited. Nor am I aware that ANL has even claimed an acceptable upper bound of the explosion potential.

It is true that recent analyses of hypothetical accidents using the mechanistic approach of the MELT/VENUS accident analysis

codes are, by themselves, encouraging, for they tend to predict that at least during the initial stages of malfunction, no unacceptably strong explosion is likely to occur. But, as I pointed out earlier, these codes have serious theoretical uncertainties. For one thing, there are later stages of an accident, when the fuel is less defined, and therefore more complicated to analyze, which remains to be addressed. Also, there is the insufficient analysis of autocatalysis; and there is the need for full-scale, core-destruct verification experiments. Whether the deficiencies in the analysis methods can ever be corrected satisfactorily is subject to question. For example, Simpson, *et al.*, of HEDL stated that:

> "it is impossible to establish the actual course of the most severe reactor accident which might possibly occur." [20]

Despite this statement, though, these authors concluded that the MELT/VENUS accident analysis method "represents a reasonable conservative basis for evaluation of the containment design . . ." [145] Yet, when submitting its more recent analyses, HEDL admitted that the analyses does not amount to a complete case for an upper bound on the explosion potential. [102] Thus, we have to chose between (1) the personal judgments of those who have an obvious vested interest, and (2) the hard, scientific fact that the accident analysis codes are fundamentally deficient and have not been experimentally verified, nor are there plans to do so. In view of the frightening consequences of an LMFBR disaster, I must choose against personal judgments in favor of theoretically sound and verified analyses. (Incidentally, the HEDL analysts are employed by WADCO, a subsidiary company of Westihouse Electric Corporation. This company has a

vested interest in the LMFBR Demonstration Project and LMFBR development overall from a revenue and profit standpoint inasmuch as Westinghouse has been selected to make the reactor for the Demonstration Plant and is aiming to be a key supplier of commercial fast breeder reactors; i.e., LMFBRs.[92] Therefore, without wanting to imply any lack of integrity, the conclusions of the HEDL analysts can be expected to be naturally biased.)

Basic to my concern is a fear that the fission product and Plutonium radioactivity can be dispersed into the Environment by a nuclear explosion, aggravated by an attending sodium vapor explosion. Because the maximum explosion potential has not been established, and because one can easily conceive of an explosion potential of 10,000 lb. TNT equivalent and higher, which exceeds by ten times the highest LMFBR containment design capability that has been mentioned,[169,5] there is a valid concern that it may be possible that most of the radioactivity could be dispersed into the Environment. Under a 10,000 lb. TNT explosion, most or all of the core fuel material would be vaporized, and the explosion could presumably rupture the plant container and allow most of the fission product and Plutonium vapor and mist to be expelled into the Environment. Aggravating the situation is the sodium coolant, which burns in the presence of air. This would be ignited within the secondary containment structure to contribute to the explosion and expulsion pressures. Of course, if the explosion is less, the quantities of radioactivity that will be dispersed into the Environment will be less. But because of the extreme toxicity of the radioactivity and the tons of Plutonium involved, any fractional amount released is of vital concern. Hence, it is necessary that not only the

maximum explosion potential be determined, but the fraction of the radioactivity that would be released by the worst explosion as well, and the consequences of such, if the containment were breached. Neither have been determined as yet.

Instead of building an LMFBR Demonstration Plant, I would prefer to see the good talents and energies of the administrators, draftsmen, engineers, machinists, mechanics, scientists, and technicians in the nuclear laboratories and companies directed toward the full theoretical research into the LMFBR explosion potential and safety verification experiments, which would be much more challenging than the present Demonstration Project, and wholesome from a public service standpoint. It would be unwise, however, to plunge headlong into building large numbers of LMFBRs with the Demonstration Plant(s) being the forerunner, without performing the necessary safety research first. The "energy crisis" that is alleged by the nuclear promoters should be no excuse for doing the unwise. Sould an energy crisis be real, then it would call for a "crash program" of scientific investigation of the LMFBR maximum hazard potential,* not a plunge into LMFBR construction with virtually irrevocable commitments of resources without a firm scientific ground for the theoretical estimates of the explosion potential. (I personally believe that there is an energy crisis which has been brought on by thriftless use of our energy resources, which could be alleviated by a change of habits and life styles, although with difficulty. But this is another subject, which is outside the scope of this Rebuttal.)

The People and Congress have been assured that there are

*And an investigation of other energy sources and ways of minimizing energy usage.

built into the LMFBR "three independent levels of safety" which supposedly ensure the health and safety of the public. These levels are:[146]

(1) Accident Prevention by quality control and sound design, construction, operation, and so forth;

(2) an active Protection System which detects malfunction should failure occur and safely shuts down the reactor by mechanical action (SCRAM); and

(3) Guaranteed Public Protection, which the nuclear community defines as follows:

> "Further protection is provided through the development of an understanding of the inherent physical properties of the nuclear systems. The consequences of very severe hypothetical accidents (whose probability is vanishingly small) are studied and evaluated to serve as tests of plant safety to guarantee protection of the public."[146]

Presumably, this third-level protection means passive concrete and steel containers and blast shielding.

However, the effect of my testimony here is to contend that the third level of safety has not been achieved. That is, as things now stand the public safety will depend on the first two levels, since there is no guarantee that an accident, if not quickly controlled by the level-two action (i.e., the automatic electronic and mechanical detection of trouble and SCRAM), will not end in a disastrous explosion. The first two levels are not totally independent, either. For the same lack of quality control which could lead to an inoperative protection system, violating

level-two, could lead to the accident initiating malfunction, the level-one violation as well. That is, both the first and the second levels of safety are really one level of safety in one important respect--human management.

The results of accident analyses cited by the AEC so far do provide some assurance of the public's protection, but these analyses are no guarantee. And without the guaranteed protection against LMFBR explosions, can the public be said to be protected? It is conceivable, I suppose, because of the care being given to the design, construction, and operation of the LMFBR, that the People will accept as adequate such a philosophy, and will judge that the benefits will warrant the risks. That is, the AEC appears to be working hard to make the LMFBR operate without serious mishap, and to provide some explosion protection at least in case mishaps occur, which is based on some conservatism argument. On the other hand, our experience teaches us that man-made systems do break down on occasion; that is, mishaps do occur. Because of this human experience, and because of the enormous disastrous potential of the radioactivity in the LMFBR, especially the Plutonium, the People may want the guarantee of the third level of safety mentioned above. This would require adopting my recommendation of theoretical and experimental research into the LMFBR explosion potential. That is, the People may want the guarantee that the worst possible explosion will be contained (or even the worst conceivable explosion which cannot be ruled out as impossible) by scientifically establishing the maximum explosion potential with full-scale, underground explosion experiments, and then designing the level-three protection accordingly (i.e., the containment),

unless the theoretical research I call for reveals that the explosion potential is unacceptable without the need for full-scale explosion experiments.

It may very well turn out that the maximum possible accident cannot be practically established, because of the complexity of core behavior; and to be safe, the maximum conceivable accident should be the basis for assessing the LMFBR explosion potential. Again, by "conceivable" I mean those patterns of core behavior which cannot be ruled out as physically impossible--i.e., shown to violate well-established laws of nature. The AEC has already rejected such a criterion, however. In the LMFBR Demonstration Plant Environmental Statement the AEC states:

> "[T]he SARs [safety analysis reports] for the demonstration plant will cover the design of the reactor structure and containment and must show that there is no credible rearrangement of the demonstration plant core which could lead to the release of explosive energy with a force sufficient to breach the containment." (Emphasis added.)[147]

Thus, the AEC shifts the "burden of proof" onto those who question the safety of the LMFBR by requiring them to prove, or at least to demonstrate by analysis based on undisputed assumptions, that a core implosion or compaction event that results in an explosion exceeding the containment design limit is theoretically possible. That is, the core rearrangement must be "credible," or believeable to the AEC. This is another manifestation of objective evaluations of public safety giving way to subjective value judgments of nuclear power promoters. Should not the "burden of proof" rest with the nuclear promoters in demonstrating that a worse conceivable

accident is impossible? If the public safety is to/be fact and not a fallacy, subjective personal "beliefs" of AEC officials must give way to the hard, scientific fact that the LMFBR accident analysis methods are inadequately developed theoretically, and have not been verified by full-scale, core-destruct tests, since the methods rely on such assumptions as perturbation theory for reactivity changes, extrapolations from in-pile tests, simplified models of fuel motion, arbitrary initial conditions, instead of of all possible conditions, and no secondary re-assembly of fuel.

My own view was given in my Statement by the following premises:

(a) The Plutonium and the fission product radioactivity in the LMFBRs must absoluetly not be allowed to be spewed into the environment by a reactor plant explosion.

(b) The LMFBR containment structures should be designed to contain all possible accidents, which would require the containment of the worst conceivable accident in order to ensure that the worst possible accident is covered.

The main basis for my views is the fear of the Plutonium hazard. The Demonstration Plant will contain up to 1.3 tons of Plutonium, and the projected 3880 MWe LMFBR will contain 11.6 tons of Plutonium. Based on reputable estimates*, a plutonium dust particle weighing just one-billionth of an ounze, if enhaled and lodged in the human lung, will produce lung cancer. This would mean that the 3880 MWe LMFBR has the potential of spewing

* See Gofman, footnote, p.1.

the equivalent of 320,000 billion (i.e., 320,000,000,000,000) such cancer producing dust-like particles, if the core were vaporized by a nuclear runaway and the resultant explosion were not contained. Now, there are about three million square miles of land in the United States. If we assume that a disastrous LMFBR explosion rained these Plutonium particles over one million square miles (East of the Mississippi River), then on the average, there would be a Plutonium particle density of ten cancer-producing particles per square foot of land. Assuming that a person's domain is a patch of land 100 feet by 100 feet, square, such a density would seem to mean that a person would be exposed to the danger of 100,000 such Plutonium particles, continuously. Moreover, the Plutonium decays extremely slowly--requiring 24,000 years to decay to half of its strength. Thus, such an LMFBR explosion would seem to mean the eternal contamination of a vast region of the United States with the population virtually forever being exposed to lung cancer producing particles should the Plutonium particles become a part of the ordinary dust in the Environment. There is also the hazard of the fission product radioactivity as well; and there are other effects of Plutonium injestion that are of concern, such genetic effects. I have seen no upper bound estimates of the injury and contamination effects due to the release of the Plutonium and the fission product radioactivity; but I estimate from the AEC's WASH-740 report[154] that the fission product contamination alone could agriculturally ruin land areas the size of Pennsylvania and New York (State), combined, or greater.

Whether my assumption of uniform deposition of spewed Pu is accurate is not controlling, as the above figures are given to show the enormous potential for contamination. The fact is that there has

been no authorative WASH-740 type study and published report on the consequences of an LMFBR explosion which releases virtually all of its radioactivity, or even a substantial fraction of it. In the absence of such a study, I must rely on the above figures as grounds for concluding that the radioactivity, especially the Plutonium, must absolutely not be spewed into the Environment by a nuclear explosion.

I have been criticized that there is no such thing as absolute safety--that it is silly to say that the Plutonium absolutely must not be allowed to be spewed into the Environment, and that accordingly the containment structures need not contain the worst possible explosion. Dr. A.M. Judd, a co-author of ANL-7657, "Safety Problems of the LMFBR," has stated, for example, that:

> "It is not necessary to prove rigorously that the secondary event [i.e., a secondary criticality that may arise during an LMFBR accident and cause a disastrous nuclear explosion] is impossible."[148]

Judd stated that it is only necessary to show that the probability of a secondary excursion is very low.[148] (The limitation of the use of probability theories is discussed in my Statement.) My answer to this criticism is that my values are different. Once such an explosion occurs, and the Plutonium is spewed into the Environment, then the People and their Posterity are forever exposed to the Plutonium hazards with no remedy other than abandoning the land (it would seem), which I contend is absolutely unacceptable.

I should clarify what I mean by containment of the worst possible accident. I have implicitly assumed that the containment structures are constructed properly, and that all movable parts of it are correctly installed and in-place prior to operating the LMFBR. Of course, there is always the possibility that the containment will be faulty when it is called upon during an explosion, and won't contain the worst possible explosion, or perhaps even lesser explosions, even if the containment were designed to contain such explosions. So in this sense, there is no absolute safety against the release of the Plutonium and other radioactivity; and perhaps this point is enough to reject the LMFBR altogether. As a minimum, however, the containment should be designed to withstand the worst possible explosion, assuming that this is found to be practical after the maximum explosion potential is scientifically established.

Some nuclear advocates contend that the risks of LMFBR accidents are no different than the risks people take every day, such as the risks of riding in an automobile. I contend, however, that the nuclear risks are of altogether different character. Based on what is known and unknown, I must assume that a LMFBR accident, if one releases the core loading of Plutonium and other radioactivity, could kill of the order of a million people and permanently ruin vast land areas of the United States. Since the land is our most precious resource, we cannot tolerate such a disaster. Surely, such a risk is not the same as the risks we individually might accept in riding in a car. An auto accident at worst would kill the passengers and several others; but the release of the Plutonium in an LMFBR accident affects the population and the land we live on.

Some nuclear advocates point to the fact that we accept the risks of holocaust due to nuclear weaponry; and that similar risks of the LMFBR should too be acceptable. However, the argument ignores the fact that it is also the policy of the United States to seek the disarmament of nuclear weapons (The 1961 Arms Control and Disarmament Act) because of this danger of nuclear holocaust; and that it is the policy of the United States to keep our nuclear arsenal in the mean time in order to prevent nuclear holocaust by deterence--i.e., to prevent, among other things, nuclear contamination. No such purpose is ascribed to the LMFBR--i.e., the LMFBR is not being built to prevent nuclear contamination.

My other allegation that the civilian nuclear power program is unconstitutional is not lightly made; but is based on exhaustive historical and legal analysis, which will be included in the book which I am preparing, and which is already available to the JCAE in the form of my law suit materials in Webb v. AEC, and which the AEC has not disputed in any detail. I attach this allegation with my LMFBR safety evaluation because the two are inseparable, and since a decision on which LMFBR safety philosophy to adopt is ultimately one of judgment, where honest people could disagree. Had the People granted Congress the power, expressed or plainly implied, to promote civilian nuclear power, then the People would have delegated to Congress, and through Congress by the 1954 Atomic Energy Act and subsequent amendments to the AEC, the power to decide the safety issues and make the appropriate value judgments. But having not done so, the People have retained the

power; and Congress and the AEC are, therefore, acting outside constitutional authority in promoting the LMFBR and judging its safety accordingly. That is, the necessity for and safety of the LMFBR are not for the Congress and the AEC to decide affirmatively for the People. The LMFBR safety R&D has reached the point where a profoundly fundamental decision has to be made as to philosophy. (Safety will never be totally quantifiable.) The profundity of the decision has virtually unlimited and eternal dimensions for mankind. It is only proper, therefore, that we turn to fundamental principles of social relationship in making the decision, especially since the LMFBR promoters are acting by authority usurped from the People. The Welfare and Safety of the People are the reasons why we have a Constitution in the first place. To decide the People's safety and welfare by unconstitutional means defeats the purpose.

As I believe it, submitting the questions of the necessity for and safety of a civilian nuclear program to the People through constitutional procedures would be a healthy exercise for the nuclear community as well. For what better way is there to resolve the safety issue, than by referring the matter to the People for judgment--the ultimate source of authority. Instead of endless litigation and confrontation, we'd have fruitful deliberation and judgment. Should the People decide in favor of proceeding with nuclear power, the nuclear community would then be entrusted with responsibility; and would, in the eyes of the People, be performing a public service, instead of the way it is now, where the nuclear community is looked on by a large segment

of society as a vested government-industrial-university-labor complex, taking chances with the safety and well-being of the People and their Posterity for its own immediate private gain and power. Should the People decide to postpone the development of the LMFBR in favor of further safety research, or to discontinue the civilian nuclear power program altogether, then the People should, of course, prevail. But it would be better to have this happen now, then after a huge growth period for the nuclear industry, when there would be more at stake to lose in terms of personal careers and investments (losses which will be harder to compensate), and when there would be a larger radioactivity burden to leave for our Posterity to contend with.

Again, I hope there is no severe explosion potential in the LMFBR; but I do not trust hope or self-deceiving rationalization, but only rigorous and verified analyses. Many analysts in the LMFBR safety field have convictions that the explosion potential is small. But I call on them to submit their justification for this conviction in the form of analyses and documentation. A strict search of the open literature finds such justification lacking, and formal, written requests for it have gone unanswered. Indeed, the literature is replete with statements that protect the analysts, such as:

✓ "However, we cannot quite conclude definitely that there is no rearrangement of fuel which would give a larger release."----------R.B. Nicholson, Methods for Determining the Energy Release in Hypothetical Reactor Meltdown Accidents, APDA-150, p.102.

✓ "Although a substantial amount of effort is yet required to understand fast reactor accident behavior

completely, the integrated model presented is believed to offer a potentially significant tool for the analysts to assess the safety implications of modern fast reactor systems." (Emphasis added.) ---------- W.T. Sha and A.E. Waltar, "An Integrated Model for Analyzing Disruptive Accidents in Fast Reactors," Nuclear Science and Engineering, 44, 135-156 (1971)

✓ "[I]t is not likely that this will be found necessary. But if it is, then the complete asymmetric-accident problem may require some proof tests consisting of whole core destructive tests."----------- C.N. Kelber, A.M. Judd, et al., "Safety Problems of the LMFBR," ANL-7657, p. 84.

✓ "These questions are under continuing investigation . . ."

-----------Ibid.

✓ "This approach clearly has some limitations . . ." ----Ibid.

✓ "This is an area that conceivably could benefit from a proof test of a complete whole-core destructive-excursion experiment."-------------Ibid.

✓ "[I]t is impossible to establish the actual course of the most severe reactor accident which might possibly occur."------------ D.E. Simpson, et al., "Assessment of Magnitude and Uncertainties of Hypothetical Accidents for the FFTF," HEDL-TME-71-34, March 27, 1971

✓ "Since the results reported here represent a current assessment of on-going work, a complete case for a single upper limit energy value is not made."--------Fast Flux Test Facility Design Safety Assessment, HEDL-TME-72-92, July 1972

"Neither the . . .United States Atomic Energy Commission, nor any of their employees, nor any of their contractors [such as Argonne National Laboratory], . .or their employees [authors of R&D reports], makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, . . .disclosed, . . ."-----

-----Inside cover of ANL-7657 cited above and ANL-7701, VENUS, "A . . .Computer Program for Fast-reactor Power Excursions," by W.T. Sha and T.H. Hughes, and other LMFBR R&D reports as well.

Others in the LMFBR field have expressed opposite convictions or reservations about the calculability of LMFBR accidents, the potential for explosion, or the adequacy of existing methods--namely, Murphy, Teller, Cohen, and Boudreau. 175

This rebuttal discloses and refers to certain limited distribution documents, despite notices on these documents prohibiting such reference. I violate these notices, not out of disrespect to the authors, but because the "hour of decision" is here and the JCAE is holding hearings on the LMFBR Demonstration Plant, which calls for a candid, full-disclosure of the matters touching on the public's health and safety; and because of the demonstrable unconstitutionality of the AEC's civilian nuclear power program.

I sincerely hope that those in power will yield to the overwhelming evidence that I have served on the AEC which proves that the civilian nuclear program is unconstitutional. There is absolutely no evidence to the contrary. The AEC has had two opportunities to reply to my proof--in my law suit and with comment on my Statement on the LMFBR Demo.; but has not done so.

Because the AEC and the JCAE are bound to support the Constitution, and in view of the evidence I have offered and the gravity of the matter, I invite the AEC to debate the constitutional issue, with the JCAE overseeing the debate, in which the arguments and evidence offered by myself and the AEC, and other interested persons, are published unabridged.

There can be no more awesome decision than a decision to adopt widespread civilian nuclear power, including the LMFBRs, save perhaps the decision to deploy nuclear weaponry. Let us make this decision in honest consultation and concert with the People through their constitutional representatives, instead of deciding safety issues unconstitutionally, evasively, and out of public view. The safety and constitutional issues should be debated openly, and frankly. Nuclear power is extremely complicated machinery, employing numerous forms of science and technology, such as:

nuclear theory,
heat and thermodynamics,
hydraulics, hydrodynamics,
mechanical design,
equipment manufacturing,
quality control
economics,
administration,
industrial arts,
operator training,
nuclear waste disposal (perpetual storage),
reactor physics,
reactor kinetics,
radiological controls,
radiation detection and "health physics,"
decontamination,
refueling techniques,

chemistry and chemical engineering,
electronics,
electrical machinery,
valves,
plumbing,
metallurgy,
plant construction methods,
computer methods,
fuel fabrication,
labor relations,
maintenance equipment,
cybernetics of reactor control,
materials science, and sodium technology,

and other fields I may have omitted.* The list seems endless. Each field has many subdivision, and with each of these one could devote a career to; and all aspects affect the safety of the LMFBR. It is beyond the capability of one man of the five persons on the Atomic Energy Commission to assess these facets adequately to make a sound decision of nuclear safety. Thus, we must resolve the question through constitutional procedure and place the decision making with the People through their delegates in State conventions, since only the People can bring to bear the multi-faceted experiences and expertise needed <u>without a vested interest to bias the decision process</u>. For the health and safety of the People <u>are</u> the vested interest of the People.**

Regardless of my opinion about the safety of civilian nuclear power, including the LMFBR, which I expect in due time to make final, but judge it unsafe for the time being, I trust that were the right of the People to decide the necessity for and safety of a federal

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* Such as biology, genetics, ecology, etc.

** Moreover, the People can reject nuclear power for no other reason than they are afraid of it; so the People don't need to "prove" their judgment with sophisticated evaluations.

civilian nuclear power program restored, a safe determination would be made. As it is now, I cannot, without betraying the People and our Posterity, put my trust in the AEC and its managers and join the AEC directed LMFBR Nuclear Safety Program, doing only what I am assigned. Because the civilian nuclear program is unconstitution without any doubt in my mind whatsoever, I must lay my case before the People--the only moral thing to do.

Conclusion

The AEC staff review of my Statement on the LMFBR Demonstration Plant presents no information that discounts my Statement. The comments which the AEC offers are unfounded, premature, or rhetorical in nature, which do not address my Statement squarely. Therefore, as I concluded in my Statement, the LMFBR Demonstration Plant should not be built and the steps I urged for pursuing and deciding the necessity for and safety of the LMFBR should be followed. That is, the JCAE has no basis in the AEC's staff review for not yielding to my Statement.

Corrections for Original Statement

I stated that the LMFBR Program Plan did not mention the "direct method of testing prototype reactors" for confirming explosion calculations. This is in error, as the Plan did mention that if an Excursion Test Facility were necessary, it may have to be "an accurate mockup of the reactor system . . ." (See page 48 of this Rebuttal.)

Also, I stated in my original statement (on p. 184 of the Hearings) that the potential for autocatalysis is aggrevated

as the core size is increased. I was alluding to autocatalysis due to fuel motion during or right after a nuclear runaway, since my next sentence said that autocatalysis due to sodium voiding is also worse with larger core sizes. However, I should have added that I personally can not yet vouch for the claim that fuel-motion-autocatalysis is worse for larger core sizes. My assertion was based on the implication of such given by Okrent,[49] and McCarthy.[162] However, Boudreau has concluded that the said potential is larger. See note 49. Furthermore, my other statement that the core-compaction-induced nuclear runaway is worse for larger core sizes presently still holds. I found this to be true for the "meltdown/crashdown" accident that I studied for my dissertation when comparing the EBR-II results for this accident with the Fermi results. In support of my finding Wolfe, et al., stated that:

> "Since the energy release for a given set of assumptions is roughly proportional to core mass, the possibility of a meltdown accident poses a serious problem for the power reactors of the future which are expected to have more fuel in the core by over a factor of 10 than the present generation of experimental breeder reactors."[4]

[continue]

Corrections (Continued)

In my Statement I erroneously included the SPERT destructive accident as one of those accidents of which the power excursion was under-calculated. According to Thompson,[24] the "reactivity transient" (meaning presumably, the super-prompt-critical power excursion) was adequately predicted, but not the destruction resulting from the predicted power excursion.

In my letter forwarding my Statement, which was also published in the JCAE Hearings, I stated as part of my training that I successfully completed the "Bettis Engineering School" at the Bettis Atomic Power Laboratory. That should have read "Bettis Reactor Engineering School." Also, the topic of my book which I am preparing is not "civilian nuclear power" but "civilian nuclear power safety."

Post-Script

As discussed in the Rebuttal, the LMFBR promoters are aiming to "prove" an acceptable explosion potential by very sophisticated technical or theoretical accident analyses without the verification from full-scale, reactor destruct tests, or even less than full-scale reactor excursion/destruct experiments. The philosophy is that if all significant effects are carefully accounted for, and then properly interconnected in the analyses, then the calculated bounds on the accident potential can be believeable. I have already in the Rebuttal argued the demerits of relying on unverified mechanistic theory, and have also pointed out serious shortcomings in the analyses themselves.* But putting these arguments aside, there is another problem with the mechanistic approach which has to do with review. George Fischer of ANL, who until

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* And the fact that all possible accidents are not analyzed.

recently managed the Accident Analysis Group at Argonne National Laboratory, admitted that the "calculations contain a great deal of detail," and asserted: "If you will try to fault these analyses you will have to tell me where I went wrong in technical assumptions or use of basic data."[159]

The problem with Dr. Fischer's statement is that there is no funding for independent scientists to carryout detailed reviews of the accident analyses in order to determine whether there are serious "faults" in addition to those I mentioned. Without such funding, the public may be overwhelmed by the expert testimony from the AEC funded, LMFBR accident analysts and reviewers, who all have an obvious, natural bias.

