SOME IMPORTANT UNEXAMINED QUESTIONS CONCERNING THE BARNWELL NUCLEAR FUEL REPROCESSING PLANT

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TESTIMONY BEFORE THE

NUCLEAR STUDY COMMITTEE

THE LEGISLATURE OF THE STATE OF SOUTH CAROLINA

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Introduction

I consider it a privilege to discuss with you some crucial questions concerning the siting and operation of the proposed Barnwell Nuclear Fuel Reprocessing Plant of Allied-Gulf Nuclear Services. And I wish to express my appreciation to Mr. H. J. Larson, President, and Mr. R. I. Newman, Vice President of the Allied-Gulf Nuclear Services Company. They have both been gracious and totally cooperative in making available to me for study the full Environmental Report on the proposed Barnwell Plant. More than that, they have both expressed their sincere desire to have my comments and suggestions.

Allied Chemical and Gulf Oil Corporations are two of our foremost U.S. industrial corporations. I accept completely the statement of Mr. R. I. Newman in a recent letter to me that:

"It has been, is and will continue to be our prime goal to insure the safety of the public as well as our workers, and to insure that our operations have a negligible, if any, impact on the environment."

Therefore, the issues I shall raise here are addressed to these two great American corporations, as well as to the South Carolina Legislature. As we get into the discussions more deeply, I hope it will become clear that the Barnwell facility raises questions requiring that the necessary participants are far beyond Allied-Gulf and South Carolina - indeed, we must truly consider the interests of everyone living on the Eastern Seaboard of the United States, as well as those of more inland States. Some of the considerations will demonstrate that because of potential risk of requiring evacuation of Washington, D.C., the entire National interest is definitely involved in our considerations.

Some of you may have heard that I am a "nuclear critic". Let me assure you that this is absolutely correct. I am a critic because I have found through my long period of association with and research in nuclear energy that some extremely serious questions concerning nuclear power generation have not been adequately examined, while the industry moves forward at a rapid rate. But while critical questions are being raised, let me assure you that I have no interest in doomsday predictions, no interest in alarmism.

We in America all must share in the task of insuring a good quality of life for Americans, and that means due attention to providing energy, including electric energy, for our industry and our home uses, to sustaining a healthy economy (and here I am particularly cognizant of South Carolina's needs for industry and jobs), and above all, to insuring that we provide such energy consistent with the good health and safety of Americans. You of the South Carolina Legislature surely share these views, and I am certain that the Allied Chemical Corporation and Gulf Oil Corporation both share these views completely.

It is precisely because of the enthusiasm all of us share about "getting on with the job", that we must pause to examine whether we may not have overlooked some very disturbing possibilities associated with nuclear fuel reprocessing plants such as the Barnwell Facility. While it may seem that a facility ultimately employing only some 300 employees (1000 during construction) is a small industry, other associated factors make this industry and its development one of the most far-reaching, significant industrial developments of all time. Neither the South Carolina Legislature nor the Board of Directors of both Allied Chemical and Gulf Oil can afford to leave questions of all-time importance unanswered. I hardly think the stockholders of these two great corporations would appreciate a venture that might ultimately destroy these Corporations. Nor would the people of South Carolina appreciate the overlooking, by this Legislature, of questions that deal with the possible evacuation of a large part of the State of South Carolina.

It will be necessary for us, mutually, to examine two major areas:

(a) The question of financial liability and how it relates to critical examination of the dangers of the Barnwell Facility.

(b) The technical question of possible accidents at Barnwell and their local and national consequences.

Financial Liability and Critical Evaluation of Risks

Every great corporation must necessarily consider financial liability for its ventures and the implications of such liability for the Corporation's future.

Unfortunately, through the existence of the so-called Price-Anderson Act, liability for the consequences of a serious accident at Barnwell is limited to 560-Million Dollars. But I propose to discuss with you accidents that could easily lead to damages in the neighborhood of 10-Billion Dollars or more, to say nothing of the most massive civilian dislocations and suffering in peacetime history. The existence of the Price-Anderson Act means that no one carries the financial liability for about 95% of the damages that could accrue - no one at all.