Dr. Fischer had commented on my query about the possibility for autocatalytic nuclear runaway:

> "There are two recent articles which may interest you. At a Conference on Engineering of Fast Reactors for Safe and Reliable Operation, at Karlsruhe, Germany in October, 1972, E. Kintner of the USAEC summarized the results of an ANL postdisassembly study we made on whether fuel-coolant interactions, as the hot fuel after nuclear shutdown is ejected into outlet sodium, could result in sodium vapor pressures which could then lead to core recompaction. The result of that analysis was that the interaction is essentially surface-limited so that momentum reversal did not occur. That analysis is being extended with much more detail at present. A second paper at the same conference was a joint Karlsruhe (German AEC)/Argonne paper which analyzed the German Demo reactor response to hypothetical coastdown and ramp [overpower transient] accidents. It was shown with SAS2A (ANL's code) that, primarily, the combined effect of the Doppler effect reducing the severity of the reactivity ramp being

induced by the sodium voiding led to a mild disassembly on the coast down accident, but such that the core fuel was hot enough to largely be carried out into the outlet sodium where it is readily coolable. We have now specified some experiments for the TREAT reactor which are intended to test an argument we have not used so far, that the fission products in fuel should be able to significantly enhance the fuel carryout mechanism. These fission gases will also partly inhibit rapid heat transfer from fuel to sodium." [159]

I have sent for these articles; but until I can evaluate them, I can only give the following general comments:

1. Regarding the first article, Dr. Fischer is saying or implying that no secondary nuclear runaway was calculated by a model which investigates whether a sodium vapor explosion can compact a core and lead to a severe nuclear explosion. Evidently from his description, the sequence studied was as follows:

(a) A core disassembles (blows apart) due presumably to an initial nuclear runaway. The disassembly makes the core subcritical or shutdown.

(b) Some of the fuel moves upward at high speed and enters the pool of liquid sodium coolant above the core.

(c) The hot fuel mixes with the sodium and vaporizes it, creating strong sodium vapor pressures, which then tend to reverse the outward fuel motion. However, the analysis, according to Fischer, showed that the outward fuel movement was not reversed, so that core compaction did not occur, making a secondary runaway seem unlikely.

I expect to evaluate this analysis, and others as well, when I receive them; but for the time being, I will only refer to my

Rebuttal in general, and emphasize the need for full-scale, core-destruct tests for verification of the theoretical result.

Also, the sodium-vapor-pressure-induced-core-recompaction possiblity that was investigated may not have been the one mentioned in Kelber, et al., about solid fuel motion produced by a sodium vapor explosion, which I estimated could conceivably produce an extremely severe nuclear explosion. (See p. 134 herein.) Finally, I note that the "analysis is being extended," which indicates that no firm conclusions have yet been made that precludes a disastrous recompaction accident.

2. About the "second paper" on the SAS2A coastdown accident analysis, I need only comment that the critique of this Rebuttal applies generally to this analysis. (I should note that the 160 Karlsruhe conference brochure lists among the papers given one by G.J. Fischer et al., entitled: "Progress in Analysis of Severe Accidents," which I sent for, but have yet to receive.)

(Continue for Postscript on Karlsruhe Conference.)

Post- Post Script: The Karlsruhe Conference

The published proceedings of the above-mentioned Karlsruhe Conference on "Engineering of Fast Reactors for Safe and Reliable Operation," October 9-13, 1972,[180] have just been sent to me. Inasmuch as these conference papers are highly relevant to LMFBR accident analysis, and noting that the conference was held after my original statement was submitted to the JCAE, it would be appropriate for me to comment on the information presented. My comments are as follows:

1. Judging from the comments and questions of many of the participants, the conference proceedings support my view that the maximum explosion potential of the LMFBR has not been established on the side of economical containment of possible explosions. For example, in summarizing the conference, D. Smidt noted in regards to fuel motion during a loss-of-coolant-flow accident that:

> "[The] process has to be modelled in more detail to see what the final figures [explosion energy value] will be."[181]

Regarding the experimental effort, Smidt stated:

> "Certainly this should be the onset of a lot of further work and further discussion."[182]

In the "General Discussion" following the papers on "Analysis of Hypothetical Accidents," Dr. H. Küsters questioned the "confidence level" of the explosive force predicted by the "very elaborated" accident analysis codes. He added that "many experiments are lacking," and asked if the accident analyst can be sure that the "most serious" accident sequences have been taken into account, and if the predictions are on the "pessimistic

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side". Dr. G.J. Fischer of ANL replied:

> "There seems in many instances to be no simple or even adequate answer to the question of whether our calculations are clearly pessimistic. . . . [T]here always is a more pessimistic analysis. . . .No conclusive value has been established yet [of the explosion potential] . . .[and] the consequences of secondary criticality evaluations must be added to the analysis." (By "secondary criticality" Fischer means secondary nuclear runaway and the associated explosion.) [184]

2. Concerning the AEC's staff review comment about <u>fuel motion</u> being a safety shutdown mechanism as evidenced by "recent analysis" using the MELT and SAS accident analysis codes, the conference proceedings, if anything, support my conclusion that such codes are no valid basis for the AEC's implied assertion that fuel motion during an LMFBR accident will avert a disastrous nuclear explosion. Recall that my conclusion was based partly on the following two points:

(a) The recent fuel motion models apply to initial fuel motion and therefore are useless once gross core meltdown and/or nuclear runaway (GCM/NR) occur (i.e., once the fuel rods no longer retain their geometry or shape). Hence, the only way such models could be used to fix the maximum explosion potential is to show that GCM/NR is impossible. However, I argued that GCM/NR is certainly possible, and that the extremely complex problem of fuel motion under GCM/NR conditions needs solution before the maximum explosion potential can be established. This GCM/NR problem is far from being solved, and is the heart of

of the question of autocatalytic reactivity effects and the nuclear explosion potential.

(b) The recent MELT code fuel motion models are not valid for a reactivity insertion rate greater than 5 $/sec.

(These points are discussed on pp. 90-104 herein.)

Regarding point (a), a conference paper by G. Heusener, et al., reported the results of applying the SAS accident analysis code (and VENUS) to Germany's LMFBR demonstration reactor (SNR-300).[185] One of the accidents analyzed involved gross core meltdown and nuclear runaway. For this accident it was concluded:

> "[A] total of 2100 kg of fuel in the core [which is about 1/3 of the core] is completely molten and is no longer contained in its original fuel pin or pellet geometries."[186]

This SNR-300 analysis, therefore, provides additional support for my assertion that GCM/NR in an LMFBR is a possibility for which the "recent analyses" alluded to by the AEC have no applicability or proven validity. That is, the SNR-300 analyses run contrary to the AEC's staff review implication that the fuel motion during any accident will shutdown the reactor before a nuclear runaway and explosion can occur. (Recall that the only way one can verify an accident analysis code for the GCM/NR condition is by full-scale, core-destruct tests, which have not been conducted and are not planned, and which may very well be impractical.)

Regarding point (b), the same paper by Heusener, et al., reported that the SNR-300 accident analysis required the analysis of a control rod ejection accident which yielded a

25 $/sec reactivity insertion rate, which exceeds the 5 $/sec limit for the admitted range of applicability of the MELT fuel motion model referred to by the AEC.[187]

Incidentally, the SNR-300 accident analyses used the SAS and VENUS codes, which are deficient from an autocatalytic investigation standpoint, as discussed in this Rebuttal. Also, the SNR-300 anaysis did not consider the ultimate course of fuel motion in the accidents. These deficiencies, plus the lack of full-scale confirmatory experiments, prevent the limited explosion calculated for SNR-300 (about 100 lb. TNT equivalent) from being used as a reliable value for the maximum explosion potential for the LMFBR.

Finally, G.J. Fischer of ANL in a "written comment" for the conference affirmed that analyses have shown that fuel motion could be a safety shutdown mechanism:

> "As an example, we have relatively dependable reasons to believe code calculations predictions that for some ramp accidents [i.e., over-power transients], cladding will fail well above the core midheight and allow molten fuel to be ejected in a reactivity-reducing manner." [188]

(This is the MELT fuel motion model mentioned above,* or a SAS code version of it.) However, Fischer added:

> "We have other technical reaons to believe that for other ramp accident conditions clad will rupture near the core midheight, leading to fuel ejection near the core midheight, and thus to reactivity addition." [189]

* Pp. 95-97.

Since "reactivity addition" leads to nuclear runaway and gross core melting, it appears, therefore, that the AEC staff review highlighted the theories which predict a safety-shutdown effect ("reactivity-reducing manner"), while neglecting to mention other theories that point to the opposite--fuel motion which causes reactivity addition and nuclear explosion, instead of a shutdown of the reactor in a safe manner.

4. In several places in this Rebuttal I discuss the possibility of rapid core compaction caused by a coolant vapor explosion as one means of producing a severe nuclear runaway and explosion. (See pp. 134, ~~206~~-208.) The conference proceedings show that this concern is still valid, and more so. In a French paper by Puig and Antonakas, it was stated:

> "Though all the events leading to a large reactivity increase, cannot be defined, some of the primary malfunctions can be guessed. The explosion of a peripheral subassembly, due to a vapor explosion after [flow] blocking and fuel melting, could crush the core [i.e., compact the core]. The reactivity change has been evaluated assuming various core configurations." 190

The reactivity changes that were calculated by Puig and Antonakas would be sufficient to produce a nuclear runaway, although several unrealistic, but unevaluated, assumptions were made. The authors conjectured that such occurrence is unlikely, however, according to a french translation that was given to me; but nevertheless, the paper does show that a severe core compaction-induced— nuclear runaway due to a coolant vapor explosion may be possible.

Specifically, Puig and Antonakas studied the <u>reactivity</u> effects of a coolant vapor explosion occurring within a fuel rod bundle (core subassembly) that is located at the edge of

an LMFBR core (i.e., the core periphery). (The vapor explosion would occur upon the mixing of molten fuel and coolant within the fuel bundle. Also, being at the edge of the core, the explosion would tend to compact the rest of the core, and thereby increase the reactivity.) They assumed various degrees and configurations of core compaction that might be caused by an edge-of-core coolant vapor explosion, and computed the reactivity change for each case. The results of their reactivity computations are worrisome, since their data indicate that only about 5% of the core volume need be compacted with about a 30% rise in the fuel density* to raise the reactivity by one dollar (1 $) and thereby trigger a dangerous nuclear runaway. Recall that a $1.00 reactivity rise would bring the reactor to the threshold of nuclear runaway, assuming that the reactor were critical before the rise; i.e., assuming that the reactivity were initially zero. But if the reactor were on the verge of nuclear runaway at the time of the coolant vapor explosion (i.e., if the reactivity were high to begin with), then of course considerably less additional reactivity would be required to trigger a runaway, and, therefore, less core compaction would be needed, making the conceived accident all the more worrisome.

A major shortcoming of this paper by Puig and Antonakas is that this paper does not consider the question of whether a coolant vapor explosion in a fuel rod bundle can in fact be strong enough to cause the degree of core compaction required for producing a rapid core compaction-induced nuclear runaway, even though that degree appears to be slight. This complementary question was substantially investigated by N.J.M. Rees in another

* Which is plausible since the upper limit for the potential for core compaction is about a 100 % rise in the core density, because of the coolant passage space between fuel rods.

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paper at the Karlsruhe conference.

The paper by Rees reveals quite dramatically that a coolant vapor explosion may well be, and probably can be, strong enough to cause the necessary core compaction to produce the reactivity change that Puig and Antonakas indicated is required to effect a severe nuclear explosion. Rees reported a set of TNT-type explosion experiments in which a charge was detonated at the center of a group of simulated fuel rod bundles (core subassemblies), which mocked up a region of a core. The results of one experiment using an explosive charge equivalent to 1.6 lb. of TNT showed considerable compaction of the simulated core material in the manner similar to what Puig and Antonakas assumed, and to a degree which would seem qualitatively to produce ample reactivity insertion for a severe nuclear explosion, especially if the core were on the verge of nuclear runaway at the time of the hypothesized edge-of-core vapor explosion. (This is shown quite dramatically in Figure 7 of Rees' paper.)

Rees estimated that a coolant vapor explosion in a fuel bundle could be much greater than 1.6 lb. TNT--as high as 10 lb.TNT equivalent, according to the "thermodynamic limit"-- and therefore, there is ample explosion energy available to severely compact the core. Rees also noted that a coolant vapor explosion has already been observed to approach the thermodynamic limit in a steel foundry explosion incident (86% of the thermodyanmic limit), which demonstrates the thermodynamic theory of coolant vapor explosions. Thus, Rees' paper in conjunction with that of Puig and Antonakas indicate quite strongly the concern for

coolant vapor explosions causing sufficient core compaction to produce severe nuclear explosions, which, because of the high rates of such compaction, would probably be disastrous.

That Rees' experiments were conducted partly because of this concern is shown in the introductory of his paper where he expressed the concern that:

> "The largest credible coolant vapour explosion in a sub-assembly must not distort the core too much, so that control of the reactor cannot be lost and a major core meltout does not occur; <u>in addition, this core distortion must not cause a super-prompt critical excursion of the whole core</u>." [192] (Emphasis added.)

It is significant that upon reporting his experimental findings and supportive analysis Rees did not discuss the significance of such in terms of any alleviation of his concern that "core distortion must not cause a super-prompt critical excursion." If anything, he views the state of knowledge in this area quite inadequate:

> "In the case of the fuel-coolant interaction in a subassembly [i.e., the vapor explosion] we still have little clear idea of what the detailed accident mechanism is and what the scale of the energy releases are likely to be. . . . Obviously, a great deal more work is required here, both on the energy release process and on understanding the mechanical response of the core structure. I expect we shall be working here for a long time." [193]

Also, Rees reported that an explosion experiment using a a whole core mock-up has recently been conducted, using also an improved explosive charge that better simulates a coolant vapor explosion, and that the "results are being assessed." [194]

The experiment was designed so that the simulated fuel bundle explosion occurred at the center of the core, instead of at the edge of the core where the paper by Puig and Antonakas indicates the reactivity change is worrisome. Still, the observed core distortion, or core compaction, would have to be analyzed for the potential for a core compaction-induced-nuclear runaway, since compaction of any region of the core could conceivably produce a runaway, as discussed earlier in this Rebuttal, pp.10-11. Presumably, this is one of the purposes of Rees' experiment in light of his introductory remarks cited earlier.

There is an indication that Rees is quite cognizant of the reactivity implications of a coolant vapor explosion occurring at the edge of the core. Rees noted that his whole core experiments may be extended to investigate this concern:

> "Later experiments may include some vapour explosions in wrapper near the edge of the core to examine the fuel compaction possible in the central region of the core." (A wrapper is the steel can that houses the fuel rod bundle.)[195]

Furthermore, Rees explosion experiments of fuel bundle mock-ups involved normal strength steels for the simulated fuel rods and wrappers. But if the core were on the verge of a meltdown, the core materials would be more pliable, and therfore, more easily compressible.* This means that under a core meltdown condition the compaction of the core by a coolant vapor explosion seems even more likely than what the Rees' experiments might indicate, which strengthens the concern that this phenomenon of coolant vapor explosion may be capable of producing a disastrous nuclear explosion.

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* Also, Rees' mockups were filled with water to simulate the

4. The ANL "postdisassembly study" alleged by G. Fischer as having been summarized by E. Kintner of the USAEC at the Karlsruhe conference could not be found in the published proceedings. (See post-script, pp. 205-208 above.) As this study is important, since it deals with another means by which the core might be compacted by a coolant vapor explosion, I wanted to evaluate it before submitting this Rebuttal. However, it is more important to avoid any further delay; so I'll just note the matter, and that I am seeking whatever analysis that has been performed.

5. The conference proceedings do not support the clear implication given by the AEC (in their staff review of my Statement) that the "mechanical damage potential" of molten fuel-coolant interaction (sodium vapor explosion) is low; i.e., less than 1% of the thermodynamic maximum. In his paper discussed in 3. above, Rees reviewed the matter and concluded:

> "[W]e cannot estimate what energy release [i.e., the mechanical damage potential] will occur under given conditions with any degree of certainty." 196

I have already noted that Rees reported that a coolant vapor explosion has already been observed approaching the thermodynamic maximum or limit (86% versus the less-than-1% implied by the AEC). Rees also indicated that based on experiments and industrial accidents it is more likely that a coolant vapor explosion will occur with a mechanical damage potential approaching thermodynamic limit when large quantities of molten material are involved, as distinguished with the small quantities used in the TREAT in-pile meltdown tests cited in the AEC staff review.

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coolant. But if the LMFBR core were substantially void of coolant during a coolant-vapor-explosion incident at the edge of the core, the core would be even more compressible.

(Rees is supported by another Karlsruhe conference paper by Jakeman and Potter.[197]) Rees stated that tests so far with LMFBR materials (sodium and UO_2) involved only small quantities of such; but that tests with larger quantities are planned. Also, these additional tests involve modes of fuel-coolant interaction which the TREAT tests have not tested, which I mentioned on p.78 herein.

Inasmuch as coolant vapor explosions are apparently more likely to occur with the mechanical damage energy approaching the thermodynamic limit when large quantities of molten material are involved, it would seem that in order to resolve the question of whether the thermodynamic limit can be approached in LMFBR accidents, core-destruct tests are required. This is another reason why full-scale, core-destruct tests are necessary. Referring to the TREAT in-pile meltdown tests, which the AEC staff review cited as evidence of a low damage potential of molten fuel-coolant interaction, and which involved small quantities of molten fuel, Rees maintained that:

> "Many questions have to be answered about the probable dispersion [the process by which molten fuel interacts with the coolant to produce the coolant vapor explosion], the amount of coolant that would be involved, and the validity of the data we are obtaining from experiments [such as TREAT] which do not reproduce conditions that will be found in an actual reactor meltout." [198]

In another paper at the Karlsruhe conference, Teague stated that large-scale tests may be necessary.[199] Incidentally, both Rees and Teague reported that in an ANL experiment an "extremely violent" fuel-coolant interaction has been observed,[200] which also suggests that a high mechancial damage potential is possible for LMFBR coolant vapor explosions, which, if true, would

be contrary to the optimism of the AEC. Moreover, both papers by Rees and Jakeman and Potter referred to the coolant vapor explosion that occurred in the SPERT reactor upon fuel melting following a nuclear excursion, which totally destroyed the core. Rees pointed out that 20 "megajoules" of thermal energy was available in the molten fuel to cause explosion, which would indicate that the upper limit for the mechanical damage energy of the explosion was no more than 10 lb. of TNT equivalent.[201] (I would guess about 5 lb. of TNT, since not all of the thermal energy or heat would be converted into mechanical blast and shock energy. Also, 2 megajoules of mechanical damage energy equals 1 lb. TNT.) Based on Rees' explosion experiment involving 1.6 lb. TNT, which seems to have caused less damage than that observed in the SPERT destructive test, it seems to me that the SPERT reactor-destruct test may have demonstrated that the mechanical damage energy can approach the thermodynamic limit in nuclear reactor accidents, and that large quantities of molten fuel are more likely to produce severe explosions than what the TREAT tests with small quantities of molten fuel might indicate. Therefore, this question of the significance of the SPERT reactor explosion should be address in the considerations of the necessity of full-scale, LMFBR core-destruct tests.

We must keep in mind that <u>coolant vapor explosion</u> is only one mode of an LMFBR explosion. The other mode, <u>fuel vapor explosion</u> resulting from a severe, autocatalytic nuclear runaway, is my primary concern, which may not depend on a strong coolant vapor explosion potential.* Nevertheless, the implication of a possibility for coolant vapor explosions approaching the

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* See p. 72 herein.

thermodynamic limit is great, since such an explosion could help breach the reactor containment structure, or produce rapid core compaction sufficient to generate a severe nuclear runaway that ends in a disastrous fuel vapor explosion.

6. Regarding the TREAT in-pile tests cited in the AEC's staff review as evidence of fuel motion being a shutdown mechanism, Küsters questioned "the applicability and possibility of extrapolation of results obtained in TREAT to fast reactor accident situations." He cited an example of a shortcoming in the TREAT tests.[202] It is significant that in reply Marchaterre of Argonne National Laboratory did not definitely affirm such applicability, and furthermore admitted that improved experiments are needed,[202] which shows that the AEC's optimistic comment in this area of TREAT experimentation is premature.

7. G. J. Fischer, et al., of Argonne National Laboratory presented a paper on the "Progres in Analysis of Severe Accidents. (See general comment No. 2 on page 208 herein.) This paper does not discuss the progress in the understanding of the potential for autocatalytic reactivity effects--the main concern of this Rebuttal and my original Statement. The only reference to the matter is a statement that "recriticality problems [i.e., secondary nuclear runaways] are presently evaluated outside of the SAS code."[203] (Apparently, this is the postdisassembly study discussed herein on pp. 206-208 and comment No. 4 on page 218.) Since the AEC cited the SAS accident analysis code for its optimistic statement about fuel motion being a shutdown mechanism, which implies safety, it appears by this paper that the AEC

neglected to mention other calculations of fuel motion (outside of SAS) which are more relevant to the concerns for rapid core reassembly and nuclear explosion that were expressed in my Statement. Thus, the AEC failed to adequately address my primary concern for autocatalytic reactivity effects with information that apparently existed at the time of their staff review, since the Fischer, <u>et al.</u>, paper was presented before the AEC's staff review was submitted.

8. As a final comment, the Karlsruhe conference heard a paper by Stratton, <u>et al.</u>, which discusses the development of another calculational method for LMFBR nuclear runaways (similar to the VENUS disassembly code) and compared the method with the KIWI-TNT reactor explosion experiment.[204] Recall that my original Statement (See pp.180-181 of App. A herein.) contains critical comments on a previous comparison of that KIWI test with an LMFBR disassembly code--MARS. My comments apply to this Karlsruhe paper as well. Although the newer method calculates the "energy release" of the KIWI-TNT excursion in good agreement, as did the MARS comparison, the paper does not compare the peak power (pulse height), power pulse shape, and pulse width, which are crucial characteristics that must be calculated well if the method is to be supported by the KIWI test. Further, the paper acknowledges that the method could not duplicate the power distribution or "flux shape"

throughout the core, and that this important deficiency, which I mention in my draft paper, "Critical Review of the KIWI-TNT Power Excursion as Calculated by the MARS Fast Reactor Excursion Code, that is cited in my statement (footnote no. 4), is being studied. Moreover, the KIWI-TNT reactor was not an LMFBR or anything similar. Therefore, this paper by Stratton, et al., does not present sufficient experimental evidence that proves that their method might be applicable for nuclear explosion accidents in LMFBRs. Nor did the authors definitely conclude such.

In general, a reading of the Karlsruhe conference proceedings reaffirms the conclusions of my Statement and this Rebuttal that the level of Man's knowledge of the LMFBR explosion hazard is insufficient to proceed with an LMFBR Demonstration Plant (nor to operate the FFTF reactor, either). Indeed, the proceedings overall suggest that the explosion hazard will proprobably be unacceptable when firmly established, or at least suggest that an R&D program to establish the explosion potential may very well be impractical. In fairness, the conference papers and discussions all seem to end on a rather cautious, but optimistic, note. However, I see no valid basis for such optimism in the substance of the proceedings.

Advisory Committee on Reactor Safeguards, Recommendation From

The AEC's Advisory Committee on Reactor Safeguards (ACRS) has just recently submitted a letter to the Chairman of the AEC which supports this Rebuttal.[161] In it the ACRS reviewed the safety assessment of the FFTF reactor, which is now being constructed. Recall that the FFTF is essentially an LMFBR. (See p. 95-96 herein.) Thus, the FFTF accident analyses are the forerunner for the LMFBR Demonstration Plant; and the ACRS comments have applicability to the LMFBR Demo. The ACRS stated:

> "The ACRS believes that these [FFTF accident] studies have been valuable and should be continued along with associated experimental work. However, development of considerable further information is desirable and the following recommendations are made. For at least the two types of accidents mentioned above, additional studies should be made which include parallel analyses performed in one case with best estimate assumptions and in the other case with conservative assumptions at each step of the accident calculation. A range of initiating conditions should be examined and, where appropriate, event sequences should be extended in time until a stable condition is reached, so as to assure that possible subsequent events cannot lead to significantly greater energy releases. Additional and continuing emphasis should be placed on the search for and investigation of possible autocatalytic effects that might occur in the abnormal states encountered in these studies. It is important that types of accidents additional to the two described [loss of coolant flow accident and over-power accident], as well as different possible mechanisms and accident sequences, be analyzed with similar scope, thoroughness, and conservatism. Studies of the probability of accidents of differing severity should be initiated. These could be useful even

if the probability of a given energy release were determined only on a relative basis for a specified accident sequence.

"In view of the above comments, the Committee at this time is not persuaded that the search for accident event sequences that might be significant in regard to the health and safety of the public has been completed, and that provision for capability of containment of an accident of greater than 150 MW-sec work energy should not be required. However, because the above future studies can be expected to provide important additional information prior to start of operation of FFTF and because of the existing commitment to retain flexibility for the accommodation of larger energy releases, the Committee believes it reasonable to defer a final decision in this regard." (Emphasis added.)

The ACRS comment on stable condition was made herein on pp. 63 and 128-130, and on pp. 15-17 of my dissertation.[9] The ACRS comment about the need for additional investigation of possible autocatalytic effects is the gist of my testimony and this Rebuttal. The ACRS, therefore, essentially admits that the maximum explosion potential of the LMFBR has not been established.

Incidentally, just as the LMFBR Demonstration Plant should not be built because the maximum explosion potential has not been scientifically established, neither should the FFTF be operated.

A P P E N D I X   A

My Original Statement
on the
LMFBR Demonstration Plant
and the
AEC's Staff Review

(As published by JCAE)

Excerpt from Hearings before the Joint Committee on Atomic Energy, Congress of the U.S., 92 Cong., Second Session, Sept. 1972: Liquid Metal Fast Breeder Reactor (LMFBR) Demonstration Plant

APPENDIX 5

STATEMENT BY DR. RICHARD E. WEBB

BLOOMINGTON, IND., *September 20, 1972.*

JOHN O. PASTORE,
Chairman, Joint Committee on Atomic Energy,
U.S. Senate, Washington, D.C.