I happen to regard the Price-Anderson Act as unconstitutional. There is a bill in the U.S. Senate, introduced by Senator Gravel, to repeal this Act. So the Act may be repealed, or there may in time be a Supreme Court test of its constitutionality. If this Act is repealed or declared unconstitutional, are the Allied Chemical Corporation and the Gulf Oil

Corporation prepared to risk their assets, even though large, on a $10-Billion liability?

Even if the Price-Anderson Act is not repealed, the situation for these two corporations is hardly better. There can be no doubt that if an accident involving $10-Billion in uncompensable damages occurs, the reputation of both corporations will suffer irreparably, and the revulsion in the public may, in effect, destroy both corporations and much of the value of their securities in the marketplace.

It is neither my intent nor my ability to estimate the probability of such an accident occurring. But I am frankly amazed that both the South Carolina Legislature and the Boards of Directors of both great corporations involved have not insisted upon a fully independent engineering assessment of such probabilities, including especially the possible effects of internal or external sabotage. We live in perilous times, and to neglect such possibilities as sabotage is simply to bury our heads in the sand in the fashion of ostriches.

I have a high regard for the detailed efforts of Allied-Gulf Nuclear Services and their consultants who prepared the Environmental Report on Barnwell. But simple, hard-headed business sense tells us that this must necessarily be the last source one would go to for a critical, independent assessment of the probability of a serious accident. What is required is assignment of responsibility to an independent group of engineers to figure out all the ways it is possible for such an accident to occur, and to try to assess the probability of its occurring. Such assessment would not be very costly. I believe the South Carolina Legislature and the Boards of Directors of both major corporations can accept no less. I have seen no such independent assessment. Under no circumstances should reviews either by the Atomic Energy Commission or any of its Licensing or Advisory Boards be misconstrued as an acceptable assessment.

Once such an independent assessment is made, the evidence on both sides deserves debate and presentation in a full open public forum. Nothing less will allay public concern, a concern that will grow.

If everything goes as planned and as considered in the AGNS Environmental Report, there is probably no problem of health, safety, or environmental damage. I would hardly wish to quibble over minor questions I have about that report, especially when viewed against the vastly more important questions that must be answered, and which are not described in that Report.

There are two very simple questions I propose to discuss with you:

(1) What are the consequences of 1% (that is, one-hundredth) of the radioactive inventory of Barnwell at full operation being released to the environment?

(2) What are the consequences of 0.01% (that is, one-ten thousandth) of the radioactive inventory being released?

To do this we must turn our attention to some simple technical realities of Barnwell at full operation.

The Radioactivity Inventory at Barnwell at Full Operation

The Barnwell facility proposes to process 5 metric tons of spent nuclear fuel per day, or 1500 metric tons per year. The long-lived radioactive waste, after processing, will remain at Barnwell between 5 and 10 years, assuming optimistically that some Federal repository can be developed, which is very much in doubt. Let us minimize the problem, and assume that the radioactive waste is at Barnwell for only 5 years even though it may remain in South Carolina indefinitely.

The processing of 5 metric tons per day of spent uranium fuel means the servicing of about the equivalent of 50 large nuclear power plants, each, say, of 1000 megawatts electrical [MW(e)] generating capacity. Since each plant discharges 1/3 of its fuel each year, the Barnwell receipts will be of fuel elements each having spent an average of 2 years in the power plant. The equivalent delivery to Barnwell is 2/3 of the yearly long-lived radioactivity produced in the 50 plants, which is equivalent to the output of 35 such 1000 MW(e) plants.

Each 1000 MW plant produces, in one year, the long-lived radioactivity of 22 megatons of atomic fission bombs. So, 35 x 22 = 770 megatons of bombs. And for a five-year storage period, this means 5 x 770, or 3850 megatons. Note, nothing of this should be misconstrued to mean any explosive power of this radioactive waste. It is simply necessary to give you an idea of the astronomical quantity of radioactive waste in inventory at Barnwell, at full operation. We may express this in three ways:

The radioactivity (long-lived) in the Barnwell inventory will be:

(a) Approximately fifteen times as much as all the fission product radioactivity produced by all atmospheric weapons tests in all time by the combined testing of the USA plus the USSR.