DEAR SENATOR PASTORE: I am enclosing my statement concerning the Liquid Metal Cooled, Fast Breeder Reactor Demonstration Plant. Please accept it for inclusion in the record of your hearings on the LMFBR Demo.

My background and expertise briefly is as follows:

1. Ph. D. in Nuclear Engineering, the Ohio State University, March, 1972. My Ph. D. thesis concerns the explosion potential of the LMFBR.
2. Served four years (1963–1967) with the AEC's Division of Naval Reactors, during which my primary responsibility was for the nuclear reactor portion of the Shippingport Pressurized Water Reactor.
   a. Certificate of successful completion, Bettis Reactor Engineering School of the AEC's Bettis Atomic Power Laboratory (1965).
   b. Reactor Plant Training (one month) at the Navy's DIG Prototype Reactor Plant at the AEC's Knolls Atomic Power Laboratory (1966).
3. Worked one-half year at Big Rock Point Nuclear Power Station (Boiling Water Reactor) at Charlevoix, Michigan as associate engineer with reactor engineering duties in 1967. (I was offered a position with the LMFBR Program Planning Office in 1968.)
4. B.S. Engineering in Physics, University of Toledo, 1962.
5. Presently preparing a book on criteria and procedure for establishing sound public decision with respect to civilian nuclear power at Indiana University's School of Public and Environmental Affairs (Science, Technology and Public Policy section).

Sincerely yours,

RICHARD E. WEBB.

Enclosure: Statement on the LMFBR Demonstration Plant.

LMFBR DEMONSTRATION PLANT

(Statement by Richard E. Webb)

Summary

The Liquid Metal Fast Breeder Reactor Demonstration Plant (LMFBR Demo) should *not* be built (not now at least) because the maximum explosion potential has not been scientifically determined. Because the LMFBR Demo will contain up to 1.3 tons of Plutonium and a large amount of fission product radioactivity, which absolutely must not be allowed to be spewed into the environment by a reactor plant explosion, the unknown explosion potential of the LMFBR Demo makes it imperative that the present plans for constructing and operating such a reactor be discarded in favor of further, more thorough, theoretical and experimental research into the said explosion potential. Moreover, the AEC and Congress lack the constitutional authority to be bringing into being the LMFBR and other civilian nuclear power projects. As officers of the Federal Government, who are bound to support the Constitution, the AEC and the Joint Committee on Atomic Energy should recommend that Congress submit an amendment proposition to the States so that the People can make the value judgment of whether a civilian nuclear program is both necessary and safe, as is their right.

Explosion potential

The "Environmental Statement" (WASH-1509, April 1972) issued by the Atomic Energy Commission for the LMFBR Demo states that the substantiation

of the claim that the reactor will be safe must await the issuance of the Preliminary Safety Analysis Report (PSAR) when the construction permit application is filed with the AEC. (See E.S., p. 37, 107). But it is obvious from reading the Environmental Statement that the AEC and the Joint Committee on Atomic Energy have prejudged the question of safety. For example, Congress has already authorized the LMFBR Demo and appropriated the money for it. (E.S., p. 1) Furthermore, the AEC asserted in the Environmental Statement that the provisions in the reactor containment structure for "blast and missile protection within the inner barrier provide substantial margins against major potential energy releases for *all* classes of accidents". (E.S. p. 54; emphasis added) The AEC added: "While it is impossible to postulate with precision the detailed course of accidents, including their likelihood and possible environmental consequences, *it is possible to place bounds on such accidents*". (E.S., p. 119; emphasis added)

These statements have no scientific foundation. Based on my knowledge of the state of the science of LMFBR explosion calculations, there is no chance that the aforesaid PSAR will substantiate such conclusions. Therefore, the construction of the LMFBR Demo should not be undertaken until after the necessary theoretical and experimental research is conducted, if such research demonstrates safety. The alternative is for Congress to recall the authorization and appropriation for the LMFBR Demo, wait for the issuance of the PSAR, and its review by the AEC and the Public, then hold public hearings on the safety of the LMFBR Demo.

The basis for my assertion is contained in my Ph.D. dissertation (thesis) which was submitted to, and approved by, the faculty authorities in the department of Nuclear Engineering at the Ohio State University. The title of the dissertation is "Some Autocatalytic Effects During Explosive Power Transients in Liquid Metal Cooled, Fast Breeder, Nuclear Power Reactors (LMFBRs)," the Ohio State University (1971).[1] A copy of the dissertation was sent to the director of the AEC's Division of Reactor Licensing (Mr. Peter Morris), which the Committee could borrow.

To summarize the conclusions of my dissertation, the calculational methods for determining the maximum explosion possible in an LMFBR have not been developed to include all possibilities, and their combinations, for autocatalytic phenomena during and after an initial nuclear runaway. That is, there are conceivable mechanisms by which "reactivity" can or might be rapidly "inserted" due to the motion of fuel material resulting from an initial core explosion or meltdown event. (Recall that in fast reactors, a core meltdown presents a mechanism by which reactivity can increase semi-rapidly and trigger disruptive or explosive power pulses.)[2] In other words, an initial event, or series of events, might cause the reactor to feed itself a massive dose of "reactivity" which would amplify the initial runaway, or cause a very servere secondary runaway; either of which might lead to a disastrous explosion.

When the calculational methods are developed to include all possible autocatalytic effects, they would still need experimental confirmation. Moreover, as I asserted in my thesis (p. 44), the present calculational methods "have not been confirmed experimentally for power reactor designs". For example, it has been claimed by Hirakawa and Klickman[3] that the KIWI-TNT power excursion experiment (TNT stands for Transient Nuclear Tests) has confirmed the MARS fast reactor excursion computer code. (The basic theory in MARS is the Bethe-Tait theory, which is partially used in the more advanced explosion codes such as VENUS. This theory provides the reactivity feedback mechanism that ends or "shuts down" the power excursion, and thereby limits the explosion force.) However, though the *post facto* MARS calculation of energy yield agreed fairly well with the KIWI-TNT measurement, the power pulse height (peak power), pulse shape, and pulse width as calculated by the MARS code are completely different than the KIWI-TNT experimental results. I used a simple

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[1] Microfilm or full size copy of Ph.D. thesis is obtainable from University Microfilm, Inc., Ann Arbor, Michigan. See *Dissertation Abstracts*, Vol. 33, No. 2 (Aug. 1972), pp. 754-B–755-B.

[2] LMFBR Demonstration Plant, Environmental Statement, WASH–1509, United States Atomic Energy, April 1972, p. 118.

[3] N. Hirakawa and A. E. Klickman, "An Analysis of the KIWI–TNT Experiment with MARS Code", *Journal of Nuclear Science and Technology*, Volume 7, No. 2, pp. 1–6, January 1970.

thermal expansion model, which excludes the basic theory in MARS that was thought to be tested (i.e., the Bethe-Tait theory), and calculated all four of the above items in excellent agreement with the experimental results.[4] This strongly indicates that the inherent shutdown reactivity mechanism in the KIWI-TNT experiment was not the Bethe-Tait mechanism, but one due to the simple thermal expansion of the KIWI core; and that the agreement between the MARS value of energy releases and experimental measurement was coincidental. In support of my conclusion, Jankus stated that the "Bethe-Tait assumption is definitely unjustified" for the KIWI-TNT excursion.[5] Furthermore, KIWI was not a fast reactor. Therefore, the KIWI-TNT explosion test has not been shown to be a confirmation of LMFBR explosion theories.

The SEFOR power excursion tests, which were performed to confirm the mitigating action of the Doppler effect for fast reactors, cannot be considered as proving out the LMFBR *explosion* calculational methods because the SEFOR excursions were not designed to lead to an explosion.[6] The tests involved (1) relatively mild rates of programmed reactivity insertion, (and then the total reactivity inserted was limited to a small amount) ; (2) designed Doppler feedbock magnitudes that were much greater than typical 1000 MWe LMFBR design values; and (3) automatic termination of the power transient by control rod scram (probably preprogrammed) to ensure against unexpected secondary excursions. Because of the strong Doppler and the limited amount of total reactivity that was inserted, the strongest power excursion tested was easily stopped with only about a 10% rise in the fuel temperature, which means that the SEFOR tests approached no threshold for meltdown or explosion. Normally in LMFBR accident calculations one assumes that the initial reactivity insertion is not limited, but is unrelenting. Thus, in a real accident situation the Doppler effect alone would not be sufficient to terminate the power excursion, and the core would continue to generate energy until there is an explosive or disruptive "disassembly" of the core that finally stops the power excursion and shuts down the reactor, if one could still call a reactor destroyed a "reactor". (Just how severe the explosion is and whether it is aggravated by autocatalytic effects is my main concern.)

Therefore. although the SEFOR tests were very useful in demonstrating the Doppler mitigating mechanism, and were evidently successful in that regard,[6] they provide no confirmation of explosion calculational methods. This is just as well, since there is a report which indicates that SEFOR was not designed to contain severe explosions.[7] With one-half ton of Plutonium in the SEFOR reactor, it appears that the AEC simply took a chance with the public safety by purposely causing power excursions, which one tries normally to prevent in power reactors, to test a safety effect (Doppler feedback) that was not beforehand demonstrated in a fast reactor power excursion. (SEFOR is now being decommissioned now that the tests are finished.) Whereas, prudence would suggest that such tests involving so much Plutonium should have been conducted only after a thorough research into autocatalytic reactivity effects was completed to establish the maximum possible accident, and with a containment designed to contain the maximum possible accident. Then, prudence would suggest that such a test reactor would be placed deeply underground just in case something was overlooked. (The EBR–I, BORAX–I, and SPERT–I reactors all suffered accidents because the power excursions were undercalculated.)[8] But instead, SEFOR was built above ground and may have been without explosion containment. Similarly, the LMFBR Demo would be an experiment with unknowns, involving 1.3 tons of Plutonium, and fission product Strontium-90 and cesium-137 and the like. That is, the LMFBR Demo is simply a chance that will be taken with the health and safety of the Public if allowed to be built without a firm ground of scientific research to establish the containment design.

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[4] R. E. Webb, "Critical Review of the KIWI–TNT Power Excursion as Calculated by the MARS Fast Reactor Excursion Code", Draft paper, unpublished.

[5] V. Z. Jankus, "Calculation of the Energy Yield in the KIWI Transient Nuclear Test, KIWI–TNT", ANL–7310, p. 366.

[6] SEFOR Reports: GEAP–13598, 10010–24, 29, 30 and 31. See Ref. 2 and 10 for discussion of SEFOR in regards to LMFBR safety, Ref. 2, pp. 19–20.

[7] R. E. Shaver and N. G. Wittenbrock, "Review of Reactor Safety Analyses of Fact and Liquid Metal Cooled Reactors", BNWL–477, UC–80, Reactor Technology, November 1967, pp. 21, 35.

[8] T. J. Thompson and J. G. Beckerley, "The Technology of Nuclear Reactor Safety", Volume 1, p. 616.

I mentioned so far the lack of experimental confirmation of existing calculational methods, as well as the inadequacy of the calculational methods from the standpoint of autocatalytic reactivity effects. The improved, calculational methods for predicting the LMFBR explosion potential, once developed. would still require experimental confirmation, just as was done to some extent for the Doppler effect in the SEFOR tests. To be sure fast reactor explosion tests were proposed by Nims at the 1963 Argonne National Laboratory Conference on "Breeding, Economics and Safety in Large Fast Power Reactors".[9] Nims considered the straight forwarded approach of simply building a prototype reactor, causing the core to meltdown, and observing the resulting explosion. Such tests would have to be repeated in a variety of ways in an effort to cover all possible or conceivable ways in which the core might meltdown. Nims indicated that the costs for such a series of tests would be prohibitive, since a series of costly reactors would have to be built, just to be destroyed. As an alternative he proposed a series of partial core meltdown experiments, short of explosion, to learn the manner in which the core would meltdown; and then with a more confident understanding of core meltdown acquired by such tests, full scale reactor meltdown tests would be designed and performed to determine the severity of the explosions associated with the prior established core meltdown patterns.

Nims argued that this alternate scheme may provide the desired information regarding LMFBR explosion potential at acceptable costs. I would add that the development of improved calculational methods regarding autocatalytic effects, that I contend is necessary, would be of help in designing such explosion experiments. (Of course, there is the possibility that such improved calculational methods might predict with confidence that the explosion potential of LMFBRs is simply too great to ever consider building LMFBRs at all). The LMFBR Program Plan (Volume 10, Safety) provides for studies of the necessity for such explosion testing.[10] (The Plan has adopted the alternate scheme investigated by Nims as that which is to be considered, without mentioning the more direct method of testing prototype reactors.) I have seen no results of such studies. Presumably, they are still being conducted. But regardless of their outcome, until improved theoretical methods are developed and tested by reactor explosion experiments, claims that the LMFBR containment structure is designed to contain "all classes of accidents" and that "it is possible to place bounds on such accidents" will continue to be groundless. Accordingly, if the United States is to pursue LMFBR development, we should discard the plans for a demonstration power reactor in favor of further research, terminating in explosion testing, unless the theoretical research proves that LMFBRs are inherently unsafe, so that we can be assured of confining the Plutonium and other radioactivity in the event of the worst possible LMFBR accident.

THE UNCONSTITUTIONALITY OF THE LMFBR DEVELOPMENT PROGRAM AND VALUE JUDGMENTS

The recurring word in the LMFBR Demo Environmental Statement is "safety". For example, on page 39 of the Environmental Statement the AEC asserts that the "safety of the LMFBR will be insured" through the use of plant protection devices aimed at accident prevention, and containers to contain explosions during "specific hypothetical accidents". Yet, there is no assurance in the Environmental Statement that the worst possible explosion will be analyzed in the Preliminary Safety Analysis Reports. The severity of a core explosion will depend on the rate of reactivity addition during core meltdown and compaction, as the LMFBR Demo Environmental Statement (p. 118) states. (It will also depend on whether autocatalytic reactivity effects are present, as discussed earlier). However, the AEC in their Environmental Statement (p. 118) state that the Safety Analysis Reports will treat only "credible" core compaction accidents (i.e., only "specific hypothetical accidents"), and not *all* possible core compaction accidents, or conceivable accidents which cannot be ruled out as physically impossible. It is obvious, therefore, that a certain amount of subjective judgment enters into the determination of where the line is drawn between "credible" and "incredible" core compaction accidents, and that this subjective judgment is influenced by other subjective judgments, such as those relating to the adequacy of the design and operating measures taken to minimize the likelihood of serious malfunction.

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[9] J. B. Nims, "Fast Reactor Meltdown Experiments", *Proceedings of the Conference on Breeding, Economics and Safety in Large Fast Power Reactors*, October, 1963, ANL–6792 (December 1963), pp. 203–231.

[10] LMFBR Program Plan, WASH–1110, Volume 10, Safety, pp. 10–213–10–23.5.

There is an indication in the Environmental Statement that the Safety Analysis Reports will draw heavily on the use of "reliability analysis"; or probability theory, for providing numerical criteria for deciding which core compaction events are "incredible", and therefore, not required to be analyzed, or, if analyzed to determine the associated explosions, not required to be contained. That is, those accidents of low enough predicted probability will be judged "incredible", and won't be guarded against. Murphy, et al, representing General Electric Company, a major LMFBR designer, expressed the view at a November 1968 Argonne Conference on LMFBR design that it "appears likely that one could assure by design that severe core-disassembly [explosion] accidents have such low probability that containment need not be provided for them".[11] On pages 106, 121 and A23 of the Environmental Statement the use of probability theory is implied with the mentioning of "quantitative evaluations of safety margins"; "technologically sound frames of reference within which judgments can be made"; "quantitative discussion of the likelihood . . . of specific accidents"; and "Exhaustive discussions of risks . . . will . . . be provided in the Preliminary and Final Safety Analysis Reports". If such probability theory and criteria are invoked, a note of extreme caution should be sounded, since it is *impossible* to predict the probability of nuclear accidents.

It can only be *assumed.* That is, ultimately in a risk calculation model, there are component subjective probability values and other assumptions upon which the "predicted" probability of a given accident will depend. In other words, the use of probability theory in risk calculations for reactor safety is merely a sophisticated form of what is ultimately a personal, subjective judgment—i.e., value judgments. Ultimately, therefore, the LMFBR Demo safety judgments will be subjective. Indeed, the very reason for developing LMFBRs is one of economics, which involves other kinds of value judgments. However, (and this is the crucial point of my testimony), Congress has not been vested by the People with the Constitutional power to make the value judgments of the necessity for and safety of civilian nuclear power. That is, the civilian nuclear power promotion program of the Congress and the AEC is unconstitutional in that the Congress acted without Constitutional authority in passing the 1954 Atomic Energy Act, and subsequent amendments, in regards to civilian nuclear power. Specifically, the Constitution does not grant Congress the power "to provide for the general welfare;" nor "to regulate and/or promote manufactures"; nor "to encourage by premiums and provisions, the advancement of useful knowledge and discoveries" (i.e., to promote civilian technologies by federal spending). Yet, Congress and the AEC assumed such power by unfounded theories regarding the *welfare* and *commerce* clauses in the Constitution. In other words, the 1954 Atomic Energy Act and Subsequent Amendments relative to civilian nuclear power are acts of usurpation. To prove my contention I refer the Joint Committee to the legal memoranda, and attachments thereto, filed in connection with my law suit against the U.S. Atomic Energy Commission, *Webb* v. *AEC*, Civil Action No. 72–14, U.S. District Court (Southern District of Ohio, Eastern Division).

I appeal to your oaths or affirmations to support the U.S. Constitution, and urge the Joint Committee to study my treatises, memoranda and citations filed with the Court. I am confident that if you will, you will believe it your duty to recommend that Congress at least suspend the civilian nuclear power program and submit to the States the necessary Constitutional amendment proposition requesting authority to proceed with such a program. Furthermore, I recommend that Congress propose the state convention mode of ratification. By proceeding in the Constitutional manner the People will then be allowed, as is their right, to make the value judgment as to the necessity for and safety of a federal program of promoting civilian nuclear power by spending and regulation. This right of the People has not heretofore been delegated to Congress or any agency of Government.

Additional Comments

Having given the Joint Committee my basic comments, I would like to offer several additional comments concerning the safety of the LMFBR Demo. These comments should not be construed as a report of an exhaustive evaluation on my part of the accident potential of the LMFBR Demo.

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[11] P. M. Murphy, et al. "The Effect of Using Different Safety Criteria and Selected Safety Studies for a 1000-MWe Sodium-cooled Fast Reactor", *Proceedings of the International Conference on Sodium Technology and Large Fast Reactor Design,* November 1968, ANL-7520, Part II, p. 346.

On page 39 of the E.S. the AEC asserts that a major objective of the LMFBR Demo project "will be to demonstrate . . . [the] safety . . . of the LMFBR power plant in a utility environment". As discussed earlier, prudence dictates that a demonstration of safety should be carried out scientifically and in such a way that the safety of the public and environment is assured *prior* to an operational demonstration of the LMFBR. That is, further theoretical research, experimental confirmation using test containers designed to contain the predicted, worst possible explosions, and then underground citing of the tests to provide protection against unforeseen effects is the approach that should be taken for demonstrating the safety of the LMFBR. However, as is now planned, the public and the environment must suffer the damage if safety is *not* demonstrated during the operation of the LMFBR Demo.

Furthermore, the 300–500 MWe LMFBR Demo *cannot* demonstrate the safety of the 1000 MWe LMFBR that the AEC plans for the 1980s. (See pages 8–9 of E.S.) This is because the larger the LMFBR is, the more hazardous are some of the safety related characteristics. For example, in a 1000 MWe LMFBR more Plutonium fissle material will be present in the core, which aggrevates the core-compaction-induced power excursion (nuclear runaway) accident and the potential for associated autocatalytic reactivity effects. Also, the larger the reactor core is, the greater is the autocatalytic reactivity effect due to reactor coolant (sodium) boiling,[12] an effect which can transform a relatively mild power excursion into a severe reactivity or nuclear runaway accident. (See pp. 112–113 of the E.S. for a brief discussion of this sodium boiling or voiding effect on reactivity.) Therefore, the LMFBR Demo will *not* demonstrate the safety of the larger 1000 M We plant, even if the LMFBR Demo reactor core is purposely caused to suffer either the worst credible accident, or the worst possible accident.

To be sure the 1000 MWe size is not the upper limit on the size of the LMFBRs that are being contemplated in the LMFBR Research and Development Program. It is common knowledge that the bigger the LMFBR is, the more profitable it is expected to be. With this incentive Argonne National Laboratory and Westinghouse Electric Corp. performed a feasibility study[13] of a 3,880 MWe (10,000 MWt) LMFBR, which would contain, not .93 to 1.3 tons of Plutonium as will the LMFBR Demo, but 11.6 tons of Plutonium. This study concluded: "The 10,000 MWt sodium-cooled fast breeder is feasible within the context of the ground rules of this study"; and "Successful development of fast breeders of nominal 1,000-MWe size will provide the technological base for very large fast breeders with no significant further R & D program required". Therefore, we must assume that the LMFBR Demo will not only be an alleged demonstration of safety for the 1000 MWe LMFBR, but for the 3,880 MWe plant as well. But as asserted earlier, the safety of any size LMFBR has not been scientifically established; and moreover, testing one size does not establish the safety of larger sizes. For justification of the LMFBR safety, the public basically has only, therefore, the statement of the AEC on p. 6 of the E.S. concerning the stages of research, development, and engineering which the LMFBR concept has passed: "This work has led to the conviction that safe commercial size plants are technically feasible and economically promising". But the People have not elevated the "convictions" of the nuclear community or the AEC to the status as the supreme Law of the Land.

The E.S. (p. 39) states that the "safety of the LMFBR will be insured" by, among other things, (1) "duplicate and independent shutdown systems"; and (2) "a plant protection system that senses any abnormalities and automatically shuts down the plant'. Item No. 1 is not reassuring, since no explicit assurance is given that each of the separate shutdown systems can individually and alone render safe all abnormal conditions where a fast shutdown would be needed to prevent serious explosion. Furthermore, the concept of "duplicate" systems does not imply systems of *diverse* design. The late AEC Commissioner Theos Thompson at the 1965 Argonne National Laboratory Conference on "Safety, Fuels, and Core Design in Large Fast Power Reactors" persuasively advocated not only redundant *scram* (fast acting) shutdown systems, but "diversity" in the design of the scram systems.[14] It has been said that the boundary line between a maxi-

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[12] G. H. Golden, "Elementary Neutronics Consideration in LMFBR Design", ANL–7532, March, 1969.

[13] K. A. Hub, et al, "Feasibility Study of Nuclear Steam Supply System Using 10,000-MW, Sodium-Cooled Breeder Reactor", ANL–7183, September 1966, p. 25.

[14] "Discussion of Papers Among Panel", *Proceedings of the Conference on Safety, Fuels and Core Design in Large Fast Power Reactors*, October, 1965, ANL–7120, pp. 269–270.

mum credible accident, and the more severe hypothetical accidents, is whether or not a reactor is scrammed during a serious core malfunction.[15] Therefore, the safety of the LMFBR Demo will depend in part on its scram systems. And inasmuch as Dr. Thompson argued *against* the concept of "duplicate" scram systems, the AEC's assertion, that the safety of the LMFBR Demo will be insured by such a concept, is in dispute. In this regard, I am reminded of the EBR–I core meltdown incident, which, incidentally, was caused by an autocatalytic power excursion.[16] During the excursion the control rods were scrammed, but that action failed to control the power excursion. The back-up scram system was then called on to stop the excursion. (If the back-up system would have been activated one-half second later than it was, a super prompt critical power excursion would have ensued, for which no bounds on the explosive energy release have yet been scientifically established). This back-up system consisted of dropping the reflector blannket away from the core, which was a different design concept than the control rod scram system that was first activated during the EBR–I incident. This fact supports the principle of *diversity* advocated by Theos Thompson.

The provision for the "plant protection system that senses any abnormalities and automatically shuts down the plant" strikes me as wishful thinking. Of course, we would have to await the specific design of such systems to evaluate how close to the ideal such systems can be designed for. However, there is always the possibility of unforeseen problems, human errors, carelessness, deliberate violations of design and operating procedures, and the like. In this regard I am reminded of the EBR–I core meltdown and Fermi partial core meltdown incidents. In the former the reactor operator failed to scram the control rods when he should have, and the attending scientist, who knew better the significance of the unfolding core behavior, promptly pushed the scram button himself. (See footnote 16.) During the Fermi meltdown incident, the control rod system was not scrammed when the fuel melting first occurred. Indeed the control rods were withdrawn further after the start of melting. Even after the Fermi Operator noticed that the control rod positions were abnormal, and after the core temperature readings were "found to be too high", the control rods were withdrawn still further, rather than scrammed. It wasn't until eleven minutes after a radiation leakage alarm sounded before a scram was initiated.[17] These incidents emphasize the possibility of plant protection systems not functioning as planned.

The "third level of safety" described by the AEC for the LMFBR Demo "concerns the postulated failure of protective safety systems simultaneously with the accident they are intended to control. The consequences of such hypothetical accidents must be evaluated and understood. Furthermore, if a practical means can be found to provide an additional measure of safety to mitigate the accident or accommodate the consequences, that also may be considered". (E.S., p. 106)

This description of the way in which severe accidents will occur is misleading, since it implies that two independent adverse happenings must occur simultaneously, i.e., at the same point in time without any connection. In truth severe accidents can occur because of prior, undetected failures of safety devices which won't function when an accident situation does develop.[18] Or, conceivably, an accident could cause the safety system to fail.[19]

I do agree with the AEC that the consequences of such hypothetical accidents must be evaluated and understood. But I could not agree that only those means practical for accommodating the consequences need be considered. (Indeed, the AEC states they *may* be considered.) Rather, if no practical means can be found to accommodate all possible accidents, the LMFBR Demo should not be built. Here is another example of how subjective judgments of AEC officials are used to justify claims of safety.