(b) Approximately the radioactivity that would be left decaying for 10's and 100's of years from a large, full-scale nuclear war.

(c) Approximately the long-lived radioactivity of 192,000 Hiroshima or Nagasaki atom bombs.

Let us turn to the kinds of radioactive substances present after the Barnwell plant has been in full operation, using the 5-year residence time for radioactive waste (remembering that the AGNS report suggests an even higher residence time). Again, from the point of view of minimizing the potential hazard, I shall consider only the major radioactive materials, and shall consider only those species which produce a hard gamma ray on decay, (more than 400 KEV).

The AGNS Environmental Report will serve as a source to ascertain the total radioactivity inventory at 5 years of operation. (Table 3.6-1, page 74, Section 3, of the Barnwell Nuclear Fuel Plant Environmental Report). I shall add one additional radioactive substance, Strontium-90, which although it does not emit a hard gamma ray, is very important for consideration of certain accident consequences.

After correcting for radioactive decay, one reaches the final figures for radioactive inventory of hard gamma emitters presented in the following table, (Table 1).

TABLE 1

Hard Gamma Ray Contributors Built Up in the Fuel Reprocessing Plant Inventory at Five Years

Isotope	Half-Life	Megacuries per ton daily input	Megacuries per 5 tons daily input	Final Equilibrium Inventory at 5 years, corrected for decay (Megacuries)
Zr^{95}	65 days	0.3774	1.887	176.2
Nb^{95}	35 days	0.7127	3.564	180.0
Ru^{103}	40 days	0.1329	0.665	38.4
Ru^{106}	1.0 year	0.7641	3.821	2011.0
Cs^{134}	2.1 years	0.2031	1.016	1128.8
Cs^{137}	30 years	0.1329	0.665	1165.1*
Total				4700 Megacuries

* The Cs^{137} inventory has been corrected for the slight decay it undergoes while in storage.

Since we will require it later, the Sr^{90} inventory is expected to be 91/133 x Cs^{137} inventory, or (0.68)xCs^{137} inventory.
In megacuries, this is 792 megacuries of Sr^{90}.

The Consequences of a One Percent Release of the Barnwell Inventory

We shall consider here how large an area and how many people might require evacuation if one percent of the inventory of the Barnwell plant were to be released to the atmosphere. Note, it is not our purpose to examine the probability of such an occurrence, but the consequences. If the consequences are very serious, then the fullest independent assessment of the probability is urgent and essential.

Prediction of which region of the United States will be affected and how much affected depends, of course, on the weather circumstances at the time of the release. We shall consider a couple of possibilities, including the local South Carolina situation and that for more distant regions. With differing weather conditions, the regions affected will, of course, be different, but the order of magnitude of consequences not very different.

Some Consequences at a Distance.

1. Assume 1% of the radioactivity inventory released to the atmosphere.
2. It is approximately 465 miles, straight line, from Barnwell, S.C. to Washington, D.C.
3. Assume a wind in the direction of Washington, D.C. of 19.3 miles per hour. Thus, in 24 hours, the center of the radioactive "cloud" will be over the Washington, D.C. area.

From the reports of Tamplin (Tamplin, A.R., "Prediction of the Maximum Dosage to Man From Fallout of Nuclear Devices I. Estimation of the Maximum Contamination of Agricultural Land, UCRL-50163 Part 1, January 3, 1967), the radius of such a cloud at 24 hours is approximately 103 miles. (Using the radius as 2σ - two times the horizontal standard deviation of dispersion of the material) $\sigma = 51.6$ miles at 24 hours.

Now let us consider that rainfall occurred at this time, which at a maximum, can wash all the radioactivity to earth in the region under the cloud. What is the deposition on the ground?

The Area of the Cloud = $\pi(103)^2 \cong$ 33,400 sq. miles.

One percent of Barnwell Inventory = (0.01)(4700) = 47 megacuries or 47,000,000 curies. (1 megacurie = 1-million curies).

Deposition, average, per sq. mile = $\frac{47,000,000}{33,400}$ = 1407 curies/sq.mile

Now, from the book, "Effects of Nuclear Weapons, p. 491-2, Samuel Glasstone, Editor, USAEC, 1962", it is known that a deposition of hard gamma emitters of 1 curie/sq.mile leads to a dose of 1.2×10^{-4} R/day from external radiation, just by being in such an environment. No eating of contaminated foods is required. Just being there guarantees the radiation.

But we have 1407 curies/sq.mile, so the dose will be

$$(1407)(1.2 \times 10^{-4}) = 0.169 \text{ R per day.}$$

The R unit is a measure of radiation exposure. Note that 0.169 R is equal to the so-called "allowable" exposure for one whole year for peaceful atomic energy purposes, and it is widely agreed that this latter exposure would have serious consequences. So, people in this vicinity would get their yearly "allowance" in one day. In a year they would get roughly 300 times as much, or about 50 R. While there will be some decay, it will not be reduced to 25 R per year for several years, and will continue at nearly that level for over a decade. It is obvious that such exposure is not thinkable, and that evacuation of the affected area must be considered. This means evacuation of Washington, D.C., Baltimore, Maryland, Annapolis, Maryland, Wilmington, Delaware - everywhere within a radius of 100 miles from Washington, D.C. In effect, this includes all of the District of Columbia, most of Maryland, most of Delaware, a good part of Virginia and West Virginia.

If the wind were blowing a little faster, before the radioactive cloud encountered a rainstorm, it could center on Trenton, New Jersey, in which case it would be necessary to evacuate Philadelphia, Pennsylvania, New York City, most of New Jersey, a fair part of eastern Pennsylvania, and a fair part of southern New York State.

It is seen that we are dealing with a situation that might require evacuating millions, or tens of millions, of people, or acceptance of the severe radiation injuries, in the form of cancer and leukemia, that would otherwise result.

If anyone doubts that the economic consequences of such evacuation could run into tens of billions of dollars, he is not being realistic. And this says nothing of the societal dislocation of evacuation of Washington, D.C., the capital of the United States.

Of course, the wind <u>might</u> blow in a different direction, and a rainstorm <u>might</u> intersect the radioactive cloud in a region with somewhat fewer people. In any event, whichever way the wind is blowing, some 33,000 square miles of the U.S. would become uninhabitable. The winds might be such that it would mean evacuation of most of the State of Florida instead.

<u>Some More Local Possible Consequences</u>.

Columbia, South Carolina is about 55 miles from Barnwell. Atlanta, Georgia is about 180 miles from Barnwell.

Let us consider the prospects at 8 hours after release of 1% of the Barnwell inventory, with winds to place the cloud over Columbia, South Carolina (requires 7 miles per hour wind) or over Atlanta, Georgia (requires 22 miles per hour wind). If the radioactive cloud then encountered a rainstorm, over one or the other of these areas, we can calculate the dosage.

The radius of the cloud at 8 hours is approximately 36 miles (again, using 2σ as the radius). The area of deposition is $\pi\ (36)^2 =$ 4076 square miles.

$$\text{Deposition} = \frac{47{,}000{,}000}{4076} = 11{,}530 \text{ curies/sq. mile.}$$

The dosage received by being in this vicinity is

$$(11{,}530)(1.2 \times 10^{-4}) = 1.38 \text{ R per day,}$$

or about 400 R per year. This is simply deadly, and in the one case Columbia, South Carolina and everything on a radius of 36 miles from Columbia would obviously have to be evacuated. In the other case, Atlanta, Georgia and everything 36 miles away from it must be evacuated.

In summary, under highly credible meteorological conditions, the consequences of a 1% release of the radioactivity inventory at Barnwell would be a disaster unimagined for any peacetime situation in the United States. The economic cost, to say nothing of making millions of people refugees from radioactivity, will undoubtedly be measured in the billions or tens of billions of dollars.