The Environmental Statement includes the AEC's response to the comments from the Scientists' Institute for Public Information (SIPI). Of special importance is the AEC's response to Dr. Edward Teller's article in *Nuclear News* (August 1967), which SIPI requested. Teller's article is critical of the LMFBR from a hazards standpoint. The article expresses concern for the possibility of

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[15] *Ibid.*, p. 268.

[16] R. O. Brittain, "Analysis of the EBR–1 Core Meltdown, page 2156, *Proceedings of the International Conference on the Peaceful Uses of Atomic Energy*, Geneva, 1958; and Reference 8 noted above, p. 628.

[17] Inferred from: R. L. Scott, Jr., "Fuel Melting Incident at the Fermi Reactor on October 5, 1966". *Nuclear Safety*, Volume 12, No. 2, March–April, 1971, pp. 123–134.

[18] George R. Gallagher, "Failure of N Reactor Primary Scram System", *Nuclear Safety*, Volume 12, No. 6, November–December, 1971, pp. 608–614.

[19] W. H. Zinn, see reference No. 14 noted above, p. 268.

secondary criticality accidents following a core meltdown, which is the same concern I am addressing in this statement. The AEC's response is unintelligible:

"This problem has been recognized, and technical efforts toward its solution include the development of means to assure that meltdown will not occur, and means to prevent reassembly into a critical mass if it were to occur". (E.S., p. A-130).

Is the AEC asserting in their response that recriticality following a meltdown is impossible? If so, it would be in conflict with its statement on page 118 where the possibility for such an accident, and associated "release of explosive energy", was admitted. The fact is, such accidents are possible, and their probability of occurring is mostly a matter of speculation. In short, the AEC did not respond to Teller's concern, except to say that he "overstates the critically hazard" by not recognizing the dilution of the Plutonium with other core materials. (However, this dilution does not preclude criticality.) It would be helpful if the Joint Committee would request and obtain Dr. Teller's answer to this reference to dilution, and to the rest of the AEC's response as well.

Furthermore, in refuting Dr. Teller's concern, the AEC asserts "that fast reactor behavior [during a mishap] is also well understood". (E.S., p. A-129). On the contrary, under accident conditions, it is not well understood. In this regard I believe the AEC distorted Teller's article. In summarizing his article, the AEC neglected to mention that Teller stated:

"I have listened to hundreds of analyses of what course a nuclear accident can take. Although I believe it is possible to analyze the immediate consequences of an accident, *I do not believe it is possible to analyze and foresee the secondary consequences*". (Emphasis added)

Similarly, an authority of fast reactor design, K. P. Cohen, of General Electric Company, stated at the before mentioned Argonne Conference in 1965 on LMFBR safety, fuels and core design:

"[W]e don't know very much about what the meltdown accident is going to be, and though one can indeed make calculations about it, one would be naive to really believe them".[20]

As I asserted earlier, the LMFBR Demo hypothetical accident predictions will be based only on *calculations*. Without the recommended improvements in these calculational methods along with experimental confirmation, we really would be naive to believe them. Sha and Waltar gave a recent status of the state of development of the calculational methods for analyzing core meltdown and explosion, and admitted that a "substantial amount of effort is yet required".[21]

I would like at this point to complain about the difficulty in obtaining technical reports. Many times I have not been given reports I have requested from the AEC and its contractors: but rather have been referred to the Springfield clearinghouse, which requires $6.00 per document, or to the AEC's Public Documents Room in Washington, D.C. It is unfair to expect that I can travel to Washington, D.C. to study documents: and it is unfair to expect a citizen to be able to afford $6.00 for each document. Furthermore, I have on occasion been denied documents because they were classified "internal distribution only". The Joint Committee should force a change in this policy and make all documents free upon request of the private citizen. In this regard I hereby ask the Committee to arrange for the AEC to send me GEAP-5092 (Vol. I and II), GEAP-5576, 13588, 13702, 13649, 10010-25, 26, 27 and 28. These documents concern the SEFOR experiment. I also request the SEFOR and FFTF safety analysis reports, and APED-4281, "The Southwest Experimental Fast Oxide Reactor", by K. Cohen et al, General Electric Company, June 1963, which the AEC's Technical Information Center has stated is for "internal distribution only", but which is cited in the open literature, LMFBR Program Plan, Volume 10, Safety, p. 10-250. I also would like the final topical reports for the SEFOR super prompt critical testing. I might add that it has been about one year since this testing and no topical report has been published as yet.

I would like to add that I have tried without success to gain employment in the AEC, and in their National Laboratories (ANL, Oak Ridge), to pursue the accident potential of the LMFBR. Oak Ridge was hiring scientists, but not in the area of my interests. This shows up the effort on the part of the Atomic

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[20] K. P. Cohen, see reference No. 14, noted above, p. 271.

[21] W. T. Sha and A. E. Waltar, "An Integrated Model for Analyzing Disruptive Accidents in Fast Reactors", *Nuclear Science and Engineering*, Volume 44, No. 2, May 1971, pp. 135, 156.

Energy establishment to use the power over personnel employment to suppress critical evaluations of LMFBR safety. This power is not in the interest of the health and safety of the public, and should be abolished. That is, the Government should provide equal employment for those scientists and others who want to pursue a truly independent, critical evaluation of the accident potential of the LMFBR, and other aspects of the civilian nuclear power which affect the health and safety of the people and the environment.

I should add that in giving this testimony to the Joint Committee, I am not "airing my technical opinions in public" without first submitting them to the AEC for examination. On February 19, 1972 I sent a letter to the Director of Regulation requesting that a special commission be appointed to investigate the potential of autocatalytic reactivity effects. My request was rejected, although the AEC did request a copy of my dissertation, which I sent them. (I am attaching a copy of the exchange of correspondence in this matter.) I have not received any comment whatsoever from the AEC about my dissertation.

Before I conclude, I would like to put my Ph.D. dissertation in complete perspective. The dissertation does not prove that severe autocatalytic reactivity effects are physically possible. Rather it proves that conceptual autocatalytic mechanisms have not been scientifically pursued to the point where conclusions can be drawn. One effect which I studied when applied to the Fermi LMFBR, along with certain assumptions which require verification, resulted in transforming an otherwise mild power excursion to an explosion of about eight times the containment design value for Fermi. (This shows that the Fermi reactor is another example of a chance taken with the Public safety.) The other effect, which I studied in detail, was the implosion of a trasverse gap in the core during an explosion. For the range of design variables I used (EBR–II and Fermi reactor designs), I found that this gap implosion may be capable of a serious autocatalytic effect, but that it probably isn't. However, because of the approximations and assumptions that were made, more sophisticated methods are needed to investigate the autocatalytic effect of gap implosion and to check my model. Other effects were considered, but could not be investigated because of the magnitude of the effort.[22]

Conclusion

The LMFBR Demonstration Reactor should not be built because the bounds on the accident potential have not been scientifically established. Because a meltdown of the LMFBR Demo core is a real possibility, a nuclear runaway is possible. It is the upper limit of the magnitude of the explosions resulting from such runaways which has not been scientifically established. Because of the 1.3 tons of Plutonium and other dangerous radioactivity to be present in the core, and because of the above uncertainty, the LMFBR Demo should not be built. That is, further safety research and testing must precede any LMFBR demonstration reactor, if prudence is to prevail. But more fundamentally, the AEC and Congress lack the constitutional authority to promote civilian nuclear power by programs of spending and regulation; that is, the AEC and Congress are not empowered to make the value judgments as to the necessity for and safety of the LMFBR. If the AEC and Congress want to continue with such a program, they should ask the People for the authority by submitting an amendment proposition to the States.

(The foregoing material was submitted to the AEC for comment. Correspondence and comment follow:)

SEPTEMBER 25, 1972.

Mr. ROBERT E. HOLLINGSWORTH,
General Manager, U.S. Atomic Energy Commission,
Washington, D.C.

DEAR MR. HOLLINGSWORTH: Enclosed is a "Statement on the Liquid Metal Cooled, Fast Breeder Reactor Demonstration Plant" by Richard E. Webb, Ph. D. The Committee is considering the inclusion of this statement in the public hearing

[22] Jay Edmond Boudreau, "Autocatalysis During Fast Reactor Disassembly," Ph. D. Dissertation, University of California, Los Angeles, 1972. See *Dissertation, Abstracts*, Volume 33, No. 1 (July, 1972), p. 230–B. In this thesis it was concluded that "autocatalysis *can* occur" and that "The potential for added energy release in the second and third excursions warrants further study."

record on the arrangements for construction and operation of the demonstration liquid metal fast breeder reactor.

Please review the enclosed document and supply the Committee with the Commission's comments on it.

Sincerely yours,

EDWARD J. BAUSER,
Executive Director.

ATOMIC ENERGY COMMISSION,
Washington, D.C., October 25, 1972.

Mr. EDWARD J. BAUSER,
Executive Director, Joint Committee on Atomic Energy,
Congress of the United States.

DEAR MR. BAUSER: In accordance with the request in your letter of September 25, 1972, enclosed is the AEC staff review of a "Statement on the Liquid Metal Cooled, Fast Breeder Reactor Demonstration Plant" by Richard E. Webb, Ph. D.

In its comments the staff addresses mainly Dr. Webb's views on breeder reactor safety and on the constitutionality of the Atomic Energy Act of 1954. Our review indicates that from technical and legal standpoints the Statement offers no justification for reversing the AEC's current plans for designing, constructing and operating the LMFBR Demonstration Plant.

If we can provide you with any additional information in this regard, please do not hesitate to contact us.

Sincerely,

JOHN O. ERLEWINE,
Deputy General Manager.

AEC STAFF REVIEW OF DR. R. E. WEBB'S STATEMENT ON THE LMFBR DEMONSTRATION PLANT

1. Constitutionality of the Atomic Energy Act

Richard E. Webb brought suit against the Atomic Energy Commission in U.S. District Court in Ohio, alleging in effect that the Congress exceeded its powers under the Constitution by enacting certain provisions of the Atomic Energy Act enabling the development of nuclear power for civilian use. The suit was dismissed by the Court on the ground that the plaintiff did not have standing to challenge the constitutionality of the Atomic Energy Act of 1954. The Government had contended that the plaintiff lacked the requisite standing to challenge the constitutionality of the Atomic Energy Act, and that it was well settled that the Congress was constitutionally empowered to provide by statute for the conduct by AEC of the nuclear power developmental program.

2. Safety Issues Pertinent to the LMFBR Demonstration Plant

The Division of Reactor Development and Technology has under way extensive base technology and development programs for the purpose of providing engineering and safety understanding and thus assuring the success of the LMFBR program objectives, including the Demonstration Plant. Volume 10 of the LMFBR Program[1] covers all questions relating to the LMFBR Safety program and in particular such questions as raised by Dr. Webb, which fall in the category of hypothetical accidents and their consequences. In the area of hypothetical accidents, the safety program has as its objective the understanding of phenomena related to hypothetical events and their consequences through the conduct of extensive in-pile and out-of-pile testing as well as analytical programs which complement the experiments. This understanding will provide realistic bounds and estimates of risk so as to permit both favorable engineering selection and assessment of risk relative to alternatives and to benefits anticipated. The LMFBR base and development program will encompass a full consideration of accident situations. Finally, the construction and the operation of the LMFBR Demonstration Plant will be subject to the Commission's regulatory requirements; as required by law, a permit or license will not issue if the Commission believes such issuance could be inimical to the health and safety of the public.

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[1] WASH-1101-1110. LMFBR Program Plan, August 1968. (It is presently being updated.)

The Commission's regulatory review will, among other things, be based on the state of the technology at that time, and on the specific features of the design being considered. Some examples of work under way in the areas of most concern to Dr. Webb are:

a. In the area of calculational methods for determining the magnitude of disassembly accidents, Argonne National Laboratory has developed the two-dimensional VENUS reactor disassembly code. This code takes into consideration autocatalytic reactivity effects such as fuel motion. The main conclusion from this work so far is that it takes only a moderate pressure and a very small amount of material movement to cause the disassembly of a nuclear reactor. Thus, during a hypothetical nuclear excursion, the maximum energy and thus the generated pressures are limited by the early occurrence of disassembly. This work has been conducted by using the FFTF parameters and characteristics. As can be seen from the referenced LMFBR Program Plan, work in this area is continuing. Because of the close coupling of potential safety problems to a particular design, a specific design (the demonstration plant for example) will be used to bring into sharp focus the LMFBR safety program, including work in the area of disassembly accidents of concern to Dr. Webb.

b. The in-pile meltdown tests performed to date in the TREAT reactor indicate that the mechanical damage potential is less than that which is thermodynamically possible by two or more orders of magitude.

Dr. Webb uses the EBR-I incident as a strong justification for his argument of the autocatalytic nature of fuel element melting. It has been established that the meltdown of the EBR-I fuel was due to fuel element bowing which because of the fuel's structural design caused a positive coefficient of reactivity. It is this effect that caused the short period transient in the EBR-I experiment and eventually led to the meltdown. The postmortem examination of EBR-I indicated that uranium was expelled from the core. More than half of the uranium which was originally at the core center had been pushed out by melting to a position near the edge of the core. Therefore, the EBR-I meltdown incident demonstrated that this phenomenon contributed to the shutdown of the reactor instead of leading the reactor into a "runaway" condition as asserted by Dr. Webb. In fact, the importance of fuel motion as a shutdown mechanism is also evident from recent analyses (ANL's SAS and HEDL's MELT Accident Analysis Codes) and the results from the in-pile testing in the TREAT reactor.

3. Additional Comments

a. Availability of AEC-Contractor Reports.—To obviate the excessive expense and complexity of having each government contractor individually print, catalog, store, process requests and mail copies of contractor reports, the Clearinghouse for Federal Scientific and Technical Information was established. It has long been the policy of the government to attempt to recover the costs of printing such reports and thus the Clearinghouse is required to levy an appropriate printing charge. As indicated by Dr. Webb it would be unreasonable to expect requestors who do not wish to purchase AEC contractor reports to travel to the AEC Public Document Room in Washington in order to inspect them. For this very reason, the AEC established about sixty report collection and film libraries throughout the United States. There are four such centers in Ohio where Dr. Webb resides: 1) Ohio State University, 2) Cleveland Public Library, 3) University of Toledo, and 4) University of Cincinnati. It would appear that Ohio State University, where Dr. Webb did his graduate study work, would be his most convenient location. Its library should have copies (on film or in report form) of all published AEC research and development reports including the GEAP reports cited in his Statement. The requested APED-4281 report is not an AEC report: this report was sponsored by General Electric Company (GE) and was prepared by K. Cohen et al for presentation at the Eighth Nuclear Congress in Rome, June 17-20, 1963. It should be available from GE upon request.

b. Review of Dissertation.—Dr. Webb asserted that although the AEC was sent a copy of his Ph.D. dissertation, no comment was received from the AEC. In this regard, the AEC had no intentions of commenting on the dissertation as, it was believed, this was the function of the University. However, the safety issues which were discussed in the dissertation concerning the accident potential of the breeder have long been under study by the AEC and continue to be addressed in the AEC's safety reviews of LMFBRs.

APPENDIX B

[Cover Page of Original Statement **Omitted by the JCAE.**]

S T A T E M E N T

on the

L I Q U I D M E T A L C O O L E D , F A S T B R E E D E R R E A C T O R D E M O N S T R A T I O N P L A N T

b y

R i c h a r d E . W e b b , P h . D .

(September, 20, 1972)

"It is, in our view, unlikely that one will be able to design for the worst accident permitted by the laws of nature and end up with an economically interesting system, even after extensive additional research and development has been carried out."

-----P.M. Murphy, et al, of the General Electric Co. at the International Conference on Sodium Technology and Large Fast Reactor Design, held at Argonne National Laboratory, November, 1968, ANL-7520, pp.356, 357. (This statement was made in support of a recommendation to use probability theory in assessing LMFBR safety.)

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APPENDIX C

Basic Theory of LMFBR Nuclear Runaway
In More Detail

A nuclear power reactor, such as an LMFBR, generates energy or heat for eventual electric power production by the fissioning (splitting) of uranium and plutonium fuel atoms. This fissioning is caused by the interaction of fuel atoms with small atomic particles called "neutrons," which fly around inside the reactor at great speeds. When a neutron strikes the nucleus of a fuel atom, it is likely to be absorbed and cause the atom to fission. The number of fuel atoms in the core is extremely large; and only a tiny fraction of these are fissioned in one second. Numerically, one ton of fuel in a large 1000 MW LMFBR is made up of about 2×10^{27} atoms, i.e., 2 thousand trillion trillion atoms. In one second our 1000 Megawatt LMFBR will fission 3×10^{19} fuel atoms, or 3 billion trillion atoms. Hence to fission all of the fuel atoms in a ton of fuel in our 1000 MW LMFBR would require $2 \times 10^{27} \div 3 \times 10^{19} = 2/3 \times 10^{8}$ seconds (67 million seconds), or about 3 years. Therefore, when I speak of fissioning, extremely large numbers are involved, even though I might refer to one or a thousand fissions. Likewise, large numbers of neutrons are involved.

Each fission, besides releasing the sought after energy, releases several neutrons (2.5 neutrons per fission on the average), which

are then available to carry on the process through the next fission cycle in order to sustain the fissioning rate (power level) in the reactor. However, since only one of the released neutrons is needed for the "next fission," 1.5 neutrons per fission are extra, the difference between 2.5 and 1.0. But as we shall see next, these extra neutrons are lost to the system either by leakage or non-fissionable absorption, except for slight imbalances which give rise to power level transients, which can be slow or extremely rapid, as in an explosive nuclear runaway.

Because of the finite size of the batch of fuel in the reactor, which is called the "reactor core," a fraction of the neutrons produced by fission are lost due to leakage--i.e., some neutrons escape the core and never return to cause more fissions. Because, too, non-fuel materials exist in the core which absorb neutrons, such as structural materials and Uranium-238, used to dilute the fuel, some of the neutrons are absorbed without causing fission. The result of the size and non-fuel effects is a competition between losses (leakage and absorption) and gains (fission neutrons). When these competing factors are balanced, the fission rate or power level is constant, and the reactor is said to be "critical." In general, whenever fissionable material in a critical reactor is brought closer together (fuel compaction), the chances for the neutrons striking fuel atoms and causing fission, rather than leaking out of the core, will improve; and the neutron balance in the fission cycle tips in favor of excess neutrons available for fissioning. The extra neutrons then produce extra fissions which in turn produce

extra neutrons, and so on as the fission-neutron cycle repeats. The result is a growing neutron population and a growing fissioning rate, and hence an increasing reactor power level. In this condition the reactor is said to be "supercritical." In the reverse case, when fuel expands (fuel moving apart), the neutron leakage increases; and then the neutron balance tips the other way, causing the power level to decay, since less than one neutron released per fission on the average is available to sustain the next fission. In this condition the reactor is said to be "subcritical."

The percentage difference between the number of neutrons available for fissioning and the number needed to sustain the fissioning rate at a constant level is a crucial parameter called the "reactivity." Therefore, when the reactivity is positive, the fissioning rate grows and the reactor is super-critical; and when the reactivity is negative, the fissioning rate decays, and the reactor is subcritical. Thus, fuel compaction increases the reactivity, and fuel expansion decreases the reactivity. When the reactivity is zero, the reactor is critical. As we shall see, +1% reactivity is very strong.

There is another kind of neutron balance involving the time scale, and concerns the controllability of reactor power level increases. Foremost is the "neutron lifetime," which is the time period between the release of neutrons from one set of fissions until these fission neutrons cause the next set of fissions (a fission cycle). The neutron lifetime is extremely short in a LMFBR--about .0000001

seconds, or one-tenth of a millionth of a second, due mainly to the fast speeds of the neutrons, which is why the LMFBR, Liquid Metal Fast Breeder Reactor, is called a "fast" reactor - meaning a fast neutron reactor. If this is all there were to fission-physics, then once a reactor was made slightly supercritical, it would quickly runaway with an uncontrollable burst of energy. In order to appreciate this, assume that a large 1000 megawatt LMFBR was critical at a feeble power level of 1/100 watt, which would be .00000000001 of the reactor's designed full-power level. Then assume the reactor is made supercritical by a slight compaction of the fuel so that the reactivity is increased to +.5%. (Roughly, a 2% reduction in reactor core volume by core compaction adds .5% of positive reactivity. Potentially, the core volume could be reduced by about 50% by compaction; but as we shall see, a nuclear runaway would explode the core before it could be compacted very much past a 2% volume reduction). A reactivity of .5% means that the number of fissions per cycle would increase by .5% with the passage of each neutron lifetime (i.e., from one fission cycle to the next fission cycle). This means that the number of fissions occurring per cycle increases, not at a steady rate, but at progressively increasing rate (i.e., "exponentially"). This is because the number of fissions in one cycle is .5% greater than the number of fissions in the immediately preceding fission cycle, and not .5% of the number of fissions in the first cycle after the reactivity was raised above zero. That is, the increase between successive fission cycles is .005 times the current number of fissions occurring per cycle. Since the increase per cycle gets larger when the current number of fissions per cycle gets larger, the growth rate of fission-

ing accelerates, instead of staying constant, as time progresses.

As an illustration, let us assume that the first cycle produced 1000 fissions, and then compare the case of steady-rise with the exponential-rise after 10, 100, 300, 1000, and 2000 cycles, respectively, given the .5% reactivity. The following table illustrates the difference between the two cases:

Number of Fissions Occurring in the "Nth" cycle

Nth Cycle	Steady Rise	Exponential Rise
1st	1,000	1,000
10th	1,050	1,051
100th	1,500	1,650
300th	2,500	4,500
1,000th	6,000	143,000
2,000th	11,000	20,500,000

From the table we see that there is little difference in the first 100 cycles. However, the number of fissions per cycle in the exponential case begins to get progressively greater than the steady-rise case, until past the 1000th cycle when the exponential rise "runs away." This process happens extremely quick in time because of the short neutron lifetime (time period of the fission cycle). For example, there are 50,000 fission cycles in just one-thousandth of a second, or millisecond, which allows a tremendous growth in fissioning in a very short interval of time.

Let us now ask what would be the power level and energy generated

after our hypothetical reactor was supercritical at .5% reactivity for one millisecond. The answer is that the power level would grow, if it were not controlled by core expansion,* to 500 billion times the 1000 megawatt full-power level designed for the reactor, starting with only a feeble 1/100 of a watt; and the energy generated during the millisecond would be 100 billion megawatt-seconds, roughly equivalent to a 25 megaton nuclear weapon explosion. Actually, the heat generated early during the transient would create pressures within the fuel to expand the fuel, which decreases the reactivity to a negative value. (Just as the fission rate grows exponentially when the reactivity is positive, the fission rate decays exponentially when the reactivity is negative. Therefore, when the reactivity is negative, the power level will quickly decay to a feeble level with the same rapidity as the runaway rise in power level). This expansion, therefore, affects the reactivity, and the course of the runaway, and must be taken into account. When it is, an LMFBR under a .5% reactivity runaway (and no Doppler feedback) will produce an explosion of the order of 1000 lbs. TNT equivalent, excluding autocatalytic reactivity effects, according to estimates. This negative reactivity effect due to expansion, thus, terminates the runaway, limiting it to a much less violent explosion--about 1000 lbs. TNT equivalent for the assumed reactivity condition in an LMFBR. This phenomenon of exponential growth of the fission rate is called a "nuclear runaway," which can produce a burst of explosive energy.

Given such hypothetical reactor behavior, the reactor would not

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* and fuel burn-up.

be controllable, since a slight increase in the reactivity, which a reactor operator would normally want to make in order to raise the power level from shutdown to full power level, for example, would lead instantly (within a millisecond) to reactor destruction before the control equipment could respond. This is because the mechanical reactor control equipment couldn't make the super-fine changes in reactivity that would be needed to raise the reactor power level at a controlled rate for our hypothetical reactor. That is, the nuclear runaway would be over within a millisecond, before the control rods would move any appreciable amount.

Fortunately, for control purposes, a small fraction of the fission released neutrons (about .3% to .7%) in a real reactor do not appear promptly with the fissions, but are emitted by the fission fragments with about a one second delay. The fraction of the fission neutrons which are delayed is called the "delayed neutron fraction." If a reactor was made supercritical, but with the reactivity kept below the delayed neutron fraction, the delayed neutrons would have the effect of suppressing the growth rate of the fissioning, enabling one to control the reactor. To understand why, consider again our hypothetical supercritical reactor with no delayed neutrons:

With the reactivity positive, there would be more fission-released neutrons to cause further fissioning than would be needed to sustain the fission rate at a constant level. But by not being delayed, the extra neutrons would cause the extra fissioning within the short neutron lifetime. Hence, the fission rate would rise extremely rapidly in a exponential, runaway fashion. But if the extra

neutrons were delayed by about one second, then the extra fissioning, caused by these extra neutrons, would be correspondingly delayed. The result is that the fissioning rate, or reactor power level, in a real reactor would grow slowly, over the time scale of seconds instead of 1/10 of a millionth of a second (i.e., instead of in the runaway fashion, if the reactivity is less than the delayed neutron fraction). In this state the reactor is still said to be "super-critical." This neutron delay, then, provides enough time for the reactor control system to maneuver the power level during normal operation. When the desired power level is reached, the reactivity is returned to zero, so that the reactor will be made critical - i.e., producing power at a constant level.

However, if the reactivity is raised to exceed the delayed neutron fraction, then there will be an excess of prompt neutrons available for extra fissioning. The growth of fissioning will then occur over the short time period of the "neutron lifetime," instead of over a long delayed period. Hence, when the reactivity exceeds the delayed neutron fraction (about .35% in a LMFBR), a nuclear runaway will ensue in the fashion of our "hypothetical" reactor previously discussed. In this runaway condition, the reactor is then said to be "super-prompt-critical." When the reactivity equals the delayed neutron fraction, the reactor is said to be "prompt critical," which is the threshold for nuclear runaway. The crux of reactor control is to keep the reactivity below prompt critical, or else an explosive nuclear runaway will occur. But this is not always possible, as an accident could make the reactor super-prompt-

critical.

Next, we shall summarize the phenomena which can change the reactivity, as these reactivity effects are crucial to the control and the accident behavior of the LMFBR. These phenomena are as follows:

(a) Reducing the neutron leakage increases the reactivity.

This is accomplished by bringing fuel together (compacting fuel or adding more fuel) so that the neutrons have a better chance of interacting with the fuel atoms, rather than being lost due to leakage. A special case of compaction is implosion; e.g., when the fuel explodes into a hollow, interior cavity, while being essentially confined from exploding outward. A fuel meltdown could produce core compaction.

(b) Increasing the neutron leakage decreases reactivity.

This is accomplished by moving fuel apart: expansion as with explosion; fuel falling away from the core; or fuel from the core being removed mechanically or carried away by the flowing coolant.

(c) Increasing the neutron absorption by non-fuel material decreases reactivity; conversely, reducing such absorption increases reactivity. This phenomenon is used to control the reactor once enough fuel is assembled to make the reactor critical. The control is effected by inserting or withdrawing "control rods" into and out of the reactor core. These control rods are made of non-fuel, neutron absorbing material. Thus, inserting them into the core robs neutrons that would otherwise cause fission, and thereby,

decreases the reactivity. Withdrawing the control rods reduces the non-fuel absorption of neutrons and increases the neutrons available for fissioning, and thus increases the reactivity. In general, the reactor is designed so that the neutron balance is achieved when the control rods are withdrawn to the "critical height" position that is part way out of the core. When the control rods are withdrawn to this height, the reactor will be critical. Further withdrawal will make the reactivity positive, and the reactor will be super-critical. If the control rods are withdrawn too far, the reactivity can increase beyond the delayed neutron fraction, and the reactor will be made super-prompt-critical, and then a nuclear runaway will ensue.

These control rods are regulated so as to raise and lower the reactor power level for normal operation while keeping the reactivity below prompt critical. Also, as the fuel "burns-up" with use (each fission destroys a fuel atom), the reactivity would tend to become negative (i.e., make the reactor subcritical) since fuel burn-up has the effect of removing fuel. (A subcritical reactor could not produce power because the power level would decay to practically zero.) To compensate for this burn-up effect, the control rods are withdrawn slowly over the period of months as the fuel is depleted to keep the reactor critical and producing power. The fuel will continue to be depleted with reactor operation until the control rods are fully withdrawn from the core, in which case the reactor power level could not be sustained for normal operations (end

of life), and the reactor would have to be "refueled." However, if the reactor suffered fuel meltdown in the "end-of-life" condition, there is still the reactivity rise potential due to core compaction and, therefore, the potential for nuclear runaway accidents.

The control rods also have a crucial safety function. In the event that the reactor should reach a dangerous reactivity condition (near prompt critical) the "protection system" is designed to rapidly insert or "scram" the control rods to render the reactor subcritical. This safety action is called "reactor scram."

(d) Increasing the fuel temperature decreases the reactivity.

This is an inherent safety mechanism called "Doppler feedback," which is being designed into LMFBR's in the United States. It is designed to act during a nuclear runaway to limit the energy burst, when a control rod scram would be too slow to have any mitigating effect. More specifically, as the temperature rapidly increases in the fuel during a nuclear runaway, the Doppler effect promptly substracts reactivity to slow the runaway and, in some mild runaway cases, can render the reactor safely subcritical until the control rod scram can permanently shutdown the reactor without the generation of excessive temperatures (i.e., explosive pressures). However, in most runaway accidents, the source of the initial reactivity increase which caused the runaway will persist to override the negative Doppler reactivity. Other sources of positive reactivity may occur as well. So Doppler feedback is not sufficient to stop most accidents. Also,

the Doppler reactivity reduction potential is limited practically to about 1% of negative reactivity. Thus, Doppler is not enough to cope with the potential for accidental positive reactivity addition.

(The negative reactivity of overall core expansion is being counted on as the main shutdown mechanism for terminating a nuclear runaway.) The chief role of the Doppler, then, is to slow down the nuclear runaway long enough to enable the expansion process to occur and make the reactor subcritical. This mitigating effect of the Doppler can be strong.

(e) Sodium coolant (liquid metal) expulsion from the core can increase or decrease reactivity, depending on which regions of the core are made devoid of coolant. This effect is due to a trade-off between increased neutron leakage and increased neutron absorption by the fuel when coolant is "voided" from the core. The net reactivity change can be positive if the sodium coolant is expelled (voided) from the inner regions of the core, where neutron leakage from the core is lowest.

Having now described the basic reactivity change mechanisms, let us learn how these mechanisms can be called into play in an LMFBR accident to bring about a nuclear runaway and explosion.

The fuel in the LMFBR is arranged in bundles of fuel rods spaced somewhat apart for coolant passage (heat removal). Therefore, the fuel is not arranged in its most reactive state, since the coolant passages provide space for fuel compaction. However, the reactor

fuel rods are designed to be fairly rigid so that they won't bow inward or slump (compact) during normal operations and add excessive reactivity. However, if the fuel should over-heat, either by unchecked control rod withdrawal, which adds reactivity and causes the power level to rise to excessive levels, or by a loss-of-coolant, the fuel will melt, lose its rigidity, and could then collapse onto itself as the molten fuel moves into the coolant passage space. The result of core meltdown, then, could be core compaction, which can cause an excessive rise in reactivity. Keep in mind that it takes only slight compaction to raise the reactivity to prompt critical -- about 2% volume reduction of the core; and then slightly more compaction to trigger the nuclear runaway. That is, slight fuel movement either way can have either a serious positive reactivity effect, or a strong negative reactivity, shutdown effect. Actually, after the reactor has operated a while, intense radioactivity builds up, so that even if the reactor was made subcritical and the fission power level dropped to feeble levels, the heat from the decaying radioactivity, called "decay heat," which is substantial, will persist. This decay heating can by itself melt the fuel and could bring about core compaction.

Besides fuel meltdown, sodium coolant voiding can trigger a nuclear runaway as well. For example, a loss-of-coolant flow accident or over-power accident can lead to coolant overheating, boiling, and then expulsion or voiding of the coolant from the core. This sodium voiding can then add reactivity past prompt critical to produce a nuclear runaway. This is an example of autocatalytic

behavior, where an LMFBR accident feeds itself a dose of positive reactivity by overheating to produce a nuclear runaway, which then worsens the accident.

The central concern in LMFBR accident analyses is the behavior of the reactivity during the accident. From the foregoing it is clear that besides coolant voiding we must be able to accurately predict fuel motion during an LMFBR accident situation to determine whether the explosion process itself can compact part of the core to a sufficient degree to increase the reactivity before overall core expansion permanently renders the reactor subcritical or shutdown. If sufficient fuel compaction occurs during an explosion to offset the negative reactivity due to Doppler and overall core expansion, then the net reactivity can increase, instead of decrease during the nuclear runaway, and the runaway will become worse (faster), instead of being terminated; or if the nuclear runaway had already been terminated, a second one could occur. As we've seen at the outset, the energy can build up very quickly to dangerous, explosive levels when the nuclear runaway condition is prolonged. The behavior of the reactor when reactivity rises instead of falls during the accident is called "autocatalytic," meaning that the core is its own catalyst--speeding up its own fission reaction rate. Conceivably, autocatalytic reactivity effects could even exhaust the Doppler negative reactivity effect, which would make an explosion all the more severe. Eventually, however, overall core expansion (explosion) would take over and drive the core subcritical.

The question is, though, how much energy can the nuclear runaway(s) generate before being finally terminated--the energy being then correlated with the size of the resultant explosion.

The energy yield of an LMFBR nuclear runaway accident, which is the measure of the force of the explosion, is related to the rate at which the reactivity rises above prompt critical.* If the rate is low, the nuclear runaway will proceed less rapidly than otherwise, giving the fuel material time to accelerate outward (expand) and provide the offsetting negative reactivity before too much reactivity builds up to generate a stronger runaway. If the rate of reactivity increase is high, then more reactivity can be "inserted" before the expansion occurs, and a stronger runaway occurs. Remember, it takes time for fuel material to accelerate and expand, which allows for reactivity insertion. Initial meltdown events are characterized by upper limits of reactivity insertion rates of about 200% per second, which when mitigated by the Doppler effect, yields the 500 lb. TNT-order explosion, assuming no autocatalysis. But, autocatalytic reactivity effects such as explosive compaction could conceivably yield reactivity insertion rates in excess of 1000% per second. Therefore, fuel motion is the primary object of study in LMFBR accidents analyses, and must be fully understood to establish the maximum explosion potential of the LMFBR.

Complicating the nuclear runaway problem is the amount of fuel

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* The "reactivity insertion rate."

concentrated in an LMFBR, which is enough to make somewhere between 10 to 40 separate critical reactors, if the fuel is fully compacted (fully dense). Thus, for example, a nuclear runaway could be terminated by slight expansion of core materials during the initial phase of a nuclear runaway explosion, only to compact enough fuel later on to return the core, or a part of it, to super-prompt-critical; i.e., to trigger secondary nuclear runaways. However, with explosive compaction, the rate at which the reactivity would increase would be great, and the momentum of the compacting fuel would have to be overcome, which delays the shutdown reactivity and conceivably could enable the runaway to grow to very dangerous levels.

These factors, then, make explosive compaction a matter of grave concern. (Indeed, the atomic bomb is produced by explosive compaction.* Whether, an LMFBR can be made to explode like an atomic bomb is a question I honestly don't know the answer for. All I can say is that I have seen no analyses which rule out the possibility; and that I'm prevented from learning the physics of the atomic bomb, since the information is kept secret. My best judgment though, is that the worse autocatalytic nuclear runaway in an LMFBR would not produce an atomic-bomb-like explosion, but that it may produce a severe enough explosion to "blow-up" the reactor and allow the escape of the radioactivity to the environment.**)

It is useful to compare the commercial, water-cooled reactors now being operated--the so-called light water reactors (LWRs)--

* The compaction is affected by detonating a TNT charge.

** The worst conceivable LMFBR explosions mentioned in this Rebuttal range from 500 lb. TNT equivalent to the order of 20,000 lb. TNT, which compares with a 20,000 tons of TNT equivalent for the first A-bomb.

with the LMFBR. The concentration of fissionable fuel in an LMFBR core is much greater than the LWR. In fact the LWR fuel concentration is so low that without the water coolant, the fuel probably cannot be made critical even if the fuel is fully compacted. It turns out that the LWR fuel can only be made critical if the fuel is spaced apart in the form of fuel rods with water in between. Unlike the sodium coolant in an LMFBR, the water in an LWR greatly slows down the neutrons, which are released at high speeds by the fissioning. A slow neutron has a much better chance for splitting atoms than a fast neutron. Hence, a lesser fuel concentration is needed in a LWR. But if the water coolant should be expelled or drained from the core of a LWR, the reactor would be rendered subcritical, since the fission neutrons would not be slowed down, and without the slow neutron the low fuel concentration could not sustain the fissioning. In contrast, the loss-of-coolant in an LMFBR core could trigger a nuclear runaway.

The loss-of-coolant accident in a LWR presents the danger of a core meltdown, and the associated possible disaster of the built-up radioactivity escaping to the environment.* But because the LWR has a low fuel concentration, it does not have nearly the reactivity or nuclear runaway problem associated with fuel meltdown or coolant expulsion in an LMFBR.

Furthermore, the Doppler effect is stronger in the LWR, and the neutron lifetime is longer by a factor 1000. These facts make a nuclear runaway in a LWR less severe compared to an LMFBR for

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*Due to the meltdown causing a breach in the reactor container.

the same initial reactivity condition. (However, the LWR still has a serious potential for nuclear runaway; but this fact is beyond the scope of this LMFBR safety review). Finally, the LMFBR has a power density in the core that is about ten times higher than that of a LWR. The power density is the amount of heat (power) generated in a given volume of core. This higher power density means that core meltdown occurs more vigorously, should adequate cooling be lost, than in a LMFBR. Also, the "decay heat" in an LMFBR is correspondingly stronger, which makes core meltdown worse than in a LWR without adequate cooling. This decay heat is troublesome for a number of reasons, one of which is that even if the LMFBR had shutdown (subcritical) after suffering a meltdown, the fuel might freeze into an uncoolable mass, which could soon melt again, generating the possibility of re-assembly back into a "critical mass" and nuclear runaway.

Such is the basic theory of LMFBR nuclear runaway accidents.

APPENDIX D

Unavailability of Certain Argonne
National Laboratory R & D Reports on
LMFBR Safety to Universities

The following is an excerpt of a memorandum from myself to a member of the Board of Trustees of Argonne Universities Association (AUA), which is an organization of universities that are affiliated with ANL and exercise policy making powers for ANL:

Memo From: Richard E. Webb

Subject: Unavailability of R & D Reports Emanating From Argonne National Laboratory

In a letter dated January 9, 1973 from the Technical Publications Department of ANL I have been told:

> "Recently, the U.S.A.E.C. revised its policy regarding the distribution of reports on LMFBR. Any future reports on the LMFBR safety program will be distributed according to this revised policy which precludes distribution of these reports by the Argonne National Laboratory except as directed by the U.S.A.E.C."

This new policy of information impedance tends to thwart my studies into civilian nuclear power safety, which I am performing here at Indiana University. Specifically, I am trying with only limited success to obtain crucial reports emanating from ANL which describe accurately and totally the progress and other findings of ANL related to the Liquid Metal Fast Breeder Reactor (LMFBR) research and

development program, a civilian project. I am writing to you to urge you to seek a change in the said policy, and re-open up the Laboratory's work for scholarly examination by universities.

The particular areas of concern are:

1. Unavailability of the Reactor Development Program progress reports with the ANL-RDP prefix designate;

2. The mal-practice of issuing "limited distribution reports;"

3. The question whether the AEC requires its review and approval ANL reports are published;

4. The emergence of two new categories of R & D, Base Technology and Applied Technology, the latter of which is meant for absolute restriction on flow of information to unauthorized persons such as universities; and

5. The propriety of the practice at ANL of reporting the ANL R & D work through the American Nuclear Society's Transactions.

The health and safety of the public should be the overriding consideration of scientific and technological endeavors, whether they be at ANL or a University. The LMFBR has the potential of doing enormous harm to the public, as well as good. The LMFBR safety issues and uncertainties are, therefore, of vital importance, and should be pursued with the utmost scientific objectivity, which I feel that perhaps only a university institution can ensure. To be sure, the nuclear reactor, such as the LMFBR, is the invention of the scientist/engineer. Only the scientist

understands the machine enough to assess the full hazards potential of the LMFBR. It is extremely important, therefore, that universities be able to fully examine in the course of their traditional functions the R & D progress described in reports or documents emanating from ANL.

The mandate from the People in the establishment of the Indiana University is to "educate the youth in the . . . arts and sciences . . ." In order to educate the youth in such matters as nuclear accident potential and the sciences involved, so that the youth can mature with the ability to provide for their safety and the safety of [their] posterity, the state university needs the full report from the laboratories it is affiliated with of the progress of the arts and sciences involved in the R & D program on the LMFBR.

The university is the institution which qualifies scientists, among its other functions. But how could the university educate scientists for work in the area of LMFBR safety studies unless the university can fully examine ANL reports that describe the progress ANL has made in learning LMFBR accident behavior? Science can be defined as systematized knowledge built on premises and verified by observation. Since ANL plays a major role in LMFBR R & D, the university cannot practically pursue knowledge of LMFBR behavior unless it can share all information with ANL in order to determine what research to undertake which will contribute to the systematic evolution of LMFBR knowledge. Otherwise, it will risk being mislead away from performing important research vital to nuclear accident potential.

I understand that the Board of Trustees of Argonne Associated Universities has advice and consent power over the appointment of

ANL managers or directors. But unless the universities have access to the said reports emanating from ANL, I don't see how the Argonne Associated Universities can make wise decisions on appointments and other policy.

Therefore, the universities must insist on open and complete access to information on R & D progress in the ANL's LMFBR Nuclear Safety Program (i.e. reports emanating from ANL, whether they be draft reports, limited distribution reports, or whatever, except truly internal ANL documents); or should dissociate from formal affiliation with the laboratory to avoid misleading the public into believing that LMFBR safety research is being scholarly examined at the universities. For consider the statement made in the inside cover of ANL-7657, "Safety Problems of LMFBRs," a report which the AEC referenced in its Environmental Statement issued for the LMFBR Demonstration Plant:

> "The facilities of ANL are owned by the U.S. Government. Under the terms of a contract between the AEC, Argonne Universities Association and The University of Chicago, the University employs the staff and operates the Laboratory in accordance with policies and programs formulated, approved and reviewed by the Association."

With this philosophy laid down, I would like to comment on the five particular areas above mentioned.

The ANL-RDP series reports, which reports the progress of LMFBR safety R & D, began with January, 1972 and are issued monthly. These are not available through ANL. In the past I was able to get ANL reports free upon request without exception. This practice was vital to my PH.D. program. Now they are unavailable. [Since then, I have received them at $3 per copy until the price was raised to $7.60 per copy. These R & D reports are still limited in distribution. See p. 180-181 of this rebuttal.] . . . These RDPs are crucial to have, because

ANL's most recent annual report for the LMFBR Nuclear Safety Program is for the period FY 69. So the RDPs provide the only link as to the progress in R & D since June 1970.

Progress reports are important not only because they supposedly should summarize all the progress,* but because they would presumably identify for the reader the documents emanating from ANL which describe the progress and findings in detail. But the RDPs presumably don't even do this. If the RDPs are anything like their pre-1972 models [which they are], which I have, they are sketchy at best without showing adequately how all of the R & D fragments are connected together. The quality of the reports are ANL's business. But <u>all</u> documents and reports emanating from ANL in a monthly report period should be reported in the RDPs and available to the universities associated with ANL at least upon requests so that the universities can at least have a complete opportunity to study the scientific results of the Laboratory and deduce how the fragments are connected, if the reports are not clear in that regard. I am not at all sure whether the RDPs report <u>all</u> of such documents and reports. This should be ascertained.

In this regard the practice of issuing from ANL "limited distribution" reports and "draft reports" (i.e., emanating from ANL) should be abolished. I am speaking of such reports sent to the nuclear industry, other laboratories, and the AEC for review and comment. Consider a typical pre-1972 Reactor Development Program progress report, ANL-7765 (DEC. 1970), p. 93, which tells of a number of such "limited distribution"

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* "Progress" should not be restricted to optimistic results indicating safety.

reports. I have obtained one such report, but through irregular channels: "Project Report: Studies of LMFBR Safety Test Facilities, Volume II, LMFBR Accident Delineation and Recommended Program of In-Pile Safety Experiments, August 1970 (Revised) May 1971, ANL/RAS 70-06, Draft." According to its Preface the report was "submitted for review and comment." (Incidentally, the project was since terminated, so that no public version of the report is forthcoming.) The Preface does not state to whom the report was submitted, but I have a letter from the AEC acknowledging that this report was submitted to them. The same Preface stated that the Volume I draft "was submitted to the AEC and to industry for review and comment." Thus, Volume I and II are important examples of limited distribution reports emanating from ANL. After review by the industry and AEC, Volume I was issued as ANL-7657, "Safety Problems of the LMFBR," but not after being "shortened and the number of appendices reduced." (ANL-7800, p.291)

It is my recommendation that as long as the universities are affiliated with ANL, all reports and documents whatsoever emanating from ANL should be published and available at the associated universities. If the AEC and industry comment on such reports, then ANL can publish an addendum to include such comments with appropriate discussion, if ANL feels it is warranted. If ANL-AEC cannot comply with this, then the universities should withdraw. If the university is to "educate the youth in the arts and sciences and so forth," but then obtains only selected and censored reports with which to educate its youth, then one must conclude that the youth are not being educated in the true sense, or that an outside force (AEC and an industry with a vested

interest) controls the education process relative to the vital area of civilian nuclear power safety. Also, consider the other statement in the inside cover of ANL 7657:

> "This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors [ANL], subcontractors, or their employees, makes any warrant, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information [contained in the report] . . ."

This disclaimer alone seriously questions the value of such reports for use in academic pursuits.

In this regard I request that you urge ANL to promptly provide the associated universities with a complete list of reports or documents emanating from ANL since June 1970 dealing with LMFBR Nuclear Safety Program, regardless of classification, so that we can select those which are necessary for our research; and make available the documents from such list upon request, free unless abused. Further, I request that you urge the other policy changes I mentioned above and others to be mentioned below. If you are unsuccessful, I urge you to review the mandate of the People of Indiana who established the Indiana University and advise against continued affiliation of the University with ANL.

Moreover, I have been told by ANL (Technical Publications Department) that the AEC has recently established two new categories of work: Base Technology and Applied Technology. Documents reporting on the latter would be for limited distribution only. Applied Technology probably includes LMFBR Safety. So, if the information I have is correct,

this new categorization will supply you with the terms used to promulgate the new policies I complain of. [I should add that I have not confirmed these alleged new categories of documents.] 205(n)

Another manifestation of this general problem is the heavy use of the publication ANS Transactions, issued by the American Nuclear Society, as the outlet for ANL's R & D results and findings. I question the propriety of this practice. Dr. C.N. Kelber of ANL referred me to the Transactions for R & D information. I very quickly spot-checked the pre-1972 reactor development program progress reports and readily found evidence of this mal-practice. For example, on page 8.32 of ANL-7872 I found that an article referenced, entitled "Partial Voiding and Fission Product Gas in LMFBR Disassembly Calculations." The reference was to the Transactions, as was the case for 21 other articles reference in ANL-7872. The R & D results that were reported in the above mentioned article on "Partial Voiding . . ." could not be found in the monthly progress reports, nor did ANL-7872 report that the said results were published in an ANL-Document. On page 8.1 of ANL-7887, as another example, a Transactions article was referenced for detail on ANL work, instead of an ANL-document.

In my opinion publishing in the Transactions should be no substitute for publishing ANL R & D results and findings in ANL documents as long as the universities are associated with ANL. That is, the Transactions should be for the use of those members of ANS who care to prepare articles for it and learn from it, but that the full report of ANL R & D work should be contained separately in ANL issued documents. It is obvious that ANS (American Nuclear Society) is biased heavily in

favor of rapid development of nuclear power.* That is the prerogative of its members. But the laboratories stem from an Act of Congress, and were established in part to pursue reactor safety information vital to the public safety, and should be free of any suspicion of a conflict of interest. It is a conflict of interest to expect ANS to include articles that might reveal hazardous conditions or uncertainties associated with nuclear reactors. That is, one cannot count on the Transactions for completeness in the systematizing of LMFBR safety knowledge for the education of our youth. My comment applies to other outside journals, such as Nuclear Science and Engineering (ANS publication also) and other private conference proceedings.

I am attaching a copy of ANL-7657, "Safety Problems of the LMFBR," to complete my point. In this document ANL outlines what work the universities could undertake to investigate LMFBR safety. Yet, if the universities are not privy to all of the reports and documents emanating from ANL containing the R & D progress and findings, then how can the universities undertake a responsible research and education program in the area of public safety and nuclear power. As was mentioned before, this ANL-7657 was cited by the AEC in the LMFBR Demo. Environmental Statement. It clearly conveys to the public that the universities are involved in the investigations into nuclear safety, a false assurance if the universities cannot share in all the information. [end of Memo]

In support of my allegations about unavailability of reports, I am including next a question addressed to a professor of nuclear

* [See for example Nuclear News, a Publication of ANS, especially, Vol. 14, No. 11, Nov. 1971, p. 31.]

engineering at one of the universities in AUA and his response.

Question:

May I ask whether your department receives from Argonne National Laboratory draft reports or ANL internal memoranda for "review and comment" in the area of the LMFBR Nuclear Safety Program; or whether your department has ever received such? Many such reports, including the most sensitive, are sent to the AEC and "industry" for "review and comment." It seems to me that since the Argonne Associated Universities partly controls the laboratory, or are at least affiliated with the laboratory, the universities ought to be the recipients of such documents (those that are sent to AEC and/or industry for comment) as well. I would like your thoughts on this opinion of mine, if you care to offer them.

Response:

With regard to your question concerning ANL reports on the LMFBR program, you probably realize that the dissemination of LMFBR material has become a very controversial matter. Most LMFBR topical reports, even though unclassified, receive restricted distribution so that they will not become available to foreign interests. I happen to have some personal access to some of this material but am not able to put the reports in our library.

In answer to your question, therefore, AUA universities not only do not receive the draft reports for "review and comment," but they are not even given access to the final reports.

NOTES and

REFERENCES

1. "Liquid Metal Fast Breeder Reactor (LMFBR) Demonstration Plant," Hearings before the Joint Committee on Atomic Energy of the United States, Ninety-Second Congress, Second Session, September 7,8, and 12, 1972.

2. Ibid., Appendix 10, AEC Comments on the Statement by Dr. Barry J. Smernoff, entitled "Underground Siting of the LMFBR Demonstration Plant: A Serious Alternative." See p. 132 of Hearings for Dr. Smernoff's statement.

3. E.P. Hicks and D.C. Menzie, Theoretical Studies on the Fast Reactor Maximum Accident, Proceeding of the Conference on Safety, Fuels, and Core Design in Large Fast Power Reactors, Argonne National Laboratory, October 11-14, 1965, ANL-7120, p. 659.