In Case There is No Rain:

Agricultural Consequences of a 1% Release of the Radioactivity Inventory at Barnwell at Full Operation

We might suppose that "luck" would be on our side, and that the radioactivity cloud won't run into a washout by rain, after a 1% release of the Barnwell radioactivity inventory. In that case we will, of course, still have what is known as "dry" fallout. While this may mean we wouldn't face evacuation of millions of people, the agricultural consequences, as we shall see below, can be almost equally devastating. Let us consider the "no-rain" situation in detail.

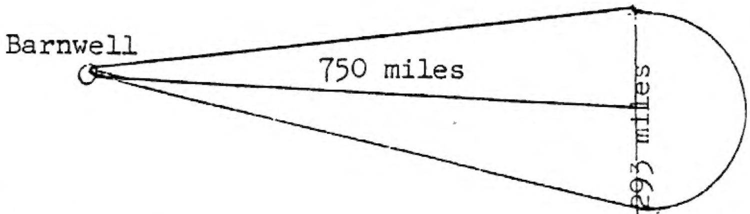
1. Let us assume the wind were blowing at about 15 miles per hour in the direction of Buffalo, New York.

2. The distance from Buffalo to Barnwell is about 750 miles, so the center of the radioactive cloud will reach the US border at Niagara Falls at some 48 hours.

From Tamplin's data* on maximum expected by fallout at 48 hours, we can expect the fraction of the total cloud radioactivity that will fall out is 8×10^{-14} per sq. meter.

Now, let us estimate the agricultural contamination. At 48 hours, dispersion of the cloud will make the cloud diameter approximately 293 miles ($\sigma = 1.18 \times 10^5$ meters, diameter in $4 \times \sigma$, so diameter = 4.72×10^5 meters, or 293 miles).

So, a sector of the country, centering upon Barnwell will be involved.



The overall area involved will be $\left(\frac{750 \times 293}{2}\right)$ + 1/2 the Cloud Area, or

$$110{,}000 + 1/2\,(67{,}800) = 110000 + 33{,}900 \cong 144{,}000 \text{ sq. miles.}$$

* See previous Tamplin reference

How badly will milk from this region of 144,000 square miles be contaminated? We can be conservative, and thereby underestimate the seriousness of the problem by considering all parts of the region to be contaminated only as badly as the most distant region - that is at 750 miles from Barnwell. We can be certain that in all regions closer to Barnwell the contamination will be more severe.

We recall that our inventory (Table I) contains

Cs^{137} 1165 megacuries, or 1165 x 10^{12} microcuries.

Cs^{134} 1129 megacuries, or 1129 x 10^{12} microcuries.

Sr^{90} 792 megacuries, or 792 x 10^{12} microcuries.

(1 Megacurie = 10^{12} microcuries)

The dry fallout depositions, for 1% inventory release, will be

For Cs^{137} $(11.65 \times 10^{12})(8 \times 10^{-14}) = 0.93$ microcuries/sq. meter

Cs^{134} $(11.29 \times 10^{12})(8 \times 10^{-14}) \doteq 0.90$ microcuries/sq. meter

Sr^{90} $(7.92 \times 10^{12})(8 \times 10^{-14}) = 0.64$ microcuries/sq. meter

And from Table 3, we can estimate the dosage to be received via milk for forage receiving such depositions. These are tabulated in Table 2.

Table 2

Dosage to Children via the Milk Pathway

Radionuclide	Deposition	Deposition required to give 1 Rad via Milk (Whole Body)	Dosage in Rads via Milk (Whole Body)
	Microcurie/ sq. meter	Microcurie/ Sq meter	
Cs^{137}	0.93	0.12	7.8
Cs^{134}	0.90	0.058	15.6
Sr^{90}	0.64	0.038	16.9
		Total Dosage in Rads (via Milk)	40.3 Rads

It is absolutely unthinkable that milk contaminated to this degree can be consumed. Children drinking such milk would have a four-fold increase in risk of cancer and leukemia. Fresh agricultural produce from this region of 144,000 square miles would be obviously unsalable. While, after a period of months, the milk level will be much reduced, the agricultural produce from the region would be unacceptable for many years, because of radioactivity acquired in the produce via the soil-root pathway (much, much less active than the early milk, but unacceptable).

It is important to have a good idea of what 144,000 square miles of agricultural land being rendered unusable really means. For the wind direction considered, this would mean render/ing unusable for agriculture the following:

	Approx.	1/10	of South Carolina
plus	approx.	1/10	of North Carolina
plus	approx.	1/5	of Virginia
plus	most		of West Virginia
plus	approx.	1/6	of Ohio
plus	more than	1/2	of Pennsylvania
plus	approx.	1/4	of New York State

plus a significant part of Ontario province in Canada.

This represents a <u>minimum</u> tabulation, for fallout rendering agricultural land unusable will still be occurring beyond 48 hours, and hence encompassing more of Ontario province, Quebec and much more of New York State.

The economic costs alone will undoubtedly be in the multi-billion dollar category, not to mention indignation, rage, fear, and dislocation.

And of course, if the wind were blowing in some different direction, the <u>areas</u> involved will be the same, but the victimized states would be different. It would only be lessened if the wind happened to be blowing to the Southeast, since much of the fallout would then be over the ocean.

Thus, the overall magnitude of the disaster will be comparable with that previously described for rainout of the radioactivity. In one case (with rain) we contemplate evacuation of millions of people; in the other case (without rain), the agricultural loss is staggering beyond usual comprehension.

The Consequences of an 0.01% Release of the Barnwell Inventory (One-ten thousandth of the Total Inventory)

We have seen above that 1% release can lead to massive evacuation of major population centers. And we shall now see the very serious economic consequences of even one-hundredth of this quantity released. For this we shall direct our attention to the effect of deposited radioactivity upon forage, thence to milk to be consumed by children.

We shall consider three radionuclides, Cs^{137}, Cs^{134}, and Sr^{90}.

From Table 1 we have the inventory at 5 years as 1165 Megacuries of Cs^{137}, 1129 Megacuries of Cs^{134}, and separately, that there would be 792 Megacuries of Sr^{90}.

Ng and co-workers* have calculated the minimum deposition of these radionuclides required to deliver 1 Rad to children drinking 1 liter of milk per day. This is the so-called "grass-cow-milk-child" pathway. The values are listed below in Table 3. (1 Rad is approximately equivalent to 1R).

Table 3

Minimum Deposition on Forage to Give 1 Rad to Children Via the Forage to Milk Pathway (Whole Body)

Radionuclide	Half Life	Minimum Deposition required to give 1 Rad**	
		microcuries/sq. meter	curies/sq. mile
Cs^{137}	30 years	1.2×10^{-1}	0.31
Cs^{134}	2.1 years	5.8×10^{-2}	0.15
Sr^{90}	28 years	3.8×10^{-2}	0.098

Let us consider the case described above, rainout at 24 hours, such that 33,400 sq. miles of land receives the deposition. Since we are here concerned with agricultural land, it is of little moment what the wind direction or speed is.

*UCRL 50163 Part IV, May 14, 1968.

**Dr. Ng (personal communication) suggests the Cs^{137} and Cs^{134} values may be raised, from more recent data, which would reduce their contribution to dosage. However, the changes would not materially alter conclusions about unacceptability of milk contaminated by Cs^{137}, Cs^{134}, and Sr^{90}.

And we are assuming $\frac{1}{10,000}$ of the inventory at Barnwell to be involved in the deposition.

Therefore

$\frac{1}{10000}$ X 1165 = 0.1165 megacuries Cs^{137} (116,500 curies)

$\frac{1}{10000}$ X 1129 = 0.1129 megacuries Cs^{134} (112900 curies)

$\frac{1}{10000}$ X 792 = 0.0792 megacuries Sr^{90} (79,200 curies)

Depositions are

For Cs^{137}, $\frac{116500}{33400}$ = 3.5 curies/sq. mile

For Cs^{134}, $\frac{112900}{33400}$ = 3.4 curies/sq. mile

For Sr^{90}, $\frac{79200}{33400}$ = 2.4 curies/sq. mile

Translating these into rads delivered via the milk pathway

For Cs^{137}	3.5/0.31	= 11.2 rads
For Cs^{134}	3.4/0.15	= 22.7 rads
For Sr^{90}	2.4/0.098	= 24.5 rads
	Total	58.4 rads

Children drinking such milk would receive 58.4 rads, which is more than 100 times the yearly "allowable" dose. Such a dose would cause a many-fold increase in cancers and leukemias in such children. It is obvious that milk from these 33,400 square miles is unthinkable for drinking purposes. The loss to agriculture from this and crop contamination would be phenomenal. In time, the Cs^{134}, Cs^{137}, and Sr^{90} would find their way into the soil, having been weathered off the forage. But the agricultural problem is not over, for we must now consider crops grown in the area, the so-called "soil-root pathway".