4. R.A. Meyer, B. Wolfe, and N.F. Friedman, A Parameter Study of Large Fast Reactor Meltdown Accidents, ANL-7120, Proceedings, above note 3, p. 681.

5. See "Safety Criteria," No. 7 of "Safety and Economic Characteristics of a 1000 MWe Fast Sodium-cooled Reactor Design," by K.P. Cohen and G.L. O'Neill, ANL-7120, pp. 185-186 (Proceedings, above note 3.)

6. G.H. Golden, Elementary Neutronics Considerations in LMFBR Design, ANL-7532, March 1969, p. 55-56.

7. R.B. Nicholson, Methods for Determining the Energy Release in Hypothetical Reactor Meltdown Accidents, APDA-150, p.52.

8. See generally, Golden, above note 6.

9. See my dissertation, cited in my original statement contained in Appendix A herein, entitled: "Some Autocatalytic Effects During Explosive Power Transients in Liquid Metal Cooled, Fast Breeder, Nuclear Power Reactors (LMFBRs), The Ohio State University, 1971 (1972)

10. C.N. Kelber, et al., "Safety Problems of Liquid-Metal-Cooled Fast Breeder Reactors," ANL-7657 (Feb. 1970). On page 105 the "critical diameter" for "fullydensified sphere of 20% PuO_2--80% UO_2" is reported at 56 cm.

    This implies ten to forty critical reactors in a large LMFBR, depending on whether the PuO_2 percent concentration is 10% or 20%.

11. Letter from Dr. Ian Forbes to Richard Webb.

12. LMFBR Program Plan, WASH-1101 through WASH-1110, prepared for the Division of Reactor Development and Technology, U.S.A.E.C. by the LMFBR Program Office, Argonne

National Laboratory. Volume 10, WASH-1110, covers "SAFETY." (August, 1968). Volume 1, WASH--1101 is the Overall Plan.

13. W.T. Sha and T.H. Hughes, "VENUS: A Two-dimensional Coupled Neutronics-Hydrodynamics Computer Program for Fast-reactor Power Excursions," ANL-7701, p.20.

14. My original statement, Appendix A herein.

15. LMFBR Nuclear Safety Program Annual Report, July 1, 1969-June 30, 1970, ANL-7800 (Dated July 1971). See chapter XI for description of TREAT meltdown experiments.

16. Safety and Economic Characteristics, above note 5, p. 191.

17. Fast Flux Test Facility Design Safety Assessment, Hanford Engineering Development Laboratory, HEDL-TME-72-92 (July 1972), Chapter 3.0, Hypothetical Events Evaluation.

18. D.E. Simpson, et al., Assessment of Magnitude and Uncertainties of Hypothetical Accidents for the FFTF (Fast Flux Test Facility), March 1971, HEDL-TME-71-34, pp. 26-43.

19. "LMFBR Accident Delineation and Recommended Program of In-Pile Safety Experiments, ANL/RAS 70-06 (Rev.) DRAFT, August 1970 (Revised May 1971), Argonne National Laboratory, Reactor Analysis and Safety Division, Project Report: Studies of LMFBR Safety Test Facilities, Volume II.

20. Simpson, et al., above note 18, p.3.

21. HEDL-TME-72-92, above note 17, p. 3.0-1.

22. Safety Evaluation of the Fast Flux Test Facility (Project No. 448), U.S. Atomic Energy Commission, Directorate of Licensing, Washington, D.C. Issue Date: October 31, 1972. See Appendix D, Preliminary Evaluation of Low Probability Accidents in the FFTF, page 53.

23. Kelber, et al., above note 10, p. 98-99.

24. T.J. Thompson and J.G. Beckerley, "The Technology of Nuclear Reactor Safety," Volume 1, p. 616.

25. WASH-1509, U.S.A.E.C., April, 1972.

26. See generally: Simpson, et al., above note 18; and Accident Delineation, above note 19.

27. LMFBR Program Plan, Vol. 1, above note 12, p.1-3. See also, Vol. 10, p. 10-232.

28. Telephone conversation, January 19, 1973.

29. LMFBR Nuclear Safety Program Annual Report, ANL-7800, above note 15, p. 25.

30. Program Plan, Volume 10-Safety, above note 12, pp. 10-92, 10-93.

31. Ibid., pp.10-225 through 10-233.

32. See ANL-7800, above note 15, chapters VIII and XI.

33. Program Plan, above note 30, p.10-231

34. Ibid., p.10-13

35. Ibid., p. 10-231 and 10-232.

36. Ibid., p. 10-81.

37. LMFBR Demonstration Plant Environmental Statement, above note 25, p. 27.

38. ANL-7800, above note 15, p.291.

39. Letter from Louis Baker, Jr., Reactor Analysis and Safety Division of Argonne National Laboratory, to Richard E. Webb, January 23, 1973.

40. Program Plan, above note 12, Vol. 2, Plant Design, WASH-1102, p. 2-138.

41. Environmental Statement, above note 37, p.39.

42. Jay Edmond Boudreau, "Autocatalysis During Fast Reactor Disassembly," Ph.D. dissertation, UCLA, 1972. (Abstract and p. 100) In my Statement on the LMFBR Demonstration Plant I should have noted that I had not then had an opportunity to study Dr. Boudreau's thesis, as I just learned of it and only had a copy of its abstract when I submitted my statement to the JCAE. Due to the relevance of his dissertation, I simply quoted from the published abstract in Dissertation Abstracts, although I should have added that I had not then evaluated the dissertation.

43. Letter from R.B. Nicholson, Professor of Nuclear Engineering at The Ohio State University and author of APDA - 150, above note 7, to Richard Webb, dated January 29, 1973.

44. ANL-7701, above note 13, p. 9.

45. Letter from R.B. Nicholson to Richard Webb, dated April 20, 1973.

46. Boudreau, above note 42, p. 22-24,40.

47. Telephone conversation between J. Boudreau and R.E. Webb, January 2, 1973.

48. Letter from J. Boudreau to Richard E. Webb, dated April 18, 1973.

49. In "A Look at Fast Reactor Safety," by David Okrent, Nuclear Safety, Vol. 6, No. 4 (1965), p.325, Okrent stated:

> "One question that has arisen, particularly for the larger, more loosely coupled fast reactor cores, relates to the possible effects on the remainder of the core when only a portion of the large core is initially involved in an energy release large enough to generate sizable pressure."

Boudreau concluded that:

> "An Increase in Size of core (overall dimensions) for Outward Motion in Either Direction Generally Means that the Probability of Autocatalysis will increase." (Boudreau, above note 42, p. 102, Table 7.1)

Generally, the energy released in an LMFBR nuclear runaway accident is roughly proportional to the mass of the core; and hence the size of the LMFBR with everything else the same. Also, the autocatalytic reactivity effects due to sodium voiding becomes worse with increasing core sizes. But I have not convinced myself that the potential for autocatalysis due to outward fuel motion during an LMFBR explosion becomes greater as the core size increases, although Boudreau and Okrent seem to have concluded that it is greater.

50. Hearings, above note 1, Appendix 9, p. 38 (p.240 of the Hearings pagination.)

51. Inferred from Hicks and Menzies data, above note 3, assuming a 1000 lb. TNT or more equivalent nuclear explosion, which is conceivable for LMFBR accidents.

52. The "mechanical damage potential" of a fuel vapor explosion resulting from nuclear runaway(s) is presently estimated (given the energy yield of the nuclear runaway events) by crude, theoretical extrapolations of "equation-of-state" data, and by simulated explosion experiments using small-scale, mechanical models of the reactor and TNT-type charges. The equation-of-state extrapolation is necessary to estimate the fuel vapor pressure, given the energy content in the fuel created by the nuclear runaway, and then the fraction of the fuel energy (called "work energy") which would be available to cause mechanical damage to the reactor

structure and containment (due to the expansion of the fuel vapor to relieve the pressure). Given the work energy, a TNT-type charge size is then selected which equals this work energy for the scale-model simulation explosion experiments. (Roughly, 2 MW-sec of work energy is equivalent to 1 lb. TNT, according to Hicks and Menzies, above note 3, p. 658.) The scale-model simulated explosions then provide useful information as to the damage that might be expected of a nuclear runaway with a specified energy yield. However, there are three basic shortcomings with this procedure:

a. It depends foremost on the "energy yield" of the nuclear runaway, which is the central uncertainty of LMFBR accident assessments due to the possibility for autocatalytic reactivity effects, etc.--the chief concern of this Rebuttal.

b. The "work energy" from the expansion of the fuel vapor cannot be confirmed experimentally, except by inferring it indirectly from the extent of damage observed from a severe LMFBR nuclear runaway experiment.

c. The scale-model, TNT-type simulation experiments are questionable themselves. The <u>fuel vapor</u> explosion is expected to be not as "sharp" as a TNT-type explosion for the same work energy (i.e., less peak pressure); but is expected to create a more sustained pressure. This means that there is the concern that a reactor containment designed by TNT simulation experiments may fail under an "equivalent" nuclear explosion because the character of the explosive "loading" on the structures is different. (See Hicks and Menzies, above note 3, pp. 665-669; Kelber, <u>et al.</u>, above note 10, pp. 87-91; and "Fast Reactor Safety," a book by John Graham, p. 299-300.) The LMFBR Program Plan stated:

"On the other hand, a more sustained pressure burst with a lower peak pressure can result in a different kind of loading, which may not be absorbed as well by shielding designed for TNT blasts." (Vol 10, above note 12, p.10-93.)

The foregoing shows up another reason why full-scale, core destruct experiments in an "Excursion Test Facility" are necessary to establish the mechanical damage consequences of LMFBR nuclear runaway accidents, even if the worst possible nuclear runaway were precisely known. Consider the fact that a key reactor-destruct test for the water-cooled reactor technology, the SPERT-1 test, resulted in an energy yield of the nuclear runaway that was predicted accurately; but the resultant core destruction was more "than planned." As Thompson summarized:

"The performance of Run 54 [the SPERT-I test], from the nuclear viewpoint, was very close to predictions. . . .However, . . .there was a violent pressure release resulting in total destruction of the core. . . .The sudden onset of total core destruction . . . was a surprise." Thompson, above note 24, p. 616, 684-685.

With the foregoing as background, it should be noted that the AEC's LMFBR Demonstration Plant Environmental Statement, above note 25, implies that the "reactor structure and containment" will not be breached by a "release of explosive energy"; and states that:

"These conclusions are based on analyses that have been conducted of the behavior of reactors with similar features and structures." (E.S., 118)

The analysis cited by the AEC about the mechanical consequences of a nuclear runaway is "Mechanical

Consequences of Hypothetical Core Disruptive Accidents," by D.D. Stepnewski, et al., HEDL-TME-71-50 (April 19, 1971). Yet, this analysis attempted to estimate the consequences of a sodium vapor explosion, and not a fuel vapor explosion, (See the preface of this document.) which indicates that the AEC has prejudged that the possibility for autocatalysis leading to severe fuel vapor explosion is of no significant concern.

As with the energy-yield calculation of an LMFBR accident (i.e., the pre-disassembly and the disassembly phases, which might involve autocatalytic reactivity effects), the AEC is relying on essentially unverified predictions of the mechanical damage consequences of a given energy yield of a nuclear explosion for assessing the adequacy of the reactor containment structures, using sophisticated theoretical analyses, such as the Stepnewski, et al., analysis mentioned above, and the REXCO computer code, mentioned in "LMFBR Safety," D. Rose, Nuclear Safety, Vol. 12, No. 5, pp. 421, 430.

The REXCO code is being experimentally tested or "verified" to some extent at least. (See ANL-RDP-8, p. 9.54; RDP-9, p. 9.47; and RDP-11, p. 9.42.) These tests are "simulated [nuclear] excursions" using chemical (TNT-like) explosive charges and scaled-down "simple models." However, as before mentioned, there are shortcomings with verifying reactor containment capability for containing nuclear explosions using TNT-type, scale-model, simulation explosions. (Hicks and Menzies stated that these shortcomings apply to sodium vapor explosions as well as fuel vapor explosions, which questions the verifications experiments for the REXCO-type codes even when the sodium-vapor explosion is the principal form of the explosive work energy. See Hicks and Menzies, above note 3, p. 669.)

Furthermore, the direct, calculational method of the REXCO-type code, while an impressive effort, should be

carefully reviewed, inasmuch as Hicks and Menzies stated:

> "The direct calculation of the effects of a hypothetical nuclear explosive release of energy on the reactor structure and its environment [containment] is practically impossible on account of the complicated geometry." (Ibid., 665)

(In contrast, ANL reports the verification experiments of REXCO involving only "simple" mechanical models.) The calculation of the damage consequences of an explosion is extremely complicated tasks; but regardless of the calculated prediction, it would have to be confirmed by reactor destruct tests, and perhaps full-scale tests, meaning nuclear excursion tests. [At this point I would like to add a note, but I am sure that it reveals classified, defense information. I request the JCAE inform me of the proper channel or procedure for transmitting this note to the JCAE.]

I should qualify my remarks on the REXCO-type code development. I am not aware of any theoretical deficiency thay may exist in such analyses, since I have not studied the analyses for the post-disassembly phase of the LMFBR nuclear runaway accident.* It should be emphasized, though, that the first thing to establish is the maximum energy yield resulting from the pre-disassembly and disassembly phase of the accident, before one can estimate the strength and character of the resulting explosion, and the consequences in terms of the mechanical damage to the reactor containment, and the possibility for a rupture or breach of the containment and release of radioactivity to the Environment. This pre-disassembly and disassembly phase is the focus of this Rebuttal, although the post-disassembly phase is the ultimate concern, of course, and must be scientifically investigated once the maximum energy yield potential is established upon an exhaustive investigation into autocatalytic reactivity effects.

However, for completeness sake, the consequences of core explosion in terms of how the containment might be breached and the radioactivity released (i.e., the post-

* Except a cursory study.

disassembly phase of an accident) are outlined here below, beginning with a brief description of the explosion containment.

The reactor and its associated coolant system of piping, etc., are housed in a concrete enclosure, which is filled with inert gas, so that if some sodium coolant should leak into the enclosure space during an accident, a sodium fire (Sodium burns in air.) and a consequent over-pressurization of the reactor enclosure will not occur. The reactor enclosure is also designed to withstand the shock and blast effects of a "credible" reactor explosion. Actually, the reactor vessel and cover is being designed to withstand much of the shock and blast.

The reactor enclosure is in turn surrounded by the reactor plant container, which is a large hemispherical-like structure designed to withstand the pressure build-up due to the heating of the nuclear runaway and a certain degree of sodium burning resulting from a reactor explosion, as some sodium could be forced through leak paths in the reactor enclosure and injected into the container air atmosphere where it will burn.

There is the additional concern that the core disassembly will end up in an uncoolable mass, and the core will then be heated up by the "decay heat" of the intense radioactivity in the core, even if the core is subcritical, and melt through the reactor. In order to prevent the melt-through from continuing through the enclosure bottom, and then through the container bottom and into the ground below, special consideration is given to an emergency core cooling system beneath the reactor to cool the core should it melt through the reactor bottom, and thereby prevent a breach of the containment.

With this brief description of the reactor containment system, the consequences of a reactor explosion will now be

outlined.

For an LMFBR explosion to be too severe, it apparently need not be so strong as to rupture the reactor enclosure, and then the plant container, by direct effects of shock, blast, and missiles, although this direct mode of rupture may be possible if strong enough autocatalytic reactivity effects of nuclear runaway occur. Rather, there are two other conceivable ways the reactor containment (the reactor enclosure and outer container) could be breached with lesser explosions:

1. If the reactor vessel and enclosure are breached, much more of the sodium coolant would seem to be capable of being injected into the container atmosphere where it could burn and over-pressurize the container, and thereby cause it to burst.

2. The reactor explosion could damage the emergency core cooling system enough to make it ineffective. This could then lead to core melting through the plant bottom due to decay heat. Conceivably, the core could re-assembly into a super-prompt-critical mass in the process and set off a secondary nuclear explosion that could then be sufficient to breach the container, if the first explosion had not already done so. For this secondary nuclear runaway, autocatalytic reactivity effects might exist.

In the cases where the reactor plant container is pressurized before being breached, this pressure would be the propellant for spewing the radioactivity (the Plutonium and the fission products) into the Environment.

Thus, the explosion resistance of the LMFBR containment structures is not simply a matter of blast-shielding protection for the outer containment. (Now return to p. 71.)

53. Program Plan, above note 30, p. 10-233.

54. Reactor Development Program Progress Report, Argonne National Laboratory (ANL-RDP series), ANL-RDP-10,

October 1972, p. 9.25. (Pre-1972 monthlies drop the RDP prefix.)

55. See limited distribution ANL draft report, above note 19, p.IV-33.

56. Telephone Conversation between R.W. Wright and R.E. Webb, January 19, 1973.

57. ANL-7800, above note 15, p. 338.

58. Wright/Webb telecon, above note 56.

59. Simpson, et al., above note 18, p. vii.

60. AEC safety evaluation of FFTF, appendix D, above note 22, p. 45.

61. Kelber, et al., ANL-7657, above note 10, p. 60.

62. W.J. McCarthy, et al., Studies of Nuclear Accidents in Fast Power Reactors, Proceedings of the International Conference on the Peaceful Uses of Atomic Energy, Geneva, 1958, p/2165, p. 213.

63. R.O. Brittan, Analysis of the EBR-I Core Meltdown, P/2156, p. 269 in the Proceedings, above note 62.

64. Ibid., p. 271.

65. Thompson, above note 24, p. 631.

66. McCarthy, et al, above note 62, p. 222.

67. Thompson, above note 24, p. 629.

68. Brittan, above note 63, p. 270-272.

69. McCarthy, above note 62, pp. 221-224.

70. Ibid., p. 223

71. J.H. Kittel, et al., Disassembly and Metallurgical Evaluation of the Meltded-down EBR-I Core, Proceedings, above note 62, P/2437, pp. 473,475.

72. W.T. Sha and A.E. Waltar, "An Integrated Model for Analyzing Disruptive Accidents in Fast Reactors," Nuclear Science and Engineering, Vol. 44, 135-156 (1971).

73. K.P. Cohen, Discussion of Papers Among Panel, Proceedings, above note 3, ANL-7120, p. 271.

74. Sha and Waltar, above note 72, p. 149.

75. Ibid., p. 156.

76. Ibid., p. 148.

77. Ibid., 149.

78. Simpson, above note 18.

79. AEC Safety Evaluation of FFTF, Appendix D, above note 22, p. 16.

80. HEDL-TME-72-92, above note 17, p. 3.2-1.

81. AEC Safety Evaluation of FFTF, App. D, above note 22, p. 16.

82. HEDL-TME-72-92, above note 17, pp. 3.2-9--3.2-10.

83. Cited in Dissertation, above note 9, pp. 28-30; "Analysis of Severe Reactivity Excursions in Fast Reactors," Z.T. Pate, Ph.D. Thesis, Massachusetts Institute of Technology (1970)

84. ANL-7657, Kelber, et al., above note 10, p. 68.

85. Ibid., p. 65.

86. Summarized in McCarthy, et al., above note 62, p. 224.

87. LMFBR Accident Delineation . . ., above note 19, p. II-57.

88. Ibid., p. III-14.

89. Kelber, et al., above note 9, p. 65.

90. Ibid., 146.

91. Ibid., p. 155.

92. Wall Street Journal, November 24, 1972.

93. LMFBR Accident Delineation and Recommended Program of In-Pile Safety Experiments, above note 19, p. IV-2.

94. Ibid.

95. Ibid., Chapter IV and V generally.

96. Ibid., III-11. See also, pp. V-2, V-3, and V-7.

97. ANL-RDP-3 (March 1972, issued April 27, 1972), above note 54, p. 8.40-8.41.

98. Ibid., p. 8.45.

99. ANL-RDP-13, above note 54, p. 9.29.

100. Kelber, et al., ANL-7657, above note 10, p. 70.

101. Ibid., p. 71

102. HEDL-TME-72-92, above note 17, p. 3.0-1.

103. Safety Evaluation of the FFTF, above note 22, p. 123-124.

104. Safety Evaluation of the FFTF, App. D, above 22, pp. 52-53..

105. Ibid., p. 55.

106. Thompson, above note 24, p. 633.

107. Ibid., Chapter 11, Sec. 3. and Sec. 6.

108. I do not mean that the nuclear runaway potential for water-cooled reactors has been adequately analyzed, or is acceptable; for I have testified that there are serious questions of the accident analyses for these type of reactors, especially the boiling water reactor. See my "Testimony on the AEC's Acceptance Criteria for Emergency Core Cooling Systems (ECCS) for Light-Water-Cooled Nuclear Power Reactor," March 3, 1972 (Revised editorially, June 10, 1972), submitted to the AEC's Rulemaking Board on the ECCS criteria.

109. Kelber, et al., ANL-7657, above note 10, p. 63.

110. Letter from C.N. Kelber to Richard E. Webb, dated February 28, 1973; a reply to letter from R. Webb to C.N. Kelber dated February 27, 1973.

111. Letter from Webb to Kelber, March 2, 1973.

112. Letter from Kelber to Webb, March 8, 1973.

113. Letter from Bertram Wolfe to Richard E. Webb, dated April 26, 1973.

114. D.D. Stepnewski, et al., "Mechanical Consequences of Hypothetical Core Distruptive Accidents," HEDL-TME-71-50, April 19, 1971, p. 2-18.

115. Telephone conversation.

116. Golden, above note 6, p. 52.

117. LMFBR Program Plan, Vol. 10, Safety, above note 12, p. 10-97.

118. Kelber, et al., ANL-7657, above note 10, p. 98-99.

119. Ibid., p. 98.

120. Ibid., pp. 84-85.

121. Ibid., p. 98.

122. Based on the Hearings, above note 1.

123. Louisville Courier-Journal Newspaper, June 1, 1973, p. A16.

124. A.J. Brook, Some Preliminary Considerations Relating to an Equation of State for Irradiated Nuclear Fuel, Nuclear Safety, Vol. 13, No. 6, November-December, 1972, pp. 467-477.

125. Ibid., p. 472

126. Ibid., p. 473

127. Ibid., p. 475, 477.

128. Ibid., p. 476-477

129. Webb v. AEC, Civil Action No. 72-14, U.S. District Court (Southern District of Ohio, Eastern Division) Order entered on Sept. 8, 1972.

130. Article I, Section 8 of the U.S. Constitution.

131. Max Farrand, "Framing of the Constitution," Yale Press (1913)

132. See, for example, the letters to Andrew Stevenson from James Madison, November 27, 1830, The Writings of James Madison, G. Hunt (ed.) IV, pp. 120-139. See also, The Writings of Thomas Jefferson, Volume 3, pp. 145-153.

133. Farrand, above note 131, p. 216.

134. M. Farrand, The Records of the Federal Convention of 1787, II, pp. 325 (Yale Press) (See entry dated August 18, 1787.)

135. Blackstone, Commentaries on the Laws of England, Introduction, p. 71.

136. Monroe's Message on Internal Improvements, Annals of Congress, May 10, 1822, p. 1803.

137. Report on Manufactures, Alexander Hamilton, December 5, 1791, American State Papers, Volume on Finance, p. 123, 136.

138. See generally, Elliot's Debates, New York Convention.

139. Farrand, above note 134, Volume I, pp. 281-311 for June 18, 1787.

140. Farrand, above note 134, Volume III, p. 627 (App. F.)

141. Farrand, above note 139, p. 291

142. Letter from Sophie V. Stephens, Technical Publication Dept., ANL, to Richard E. Webb, January 9, 1973.

143. Hearings on Executive Privilege (1973) U.S. Senate

144. The CGS VOICE, The Official Graduate Student Newspaper of The Ohio State University, Volume V, No. 3, January 1969.

145. Simpson, above note 18, page iii.

146. David Rose, LMFBR Safety, Nuclear Safety, Vol. 12, No. 5, September-October 1971, p. 431.

147. LMFBR Demonstration Plant Environmental Statement, above note 25, WASH-1509 (April 1972), p. 118.

148. Letter from A.M. Judd to R.E. Webb, March 28, 1973.

149. AEC Atomic Safety and Licensing Board Hearings: Proposed Shoreham Nuclear Power Plant, Long Island, New York; Davis-Besse Nuclear Power Plant. Also, the AEC Rulemaking Hearing on the Acceptance Criteria for Emergency Core Cooling Systems for Light Water Cooled Nuclear Power Reactors. In these hearings my questioning on technical matters highly relevant to "reactor safety" had been severely limited*; and highly relevant technical matters in my ECCS testimony were arbitrarily struck from my testimony by the AEC rulings on the motions of the nuclear promoters.

150. ANL--RDP--13, January 1973, above note 54, pp. 9.21, -9.22; and ANL-RDP-10, pp. 9.25--9.30.

151. R.E. Webb, "Treaty-Making and the President's Obligation To Seek the Advice and Consent of the Senate With Special Reference to the Vietnam Peace Negotiations," Ohio State Law Journal, Volume 31, No. 3, (1970), pp. 490-519. See also, Congressional Record, July 26, 1971, S. 12059-12075; and April 12, 1973, S. 7273-7283.

152. Senate Report No. 1699, "Amending the Atomic nergy Act of 1946, As amended, and For Other Purposes, June 30, 1954, 83rd Congress, 2 nd Session, from the Joint Committee on Atomic Energy, p. 10.

153. Boudreau, above note 42, page 37, footnote, and page 108, reference no. 27.

154. "Theoretical Possibilities and Consequences of Major Accidents in Large Nuclear Power Plants--A Study of Possible Consequences If Certain Assumed Accidents, Theoretically Possible but Highly Improbable, Were To Occur in Large Nuclear Power Plants," WASH-740,

* By the AEC panel or board.

March, 1957, USAEC   Note: No. 155 is blank.

156. Just prior to my asking for the ANL R&D program reports on the LMFBR from the AEC's Technical Information Center (TIC), I received from the AEC and TIC all ten volumes of the LMFBR Program Plan, which is a very voluminous set of documents, and the LMFBR Demonstration Plant Environmental Statement, both without charge. And afterwards I received a copy of the AEC's FFTF safety Evaluation and the AEC's two-volume Final Environmental Statement Concerning the Acceptance Criteria for Emergency Core Cooling Systems for Light Water Cooled Reactors without charge. Also, all of the SEFOR reports listed in my original statement on the LMFBR Demonstration Plant (App. A herein), reference no. 6, were too received in Sept. 1972 without charge from the AEC's TIC.

157. The plans being prepared for improving the TREAT reactor by enlarging the capability for single fuel bundle tests fall short of an STF, since the Program Plan stated that the STF "probably will be a fast reactor [and TREAT is not a fast reactor] since there will be a requirement to test experiments of assembly dimensions without the flux depression that would be encountered in a thermal reactor." (Vol. 10, p. 10-228) The TREAT improvements are being designed to minimize the "flux depression" effects, which would affect the all-important fuel motion in an LMFBR accident, but will not completely eliminate such non-LMFBR effects. ANL-RDP-3, p. 8.45 (March 1972)

158. Letter from Andrew J. Pressesky, Assistant Director for Nuclear Safety, Div. of Reactor Development and Technology, USAEC, to Richard E. Webb, February 23, 1973.

Recall that in my original statement (Hearings, p. 182, Appendix 5) I said that the "LMFBR Program Plan (Volume 10, Safety) provides for studies of the necessity for such explosion testing." I said further that I have seen no results of such studies." Mr. Pressesky's letter, then, confirms that the AEC has not yet received from Argonne National Laboratory, at least, a report of a study of whether there is a need for an excursion test facility. One can conclude, therefore, that the AEC has no basis from its own laboratory

...

to proceed with LMFBR development, inasmuch as a crucial consideration of verification experiments for accident analyses has not been submitted upon which the AEC could form a judgment.

159. Letter from G.J. Fischer (ANL) to Richard Webb, March 28, 1973. This letter was received by R. Webb on May 22, 1973, because Dr. Fischer had to "wait for approval to send the letter" because he is an "employee of the AEC". Letter from Fischer to Webb, May 24, 1973.

160. The Karlsruhe conference brochure and conference proceeding supposedly can be obtained by writing: Gesellschaft fur Kernforschung, Literaturabteilung, D-75 Karlsruhe, Germany, Postfach 3640

161. Letter to Honorable Dixy Lee Ray, Chairman, U.S. Atomic Energy Commission, from H.G. Mangelsdorf, Chairman, Advisory Committee on Reactor Safequards, U.S.A.E.C., May 18, 1973; subject: Report on Fast Flux Test Facility.

162. My dissertation (pages 22-48), above note 9, attempts to cover the various conceptual autocatalytic conditions. A minor correction of my dissertation regarding this section of my dissertation should here be made: One of the conceptual autocatalytic conditions was attributed to McCarthy. See page 27 of dissertation. However, the reference for McCarthy's concern is erroneous--i.e., super-script no. 18. The true reference is McCarthy's questions given in ANL-7120, above note 3, p. 670.

163. Boudreau, above note 42, pp. 91-93.

164. Letter from Richard E. Webb to Charles Till of Argonne National Laboratory, dated May 3, 1973.

165. D. Miller, "A Critical Review of the Properties of Materials at the High Temperatures and Pressures Significant for Fast Reactor Safety," ANL-7120, Proceedings, above note 3, pp. 641-651. See also, Kelber, et al., ANL 7657, above 10, Appendix C, "Equation of State of Core and Associated Materials."

166. The recent MELT fuel motion model also would not apply to the hypothetical sodium re-entry core compression situation suggested by Daane, since the fuel rods are not plastic at the start of reactivity insertion in the MELT model, as they are in the Daane accident.

167. Explosion Energy= Factor x (Reactivity Insertion Rate)$^{3/2}$ For this 3/2 power role, see Thompson, above note 24, pp. 588-593. There the Bethe-Tait theory is summarized. From equations (4-26) and (4-25a) the 3/2 power rule can be readily deduced, as equation (4-25a) for explosion energy ("excess energy") applies to strong explosions. The calculations of Wolfe, et al., above note 4, are in agreement with this 3/2 power rule, even with the Doppler effect included. However, my own calculations show a "linear" relation (above note 9, p. 104); i.e., explosion energy= Factor x (reactivity insertion rate), which is less severe than the 3/2 power rule. This important discrepancy should be resolved.

168. Dr. Homer Neal, member of the Board of Trustees (or Board of Directors) of Argonne Associated Universities (AAU), in a comment to R. Webb.

169. Graham has implied that the reactor containment capability could be 3000 lb. TNT equivalent. See "Fast Reactor Safety," by John Graham, p.320, although on p.299 he states that 500 MW-sec of explosion energy (equivalent to 250 lb. TNT) is the maximum capability that is presently needed.

170. LMFBR Program Plan, Vol. 10, Safety, above note 12, p. 10-6.

171. Ibid., p. 10-13.

172. Ibid., p. 10-125.

173. Nicholson, above note 7, p. 165.

174. January, 1973 Issue.

175. Murphy, p. 2 herein; Tell, see pp. 185-186 of Hearings, Appendix A herein; Cohen, see p. 186, of Hearings, Appendix A herein; Boudreau, see p. 59 herein.

176. Explosion estimates given in this rebuttal for conceivable nuclear explosions in an LMFBR range from 5000 lb. TNT equivalent to 100,000 lb. TNT, with the dominant value of the order of 10,000 lb. TNT, which is considerably greater than the 1000 lb. TNT value that has been implied as an upper limit for economic containment. (Above note 5.) These estimates were based on "Bethe-Tait"-like explosion calculations, given

the conceived accident causal mechanism, which provides the controlling "reactivity insertion rate." However, these calculations have considerable uncertainty, even if we exclude the possibility for autocatalytic reactivity effects. As Hummel and Okrent stated:

> "Thus, estimation of the explosive force of nuclear bursts in fast reactors is fraught with uncertainties, and a considerable potential for error must be conceded." ("Reactivity Coefficients in Large Fast Power Reactors," H.H. Hummel and D. Okrent, American Nuclear Society and U.S. Atomic Energy Commission Monograph Series on Nuclear Science and Technology, 1970, pp. 299-300.)

A basic theory relied on for these calculations is the Bethe-Tait theory, presented in "An Estimate of the Order of Magnitude of the Explosion when the Core of a Fast Reactor Collapses," British Report UKAEA-RHM (56)/113,1956. (U.S.-U.K. Reactor Hazard Meeting, London, England, April, 1956) From the title alone we can see that Bethe and Tait assumed that the methods give explosion values that are accurate to only within an "order of magnitude", which means that the actual explosion might be greater by three times for the hypothetical accidents considered herein. (The accuracy can never be established, except by full-scale, core explosion experiments.)

Moreover, the explosion estimates of this Rebuttal were based on calculations for a simple LMFBR core design. Actually, the LMFBRs are being designed with "multi-zone" cores (of varying fuel concentrations) in order to make more uniform the power density in the core and thereby get more life out of the core. This "power flattening" tends to increase the explosive yield for the same reactivity insertion accidents, however. I estimate that there could be a doubling due to this effect. (Inferred from Hummel and Okrent, pp. 300,302.)

Therefore, if we combine the uncertainty and the power flattening effect, we might conclude that the explosion estimates herein should be multiplied by five to be

conservative. Thus, for example, a 10,000 lb. TNT estimate would be raised to 50,000 lb. TNT. (See pp. 3, 111, 134, and 137 for other estimates that could be adjusted likewise.) Again, the implied economic containment limit is 1000 lb. TNT explosion per above note 5.

177. For example, the electricity flowing in interstate can be regulated, but not the method by which it is made (manufacture); nor can the method be promoted by a federal program of spending. The federal government's influence over the method of manufacture is, constitutionally, only that which results from the federal regulation of the amount, quality, and character of the articles of commerce. For example, if the federal law requires that interstate electricity shall be at a certain voltage, then the manufacturer must adapt his method of manufacture to suit the regulation.

178. There is a general tendency, however, to be "pragmatic," and not challenge the recent Supreme Court opinions that tend to support the AEC's claim that the civilian nuclear power program is constitutional. But "since it sometimes may happen that the judge may mistake the law," as Blackstone wrote, it is not impractical to challenge an unfounded opinion, when the true historical history of the Constitution can be re-constructed to refute the <u>Gerlach</u> opinion, for example. Furthermore, as is shown next, the constitutional question of the <u>welfare</u> clause has never been squarely before the Supreme Court for a settlement. To see this, let us briefly trace the basis for the <u>Gerlach</u> opinion, which is the most recent opinion cited by the AEC in <u>Webb</u> v. <u>AEC</u>.

The court in <u>Gerlach</u> opined that Congress has

> "a substantive power to tax and appropriate for the general welfare, . . . [and thus] the power . . . to promote the general welfare through large-scale projects for . . . internal improvement. (339 U.S. 738)

Firstly, the <u>welfare</u> clause was not at issue in <u>Gerlach</u>; it was not even mentioned in the briefs of the litigants. The issue in that case was whether Congress intended compensation for losses caused by a large federal water project. The welfare clause was commented on by the court, but only to assert that the water project was constitutional. However, the court was not settling any debate on the matter. The court said:

> "we need not here pass on any question of constitutional power." 339 U.S. 737

Thus, the <u>Gerlach</u> opinion on the welfare clause was no settlement of the constitutional question of whether Congress can spend money "to promote the general welfare through large scale projects for . . . internal improvement." Secondly, the court attempted no proof, and said only that the question "was laid to rest" in the Supreme Court opinion in <u>Helvering</u> v. <u>Davis</u>, 301 U.S. 619,640, the Social Security case.

In <u>Helvering</u> the Court held that:

> "Congress may spend money in aid of the 'general welfare.' . . . The discretion [as to what is the general welfare] belongs to Congress, . . ."

Unlike <u>Gerlach</u>, the welfare clause was at issue in <u>Helvering</u> (particularly, whether the welfare clause conferred power to Congress to establish Social Security); but the court would not consider the question, nor did the court attempt any proof, since it regarded the question as having been already settled in <u>U.S.</u> v. <u>Butler</u>:

> "We will not resurrect the contest. It is now settled by decision. <u>United States</u> v. <u>Butler</u>, <u>supra</u>." 301 U.S. 640

Incidentally, the respondent in <u>Helvering</u>, who opposed the liberal construction of the <u>welfare</u> clause, did not offer any substantive historical proof in his brief, as his argument mainly consisted of assertion. More importantly, the Govern-

ment in claiming that the welfare clause conferred spending powers to Congress **misquoted** the Constitution by alleging that Article I, Section 8, Clause 1 states that Congress shall have power:

> "to lay and collect Taxes, Duties, Imposts and Excises, to pay the Debts and provide for the common Defence and general Welfare . . ." *

In fact, the said clause reads:

> "To lay and collect Taxes, Duties, Impost and Excises, to pay the Debts and provide for the common Defence and general Welfare . . ."

By suppressing the capital "T", the Government made the Constitution appear to give two separate powers in series (one to tax, and the other to provide for the general welfare). But in fact the Federal Constitutional Convention deliberately used capital Ts to lead off the enumerated powers, and interposed the word "and" when specifying multiple powers in any one clause. (See Article I Section 8 of the Constitution.) This error of capitalization, and similar errors of punctuation, were also made by Hamilton, Story, and the Supreme Court in the Butler opinion, as I reveal in my treatise filed in Webb v. AEC. Moreover, the Government in the Helvering case relied on the Hamilton and Story opinions, and the Butler opinion, for its proof, the first two having been previously discussed. (See pages 166-171 herein.) Since the court in Helvering considered that the Butler opinion settled the issue, we must refer to Butler.

Tracing now to the Butler opinion, we find that the welfare clause question was before the court in the Butler case, but that the court's decision of the controversy was contrary to the Gerlach and Helvering, and not in support of them, as is shown next.

The welfare clause was rather vigorously debated in Butler regarding the question whether a federal program of taxation and spending to effect agricultural production (the Agricultural Adjustment Act) was constitutional.

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* See page 45 of Government's brief in Helvering.

The Act was based on the welfare clause, and was argued so much by the Government attorneys. However, the Court ruled that the welfare clause conferred no such power, and ruled that the Agricultural Adjustment Act was unconstitutional. The court stated in its opinion that the Act was:

> "a statutory plan to regulate and control agricultural production, a matter beyond the powers delegated to the federal government." 297 U.S. 68

That was the ruling in that case, and a correct one I should add. However, in the course of their opinion the court injected an opinion on the welfare clause that was not necessary for its decision; for it opined that the welfare clause does grant a power to Congress to spend money for public purposes. After adopting Mr. Justice Story's theory of the welfare clause, the court said:

> "It results that the power of Congress to authorize expenditure of public moneys for public purposes is not limited by the direct grants of legislative power found in the Constitution." 297 U.S. 66

This extraneous opinion (called dictum) is somewhat contradictory to its ruling; although the court qualified the alleged power to spend for the general welfare by insisting vaguely that the power extends "only to matters of national, as distinguished from local welfare." (297 U.S. 67) But in any event, the court ruled that Congress does not have the power to regulate agriculture.

[Continue]

The Butler dictum on the welfare clause was based only on a reference to Story's Commentaries on the Constitution, which was before discussed in relation to Story's misrepresentation of President James Monroe's Message on Internal Improvements. (I treat Story's commentary and the Butler dictum thoroughly in my treatise submitted in Webb v. AEC.)

Thus, we see that the constitutionality of the AEC's civilian nuclear power program under the 1954 Atomic Energy Act is founded ultimately, and solely, on the Butler dictum on the welfare clause. (If we substitute the word "manufactures" for "agriculture" in the Butler decision, we would have to conclude that the civilian nuclear program is unconstitutional, if the Butler holding is to be controlling.) It is unjust to accord the Butler dictum on the welfare clause as if it is an authoritative opinion, since the specific question it answered was not at issue in the case. Even by the Supreme Court's own criterion, constitutional questions cannot be resolved unless there is a sufficient "controversy as to assure that concrete adverseness which sharpens the presentation of issues upon which the court so largely depends for illumination of difficult constitution questions." Baker v. Carr, 369 U.S. 186, 204. In Butler there was no controversy over the said question with which to provide illumination of the Constitution relative to that question.

The respondents in the Butler case argued that the Agricultural Adjustment Act could not be founded on the welfare clause, and that therefore it was unconstitutional. And the respondents won! Had the other question of whether the welfare clause grants power to spend for public purposes for the national welfare been at issue, surely the Government and the respondents would have given arguments more addressed to that specific question and would have examined each others arguments thoroughly. For example, the Brief for the Government in Butler contained an appendix which compiled

a list of isolated statements taken from the records of the States' ratification conventions . These statements tend to show, if kept isolated, that the State conventions understood the welfare clause as a grant of spending power; and in the preface of the said appendix, the Government alleged that these statements show that the States understood such. Yet, these statements were interpreted completely out of their context. Most of the statements were made by opponents of the Constitution, who sought to reject the Constitution by charging partly that the welfare clause would eventually be interpreted as a grant of spending power. However, the advocates of the Constitution repeatedly rejected such an interpretation and assured the conventions that no such power was conferred by the Constitution. This is the true context of the Ratification Debates, which is shown in one of my attachments to my treatise filed in Webb v. AEC.

Therefore, when the AEC relies on the recent supreme court dictum on the welfare clause for the constitutionality of the civilian nuclear power program, and its 1954 Atomic Energy Act creator, the AEC relies on an opinion of a question that was never squarely before the supreme court for adjudication, nor thoroughly debated there. Indeed, the issue closest in character to the present issue was that in the Butler case; and in settling that issue the court declared that a federal program of spending was unconstitutional. So too is the civilian nuclear power program.

179. Zinn stated:

> "I am reminded of the fact that in the SL-1 accident, every single control rod drive was seized in its channel by a water hammer which acted on all of them in the same way, making all of them inoperative." ANL-7120, above note 3, p. 268.

180. International Conference, "Engineering of Fast Reactors for Safe and Reliable Operation," Kernforschungszentrum Karlsruhe, October 9-13, 1972, Proceedings published in three volumes in 1973. Availability: see above note 160. Hereafter, referred to as the Karl. Conf.

181. D. Smidt, "Summary of the Conference on Engineering of Fast Reactors for Safe and Reliable Operation," Karl. Conf., Vol. III, p. 1463.

182. Ibid.

183. H. Kusters, Karl. Conf., III, p. 1352.

184. G.J. Fischer, Karl. Conf., III, p. 1354.

185. G. Heusener, et al., "Analysis of Hypothetical Accidents for SNR 300," Karl. Conf., III, pp. 1235-1266.

186. Ibid., p. 1244.

187. Ibid., p. 1247.

188. G.J. Fischer, Karl. Conf., III, p. 1354.

189. Ibid.,

190. I. Puig and D. Antonakas, "Analysis of Severe Accidents in Fast Reactors of Great Power. Causes and Consequences" ("Analyse D'Accidents Graves Pouvant Survenir A Un Reacteur Rapide De Grande Puissance"), Karl. Conf., III, p. 1267.

191. N. J. M. Rees, "Mechanical Effects of Core Accidents," Karl. Conf., III, pp. 991-1035.

192. Ibid., p. 992.

193. Ibid., p. 1013.

194. Ibid., p. 1004.

195. Ibid.

196. Ibid., p. 995.

197. D. Jakeman and R. Potter, "Fuel-Coolant Interactions," Karl. Conf. II, pp. 884-897.

198. Rees, above note 191, p. 997.

199. Discussion after "Summary of the Papers Presented at the CREST Meeting on Fuel-Sodium Interaction at Grenoble in January 1972 and Rapport of Conference Papers 38a-k on Fuel-Sodium Interaction," by H.J. Teague, Karl. Conf., II, p. 836.

200. Rees, above note 191, p. 998; and Teague, above note 199, p. p. 818.

201. Rees, above note 191, p. 994.

202. Comment by H. Kusters following ""Experimental Studies of Liquid-Metal Fast-Reactor Accident Conditions," by J.F. Marchaterre, et al., of Argonne National Laboratory; and reply by J.F. Marchaterre, Karl. Conf., II, p. 786.

203. G.J. Fischer, et al., "Progress in Analysis of Severe Accidents," Karl. Conf., III, p. 1222.

204. W.R. Stratton, et al., "Reactor Power Excursion Studies," Karl. Conf., III, p. 1331-p. 1351.

205. I now have a document which promulgates this new classification: ANL Memorandum from R. V. Laney, Acting Laboratory Director, March 28, 1973, to "Staff Employees." However, this memorandum states that the applied technology reports "will be availbale for sale," which contradicts what I had been told previously; but such reports will have the distribution restriction that is placed on the ANL-RDP reports regarding foreign interests, which would be hard to enforce unless the reports were restricted to selected sales. Furthermore, the Laney memo is not conistent with the comment I received from a nuclear engineering department professor that the Argonne National Laboratory associated universities "are not even given access to the final reports." (See Appendix D, p. 10.)

206. L.J. Koch, et al., "Addendum to Hazard Summary Report, Experimental Breeder Reactor-II (EBR-II)," ANL-5719 (Addendum), p. 254. (1962)

The assumed crashdown accident for the EBR-II hazard analysis was labeled the "maximum credible accident" in the ANL-5719 document, which is a misnomer for the assumed accident, since this accident would appropriately come under my category of conceivable accidents, not credible accidents, because it has not yet been shown to be possible.

207. See generally: Rees, above note 191; Jakeman and Potter, above note 197, and Teague, above note 199; and D.L. Morrison, et al., "An Evaluation of the Applicability of Existing Data to the Analytical Description of a Nuclear Reactor Accident--Core Meltdown," BMI-1910, July, 1971, Appendix C; and W.K. Ergen, et al., "Emergency Core Cooling--Report of Advisory Task Force on Power Reactor Emergency Cooling," TID-24226 (1966), Appendix 7.

208. E.P. Hicks and D.C. Mensies, "PHOENIX, a Computer Code for the Calculation of the Fast Reactor Maximum Accident," TRG Report 1268 (d), June 1966; cited in letter from B. Wolfe to R. E. Webb, above note 113.

209. As for the fresh core situation, HEDL is hopeful that the initial fuel motion inside the fuel rods during an over-power transient or over-power accident will be in a direction away from the core in a reactivity-reducing manner, as they predict for the used-fuel ~~case~~ when the fission gases are the fuel propellant. Their chief experimental evidence in this area is the "H-2 fuel dynamics experiment" in the TREAT reactor. (G.E. Culley, et al., of HEDL, "Fast Reactor Safety Implications of Recent Assessments of Fuel Pin Transient Behavior," Karl. Conf., above note 180, Vol. II, pp. 626-642.) However, a specific model has not been developed to support the expected core behavior for fresh fuel. But when it is, the comments in this rebuttal will apply in general. Further, the TREAT tests have serious shortcomings, to be discussed next on pp.104-126, which apply to the H-2 experiment. Moreover, this specific H-2 test was questioned at a recent conference (Karl. Conf., above note 180), and Marchaterre of ANL agreed that improved tests are needed. (Discussion following the paper by J.F.Marchaterre, et al., "Experimental Studies of Liquid-Metal Fast-Reactor Accident Conditions," Karl. Conf., above note 180, Vol. II, 763,768, 786.)

210. Also, the earlier designs did not use plutonium fuel, which has a nuclear effect to worsen the reactivity insertion potential. Combining these differences, I estimated crudely that a crashdown accident in the demonstration plant would yield a 2000 lb. TNT Equivalent nuclear explosion; whereas, this accident when applied to the Fermi reactor yields a 1000 lb. TNT equivalent explosion (assuming no autocatalysis). However, the foregoing is only a crude estimate, and may be grossly in error. The estimate is based on my dissertation results of the Fermi reactor, above note 9, 175-188, the data of Wolfe, et al., above note 4, and the Bethe-Tait theory, above note 167. My estimate includes the Doppler effect and adjustments of core mass from Wolfe's core to the mass of the demonstration reactor. The key parameter in my estimate is the reactivity insertion rate, and my value used agrees with the upper limit used by Hicks and Menzies for core meltdown accident, above note 3.

211. Hearings on Naval Nuclear Propulsion Program--1969 before Joint Committee on Atomic Energy, 91 Cong., 1st Session, pp. 199-228.

212. 22nd Semiannual Report of the Atomic Energy Commission, July, 1957, p. 60.

213. Dissertation by R.E. Webb, above note 9, pp. 206-208.

214. The necessity for core-destruct tests (full-scale) is that the effects of errors in the accident analysis codes are impossible to assess adequately, otherwise. For example, an error in the prediction of the core distribution of power generation or heating during the runaway would cause an error in the distribution and magnitude of the pressure throughout the core. This error in turn could effect substantially the direction of fuel motion and the speed of the fuel movement, which in turn could, by the reactivity change brought about by the fuel motion, drastically alter the rate of the rise in the power level and the distribution of the power--the last of which is the factor that was originally assumed to be in error. The above cycle is continuously occuring in an accident. Just what the ultimate course the fuel motion or the nuclear runaway will take, in view of the potential for error, simply cannot be adequately determined, unless the real phenomenon is observed. Kelber, et al., recognized this point by stating:

> "The reactivity calculation can be partically checked by a series of critical experiments with successive loading changes to simulate the motion of the core during the excursion. This approach clearly has some limitation because we depend upon calculation to specify the material motion. This is an area that conceivably could benefit from a proof test of a complete whole-core destructive-excursion experiment." (Kelber, above note 10, p.84.

(The "critical experiments" are non-nuclear runaway tests where the fuel is mocked up (real fuel) in the predicted manner (distribution and composition) to experimentally determine whether each successive experiment is leading into a nuclear runaway or undesirable reactivity changes.) There are difficulties even with the use of the critical experiments; but even if we neglect them, Kelber, et al., statement about depending on the calculated fuel motion attests to the problem of verifying the accident analysis methods.

215. The revised values of Hicks and Menzies were obtained by their computer code PHOENIX. (See above note 208.) This code was applied to a large LMFBR, and the resultant explosion estimates are reported in the article "Factors Limiting Prompt-Critical Excursions in Irradiated Fast Reactor Cores," by H.J. Teague and D.J. Mather, Nuclear Safety, Vol. 14, No. 3, May-June 1973, p. 204, Figure 4. The revised values are about 1200 megojoules of explosive energy versus about 10 megajoules for the old Hicks and Menzies data for the same conditions. The values of Meyer and Wolfe, above note 4, are about the same as those of Teague and Mather. This is confirmation that the earlier Hicks and Menzies data are erroneous, and that the theoretical estimates of disastrous nuclear explosions given in this Rebuttal, which are based on the Meyer and Wolfe results, are reinforced.

Congress of the United States

JOINT COMMITTEE ON ATOMIC ENERGY

WASHINGTON, D.C. 20510

February 4, 1974

Dr. Richard Webb
1923 Maxwell Lane
Bloomington, Indiana 47401

Dear Dr. Webb:

This is in response to your letters of August 20, 1973, November 12, 1973, and December 20, 1973, regarding your report entitled, "The Explosion Hazard of the Liquid Metal Cooled, Fast Breeder Reactor (LMFBR)."

Last September, the Committee referred your report to the AEC for their review and appropriate comment. In view of the extensive nature of the document and the many contentions in it regarding the safety of LMFBR's, it has taken the Commission considerable time to analyze and prepare a response which it believes would be of the high quality appropriate to the situation. The review is now complete, and the evaluation is enclosed.

As I am sure you will appreciate, it is impractical for the Committee and its staff to review and comment on the specific issues raised in the report.

The Committee regrets that we were unable to respond to your letters at an earlier date.

Sincerely yours,

Edward J. Bauser
Executive Director

Enclosure:
AEC Staff Report on
Dr. Webb's Treatise

ENCLOSURE

RRD STAFF REPORT ON DR. WEBB'S TREATISE

Dr. Webb begins from the obvious initial observation that the LMFBR industry, when mature, will involve very large quantities of plutonium and fission products. These are hazardous materials which must be contained. We fully agree with this observation. Containment and control of hazardous materials has been a prime consideration in the civilian reactor power development program since very early in the program. Dr. Webb also emphasizes that LMFBR design analysis and safety assessment must consider the possibility of "recriticality." (Recriticality is the unintentional assembly of reactor core material into a critical configuration following an accident in which core integrity is lost.) Again we fully agree that this possibility must continue to be considered. To this point, Dr. Webb's discussion is valid, even though stated in what might be considered an overly dramatic fashion.

Dr. Webb's more serious allegations go beyond the concerns implied by these first two points and are associated primarily with postulated accidents of an extremely severe nature. Before speaking to Dr. Webb's specific concerns, we feel it is important to reflect briefly on the basic situation we are discussing. The occurrence of a severe accident in a large and very expensive power plant must necessarily be made uncommon. If for no other reason, the plant owner will want to protect his investment by assurance that availability and integrity of the plant are not compromised. Beyond this, the AEC through its regulations for licensing sets forth very demanding criteria and rules to assure that severe accidents are very unlikely and that even if they should occur, they would not cause undue risk to the public health and safety. Very explicit and extensive programs are underway throughout the nuclear industry to develop and confirm designs of effective and reliable reactor and plant protection devices. We are confident that these programs, coupled with operating experience of liquid metal reactors and demonstration plants, will confirm that the possibility of occurrence of any major accident in an LMFBR is very remote.

Even if accidents should occur, an LMFBR, by virtue of its inherent features such as the extremely good heat transfer characteristic of the sodium coolant, is basically a very stable machine. Primary selection criteria for materials, designs, and configurations include stability, reliability, and conservative margins. LMFBR designs and associated fuel element development programs include the requirement that, even in the instance of serious plant malfunction, there be very little likelihood that the integrity of any fuel elements will be lost. Nevertheless, we do pay serious attention to understanding the phenomena which would follow from loss of fuel element integrity. In Dr. Webb's discussion, he begins with the assumption that a very serious accident has already occurred, well beyond the range that we feel might be possible in actual

LMFBRs, and proceeds to inquire as to whether such an accident could lead to a further and catastrophically worse accident. Thus, we are discussing a situation which, by all rational judgment, must be considered to be extremely unlikely and which may not be realistically possible. (Dr. Webb's comment on page 14 - "Indeed, a mild local perturbation in the core of an LMFBR could generate a strong enough over-power transient so as to melt down the entire core and lead to an even stronger nuclear runaway" is absurd.) These considerations are frequently referred to as "end-of-spectrum accidents". Because of our concern for control of plutonium and fission products, even these extreme situations are felt to be proper areas for responsible inquiry.

Returning now to the specific areas of concern, we would describe the further allegations that Dr. Webb makes as follows:

1. Dr. Webb claims that there exists the potential for certain autocatalytic effects (as postulated in his Ph.D thesis) which have been and are being ignored in the LMFBR development program and safety risk assessments. In particular, he appears to be concerned about the possibility that an accidental situation might arise wherein various regions of an LMFBR become "supercritical," violently displacing other core material into an even more supercritical configuration. He discusses two classes of situations: 1) implosion into a void created by movement of fuel following local melting, and 2) coherent compaction from coordinated explosions.

   AEC Response
   The potential for forceful compaction or implosion of an LMFBR core has not, is not, and will not be ignored. This has been discussed by a number of people on a number of occasions. This is illustrated in Dr. Webb's bibliography by items No. 47, 49, 83 and others. The possibility of such an accident continues to be assessed, but studies are oriented toward actual cores and potential accident situations in such cores. Assumption of artificial or illogical reconfiguration of materials for the purpose of arbitrarily increasing the potential consequences of recriticality is not considered either a realistic or reasonable basis for responsible inquiry.

2. Dr. Webb claims that the maximum potential damage associated with LMFBR accident situations has not been evaluated, primarily because of point number 1.

   AEC Response
   The maximum damage potential consistent with accepted Regulatory procedures is necessarily assessed as part of Safety Analyses Report preparation. The theoretically conceivable maximum could

be evaluated by assuming arbitrary and extreme rearrangements of material but this would generally be of academic interest. Such extreme limit determinations are considered to be useful, for example, when it is not practicable to do a more detailed analyses, when scoping studies are desired, when one wishes to explore the possibility of consequence thresholds, etc. It can be misleading and counter-productive however, when the results of scoping studies are taken out of context or confused with those of more detailed analyses.

3. Dr. Webb proposes that, since there are situations for which a maximum damage potential has not been demonstrated, (potentially extremely costly) experiments must be done to demonstrate what these limits may be.

AEC Response

The concept of attempting to determine the maximum accident potential by direct core destructive tests has repeatedly been determined to be a non-productive and unnecessary way of obtaining a responsible understanding of phenomena. It is a technical judgment whether or not such tests would be productive of useful results in any particular situation. The very documents that Dr. Webb quotes reflect the current technical judgment that integral core destruct tests would not be productive of useful results. We do, however, consider experimental validation of key features of accident sequences to be essential in development of an adequate understanding of the phenomena involved, and have consistently reflected in budget submittals the need for additional safety facilities. Contrary to the implications of Dr. Webb's treatise, we are still planning, as reflected in budget submittals, to expand significantly our inventory of test facilities. Currently, we are reassessing facility needs. While we see no such need at this stage, should integral core destruct tests be shown to be appropriate, this would be put into our proposed program of work.

4. Dr. Webb proposes that such maximum consequences as have not been demonstrated to be outside of physical law, should be weighed against potential program benefits in assessing the justification for the program.

AEC Response

Risk potential must be evaluated in light of the probability of occurrence. We recognize that it is difficult to invoke the likelihood of consequences in a quantitative manner and, thus, we must to some extent rely on the judgment of reasonable men. We also understand that reliance on such judgments does involve

the risk of making subjective determinations, but we feel that such judgments are an essential feature of any assessment. We assume that Dr. Webb agrees with this as an essential feature of societal decision making. We also feel certain that Dr. Webb would agree that the proper means and forum for determining the acceptability and adequacy with which these risks have been addressed relative to specific programs and projects is through formally established Regulatory-type procedures. There are standard and accepted forms of Regulatory review for nuclear plants. There are Regulatory guides in existence and in preparation, and the procedures for preparation of Environmental Impact Statements are recognized. Development of and justification for safety development programs are subject to public and congressional review prior to their authorization.

In summary, Dr. Webb has raised several legitimate questions, but they are neither new, nor constructively presented. These concerns, however, are and will continue to be, addressed in context with the many other questions which must be answered in the course of validating the breeder option without gross misallocation of public funds. Nothing in Dr. Webb's treatise or in our evaluations of safety of LMFBR's suggests that the potential or the magnitude of any accident or accidents are such as to require a slowing of the LMFBR program.

February 13, 1974

Honorable Birch Bayh
United States Senate
Washington, D. C. 20510

Attention: Mr. Howard Paster

Subject: Response of the Joint Committee on Atomic Energy and the Atomic Energy Commission to my Treatise Testimony on The LMFBR (Breeder Nuclear Reactor) Explosion Hazard

Dear Sir:

This letter is to comment on the JCAE's and the AEC's responses to the subject treatise. You have a copy of the treatise, which raises fundamental health and safety issues regarding the LMFBR breeder nuclear reactor. These issues are basically:

(1) The maximum LMFBR explosion potential has not been scientifically established.

(2) There are theoretically conceivable explosions that greatly exceed the containment strength of LMFBRs, e.g., 20,000 lb. TNT equivalent explosion versus 1,000 maximum economically containable, which would release the radioactivity in the reactor to the environment, causing mind boggling disaster. The magnitude due to fission products could be as follows: (a) 150,000 square miles requiring evacuation for a year or so; (b) death and injury to millions of people; and (c) 400,000 square miles of land requiring agricultural restrictions for about 100 years or so. Additionally, permanent contamination of 400,000 square miles due to plutonium (24,000 years "half life") that probably would require permanent abandonment.*

(3) There are no LMFBR explosion experiments being planned to verify the AEC explosion theories which the AEC relies on for their judgment that the explosion hazard is small (10 lb. TNT equivalent) and

* 150,000 sq. miles = Illinois, Indiana, Ohio, + Pennsylvania, combined.

containable, which is untenable. Many such experiments would have to be performed to cover a large variety of conditions, before the theories could be accepted, and each would have to be a full-scale duplicate of each of the LMFBR designs, due to the peculiarities of the nuclear physics involved. There is no way around the full-scale requirement. Thus, the high cost and the hazard of the tests themselves appear to make experimental verification of the AEC's explosion theories impractical, and thus preclude the LMFBR. And,

(4) The AEC's explosion theories have fundamental theoretical shortcomings. One such shortcoming, for example, is discussed in my treatise on pages 133-135 which concerns the fact that the AEC theories do not extend in time after an initial explosion to investigate, theoretically, whether a severe, secondary explosion might occur due to the effects of the first mild explosion. On page 65 of my treatise, I mentioned an internal report by Jackson and Boudreau ~~at~~ of Argonne National Laboratory which has been kept secret, which analyzes such secondary explosion possibilities. After my treatise was submitted to the JCAE I was finally able to get this draft report from the AEC, after first being denied it. The report confirms my concern. Based on the data in the report, an explosion greater than 1160 lb. TNT for the FFTF reactor (a forerunner to the LMFBR presently under construction) is calculated, which exceeds the 150-300 lb. TNT (equivalent) containment design limit for the FFTF. Moreover, the report did not explore the worse case predictable by the theoretical "model" used.

The following are my initial comments to the AEC "staff report" of my treatise, and the JCAE letter, both of which are attached:

The AEC's Staff Report

1. It does not refute any of my specific points in my treatise with any evidence or documentation whatsoever.

It's the same old rhetoric from persons unknown (unsigned). I stand on my treatise, which addresses such rhetoric completely.

2. The AEC comments include rhetorical, unspecific characterizations of the analyses and assumptions used by me to estimate the conceivable hazards. Specifically, the AEC implies that they use "actual cores and potential accident situations," whereas I use "artificial or illogical reconfiguration of [core] materials." (P.2) I thoroughly evaluate critically the AEC's approach, which comes under the heading of "mechanistic analyses." See pages 34 through 37 of my treatise, and the rest of the treatise as well. Basically, the AEC's approach is impossible to strictly carry out because of the extreme complexity of reactor behavior under "core meltdown" conditions. Moreover, the AEC plans no experimental verification of their theories, which requies "full-scale integral core destruct tests." In short, neither does the AEC use <u>actual</u> cores and potential accident situations. To imply that my core explosion modes are "illogical" is pure rhetoric. The logic of my accident modes is expressly described in my treatise (e.g., p. 110-111, 134-135), so they are not illogical. TheAEC should address these with specific analysis or disproofs, instead of making vague generalities. Indeed, the draft ANL report by Jackson and Boudreau mentioned above using the AEC's own mechanistic approach tends to confirm my "illogical" methods (See item (4) above.) The accident sequences used in my treatise, which incidentally were used by past LMFBR safety analysts as my treatise explained, are <u>not</u> for the purpose of claiming that "there exists the potential" for disastrous explosion, as the AEC staff report suggests I'm claiming, but only to show what might be possible with "conceivable" situations that have plausibility, i.e., that have not been shown to be impossible, and that use assumptions

which at least are in accord with the laws of nature. On page 186 of my treatise I concluded:

> "Although I have not proved that the worst possible explosion is unacceptably high; neither have the promoters of the LMFBR Demonstration Plant, nor the LMFBR Nuclear Safety Program at ANL, proved that it is acceptably limited."

This is the point of my treatise - that we don't know the explosion hazard, which should at least defer ~~preclude~~ the LMFBR since disastrous explosions are theoretically conceivable.

3. The AEC alleges that I propose a series of costly "integral core destruct" experiments to demonstrate the explosion limits. (P.3) This is not accurate, as I argued that the practicality of such tests is doubtful. (See pages 132, and 140-148 of my treatise.) I said, if theory after being rigorously developed, which is not now the case, predicts an acceptable maximum explosion potential, then we would need the experiments to verify the theory before we could proceed with the LMFBR. If the theory predicts an unacceptable explosion hazard, or if such experiments are impractical, then we should not adopt the LMFBR.

The AEC implies in their Comment No. 3 that I am suggesting that we forego "obtaining a responsible understanding of phenomena", i.e., a sound theoretical understanding, by opting instead for a series of integral core destruct tests to settle the question of the maximum LMFBR explosion potential. On the contrary, I claim repeatedly in my treatise that both are necessary if we are ever to proceed with the LMFBR (See, for example, pp. 132 and 143-144.), as without a sound theoretical understanding, it is always possible that even a series of tests might not show up a disastrous explosion possibility.

Also, I note that the AEC definitely now sees no need for integral core destruct tests to at least partially confirm their deficient theoretical claims of a low explosion potential. We might ask the AEC, then, why they thought that a full-scale Cannikin H-bomb test in Alaska (ABM warhead) was necessary (to verify theoretical predictions no doubt), and why the same kind of verification is not desirable to confirm the health and safety of the nation vis-a-vis the LMFBR?

The AEC in their Comment No. 3 states that the "very documents" I quote "reflect the current technical judgment that integral core destruct tests would not be productive of useful results." I assume the AEC refers to "Safety Problems of LMFBRs", ANL-7657, page 98, to wit:

> "The need for proof tests of the integral core-destruct type cannot be justified at this time."

The AEC should explain why the draft of this report* had to be sent to them for "review and comment"; why it "was revised to take into account such comments", and why other "[c]omments stressing the need for core-destruct tests were not accommodated in the revision "? (See ANL-7800, p. 291, and pp. 51-52 of my treatise.) As it is, the AEC implies that there is unanimous "technical judgment" apart from mine against the need for integral core destruct tests, which apparently is not true.

Indent →

Moreover, there is a certain inadequacy in relying on those for technical judgment who have a vested interest against taking the chance that the safety of LMFBR would be disproven by such integral tests.** Also, there is probably no one, beside myself, out of the pay (direct or indirect) of the AEC who has the competence to exercise a valid technical judgment. Incidentally, the AEC loses sight of the historical usefulness of "technical judgment," which was to aid

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* From Argonne Nat'l Lab., the center for the LMFBR development, including the LMFBR Nuclear Safety Program.

** ... relying on such vested interests for unverified technical judgments.

in design, whether it be a machine or a theoretical model; but it is no substitute for proof tests of a design. The point is, we need verified analyses of explosion theories, not unverified technical judgments, if the health and safety of the people are to be ensured.

4. The only specific statement from my treatise which the AEC addresses and rejects is that on page 14 (See p. 2 of Staff report):

> "Indeed, a mild local perturbation in the core of an LMFBR could generate a strong enough over-power transient so as to melt down the entire core and lead to an even stronger nuclear runaway."

The AEC states that this "is absurd". Yet, no analysis or documentation is given by the AEC. My treatise supplies a specific example on p. 35 regarding flow blockage to only one out of 250 fuel assemblies in the core (a mild perturbation), which the AEC does not refute. I gave a reference (No. 26) as well. More specifically, see pp. II – 52-55 of Accident Delineation cited in Reference 26. Another reference is a paper by J.H. Wright, et al, of Westinghouse, in ANL-7120, p.219, Proceedings on the Conference on Safety, Fuels, and Core Design in Large Fast Power Reactors, Oct., 1965, ANL. The point is, that any disturbance which leads to "positive reactivity" will lead to a power rise and core overheating, then meltdown, unless checked by an active safety system. If the system is inoperable, then the meltdown could occur with potential for nuclear runaway and explosion as is so thoroughly and extensively discussed in my treatise. The AEC, therefore, is rhetorically quarreling over my adjective "mild", but they should know what "mild" means in the context of my treatise. (Note that the AEC asserts that a claim that a mild perturbation producing ultimately a nuclear runaway is "absurd", not that such is impossible; i.e., the AEC may judge that it's highly unlikely, a subjective guess, however.)

5. The AEC simply ignores all of the specific points of my treatise; e.g., the Jackson/Boudreau draft report (p. 65 of my treatise; summary item (4) above); Boudreau's Ph.D. thesis, p. 57—59 of my treatise; the ACRS* comments, p. 224-225 of my treatise, and so on and on. It seems to be the habit of the federal government to issue rhetorical and even unfounded assertions to rebut challengers who prepare rigorous analyses. It is always easy to use the "prestige" of the federal government to give credence to their superficial, unfounded, and self-serving statements. And it is extremely difficult for me with no phone budgets, typists, and income to set the record straight - to unravel the distortions. I am very tired of such runarounds. Unless the federal government seeks the truth, their power will simply quash it.

6. The AEC asserts that I would agree that the proper forum for assessing the acceptability of the hazards is the [redacted] AEC regulatory procedure. I emphatically disagree, which is well discussed in my treatise in the section on the subject of the unconstitutionality of the AEC's civilian nuclear program, which the AEC totally ignores.

7. In short, the AEC simply asserts its illegitimate power to exercise and enforce its judgment about what risks are acceptable, including the risk of not knowing the explosion potential. They escape their responsibility, though, by alleging that their "justification for safety" are "subject to public and congressional review." However, the JCAE expressly declared that they will <u>not</u> review and comment on the specific issues of my treatise, which is discussed next. So, there won't be any Congressional review as things now stand.

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* ACRS = Advisory Committee on Reactor Safeguards - a statutory body 42 U.S.C. 2039

JCAE Response

1. The JCAE's response is simply to accept the AEC's evaluation without question. Speaking for the Committee, Executive Director Bauser states:

> "As I am sure you will appreciate, it is impractical for the Committee and its staff to review and comment on the specific issues raised in the report."

Thus, the JCAE plainly demonstrates that it has no real regard for the health and safety of the people — a patent neglect of duty, especially since the AEC staff report states that "Dr. Webb has raised several legitimate questions . . ."* The Atomic Energy Act, Sec. 202, declares: "The Joint Committee shall make continuing studies of the activities of the Atomic Energy Commission and of problems relating to the development, use, and control of atomic energy." By their letter, the JCAE seeks to shun its duty. Also, Sec. 202 does not say that the JCAE can let the AEC perform the studies for the JCAE, as the JCAE letter attempts. Moreover, Sec. 202 declares that "The Commission shall keep the Joint Committee fully and currently informed with respect to all of the Commission's activities." The AEC staff report hardly satisfies this requirement.

2. The JCAE ignores the many requests made of it in my treatise for hearings and reviews. See pp. 42, 64-65, 137, 144, 148, 154, 161, 175, 178-79, 183, 201-202, 204, and N&R p. 8a.

In closing, I urge you to review the issues I raise in my treatise and do all within your power to force the Congress to fairly and fully investigate the contentions in my treatise. Being poor, in debt and no income, I am powerless to do anything

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* And since the ACRS, and now, the Cornell Workshop (see postscript herein), have expressed reservations about the LMFBR explosion hazard.

more. I can only hope that I can finish and publish my book. The matter is in your hands, if you care to exercise the responsibilities implied in your office, to take care that the health and safety of the nation and of Indiana is ensured.

Sincerely yours,

Richard E. Webb

Richard E. Webb, Ph.D.

1923 Maxwell Lane
Bloomington, Indiana
47401

(812) 339-5024
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Copy to:

Melvin Price, Chairman of JCAE
Hal Will ard, Washington Post

POSTSCRIPT

The AEC staff report (p. 1) further distorts my treatise: "In Dr. Webb's discussion, he begins with the assumption that a very serious accident has already occurred, . . ." <u>This is not true</u>, since "a very serious accident" could be taken to mean an explosion to start with. On the contrary, I start with possible reactor system malfunctions occurring during normal reactor operations (no explosion) to then inquire into the course of the reactor behavior--whether it could lead to disastrous nuclear explosions. See my treatise, pp. 35-37 and section V, pp. 87-139. A separate section of my treatise is set aside to discuss theoretical methods for calculating the course of the nuclear runaway explosion should it occur. See section I, pp. 56-66.

Then the AEC states that "very serious accidents" are "well beyond the range that we feel might be possible in actual LMFBRs".* This view has not been demonstrated scientifically, as I discuss thoroughly in Sections IV and V, pp. 80-139. It is not enough to merely claim that "very serious accidents" are not possible; one needs to demonstrate it

* If by "very serious accident," the AEC means "nuclear runaways," or nuclear excursions, then this AEC staff report is the first time such a view has been expressed by the AEC, contrary to the [illegible] regulatory staff, pp 128-12[illegible] of my treatise.

with theoretical analyses and verified by full-scale, integral core destruct tests. Iff If full-scale tests are not practical, then we'll have to discard the LMFBR, else we'll take chances with the people's safety and well-being. Consider the opinion of experts of "The Cornell Workshops on the Major Issues of a National Energy Research and Development Program", Dec. 1973, which was commissioned and funded by the AEC even:

> "The theory of the maximum hypothetical accident is thus in rather satisfactory shape. Nevertheless, we recommend that further research be done on it, especially to make sure that nothing has been forgotten. In particular, it is important to investigate theoretically what happens to the fuel [core] once it is disassembled [exploded]. Is there any possibility that it freezes on its way out (for example, in the upper blanket) and then reassembles once more, leading to a [redacted] second recriticality accident [explosion]? It seems very unlikely that this could happen, but further theoretical and perhaps experimental study would be in order. . . .

Then by citing the vaguely favorable results of the TREAT tests, which I evaluate in my treatise for their deficiencies (Sec. V.C. and V.D. and Sec. III., pp. 67-80, 95-126), the Cornell report states:

> "In spite of these satisfactory results, the problem of safety is so basic that further intensive work is essential. Some large-scale facilities similar to SPERT and LOFT should be designed and operated for this purpose. . . .
>
> In addition to the large-scale experiments, there should be model experiments on the flow of molten material. On the theoretical side, there should be sophisticated calculations to determine whether coherent reassembly of fuel* is possible."

While I do not agree that the theory is in rather satisfactory shape as the Cornell group believes, and which I support my claim [redacted] with my treatise, whereas the Cornell report does not document their claim at all, the report basically supports my position, since the SPERT type test is an integral core-destruct test, i.e., the SPERT-ID was a core destruct experiment of a water-cooled reactor (a non-LMFBR) (See p. 131 of my treatise.), and since the report calls for [redacted] more theoretical studies to investigate the kinds of concerns I have. Indeed, their own recommendations suggests that the theory is not in "rather [redacted] satisfactory shape" as they began declaring.

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* = severe explosion

Also, the AEC states (p. 3) that they are planning "additional safety facilities." These, however, fall short of integral core destruct tests. Anything less than integral core destruct tests can be helpful in developing a theoretical method, but is fundamentally insufficient for scientifically establishing the maximum LMFBR explosion hazard, as I discuss in Section III, and V.C., V.D., and V.E., and on pp. 140-147. See also pp. 43-55. Also, the AEC's plans for additional safety facilities does seem to imply that the AEC is not all that sure of their own overall "technical judgments."

May I add a personal note. I have been performing my nuclear safety studies on, not only the LMFBR, but the water cooled reactor as well, for two years with only a total grant of $4100 + G.I. Bill - over two years mind you; plus my previous work over four years in my ph.d. program, which culminated in my Ph.D. thesis on the LMFBR explosion hazard, at a minimal salary (stipend). I applied for employment within the AEC and its laboratories to pursue these matters, but got rejected. Now perhaps the government would provide me with a financial reward for my hard labors, and an appropriate grant to allow me to continue, as I can only survive one more month. If President Nixon can hire extra lawyers for his legal problems at $40,000 per lawyer per year, and if the AEC can pay their LMFBR promoters similar type salaries, surely the federal government can afford to pay me $20,000 annually to help the LMFBR and Water reactor scientists and engineers intellectually honest. A resume of my extensive nuclear engineering background is in appendix A of my treatise, specifically my letter to Senator Pastore. I understand that one past AEC chairman received $100,000 from the federal government as a bonus for his earlier scientific work; similarly, I should think that the government would want to give me a ~~similar~~ bonus (back pay) for my work on establishing the extent of man's knowledge of the LMFBR explosion potential, which will help ensure the health and safety of our people and their land. I note that the ACRS and Cornell comments followed my original LMFBR testimony* (Sept. 1972) and my treatise (July, 1973), respectively.

* See Appendix A of my treatise.

United States Senate

COMMITTEE ON THE JUDICIARY

WASHINGTON, D.C. 20510

February 26, 1974

Hon. Melvin Price, Chairman
Joint Committee on Atomic Energy
H-403 The Capitol
Washington, D.C.

Dear Mr. Chairman:

For some months a constituent of mine, Dr. Richard Webb of Bloomington, Indiana, has been corresponding with the Joint Committee regarding a treatise he prepared on the breeder reactor.

On February 4 Mr. Bauser of the Committee staff replied to Dr. Webb's letters with an analysis of Dr. Webb's treatise by the Atomic Energy Commission.

Dr. Webb has again written to me, rebutting the Commission's reply to his treatise. I am enclosing a copy of that rebuttal and Dr. Webb's previous correspondence with the Joint Committee.

Dr. Webb makes the valid point that the Commission, which reviewed his treatise for the Committee, obviously could not make an independent analysis of the points he raised in his elaborate and thorough examination of the breeder.

I am forwarding the materials Dr. Webb has sent me to you with the hope that the Joint Committee might seek an independent review of the issues he has raised. If the Committee staff, with its various other responsibilites, is unable to do this, it would seem consistent with the spirit of Dr. Webb's effort to seek the advice of independent experts who do not have the same direct interest as as the Commission.

Thank you for considering this matter.

Sincerely,

Birch Bayh
United States Senate