From Ng et al, we have the data for the deposition required to give one Rad by the soil-root pathway, presented in Table IV.

Table 4

Minimum Deposition Required to Give 1 Rad to Children via the Soil-Root Pathway

Radionuclide	Half Life	Deposition Required to Give 1 rad microcuries/sq meter	curies/sq. mile
Cs^{137}	30 years	4.2×10^2	1090
Cs^{134}	2.1 years	1.3×10^3	3370
Sr^{90}	28 years	4.8×10	124

Contribution from Cs^{137} = 3.5/1090 = 0.003 rads

Cs^{134} = 3.4/3370 = 0.001 rads

Sr^{90} 2.4/124 = 0.019 rads

Total = 0.023 rads

While these doses are not "disastrously" high, I would doubt that such agricultural products would be salable, and the effect would last for many years. The combination of severe early contamination of milk and crops from such a region, followed by long term significant, unacceptable contamination of crops from an area like 33,000 square miles (that happens to be an area just a little larger than South Carolina) would represent economic losses in the billion dollar class. And all this if only one ten-thousandth of the Barnwell inventory of radioactivity were released to the atmosphere.

Some Side Effects of Either Type of Accident

There is little doubt about one primary effect of either type of accident, which would be an immediate demand by the public for a shutdown, not only of Barnwell but also of the entire nuclear power industry. And I must say I believe this reaction would be totally appropriate, since the warnings concerning such possibilities have been quite broadly presented. There would be no reasonable excuse by the nuclear industry. And the widespread public antipathy to Allied Chemical and Gulf Oil Corporation might lead to boycotts that could shake these industries economically beyond repair. The South Carolina Legislature would have a great deal of explaining to do to the citizens of South Carolina and other states.

The Plutonium Product

There are two products of the Barnwell Facility, uranium and plutonium. There is little, if any reason to be concerned about the uranium product. There are several reasons to consider that the plutonium product may be a total nightmare. The AGNS report states carefully that plutonium must be absolutely contained in the course of shipment away from the plant. And it states further that there exists considerable difference of opinion concerning how this may be accomplished. But one does not acquire a real feeling for the fantastic implications of the quantities of plutonium that will be shipped.

There are two problems presented by the plutonium product:

(1) The Safeguards Problem

(2) The Extreme Toxicity of Plutonium

The Safeguards Problem

Plutonium has other uses besides its being a fuel for electric power production. Specifically it is the basic ingredient for the simple fabrication of atom bombs. Throughout the world, authorities on nuclear energy regard the danger of diversion of plutonium by black market techniques either to governments or to private organizations as a major, unsolved problem.

Let us consider some of the quantities involved in Barnwell shipments and compare them with the 14 pounds (7 kilograms) widely stated to be about the amount required for a 20 Kiloton atom bomb like that which demolished Nagasaki.

From Table 3.6-1 in the Barnwell report, the datum is given that each ton of uranium processed will yield 338 Curies of Plutonium-239, the desired product. One Curie of Plutonium represents approximately 16 grams of Pu^{239}. In one year at Barnwell, there will be 1500 tons of uranium processed, so the annual plutonium product requiring shipment will be (338)(16)(1500) = 8,110,000 grams of plutonium, or 8110 kilograms. That's enough to make about 1100 Nagasaki-type atom bombs, a very interesting quantity indeed for the future black market in plutonium.

On page 30, Appendix VII of the Barnwell Environmental Report, it is stated that the plutonium will be shipped in solution as plutonium nitrate in containers, each holding 25 kilograms of plutonium. It is stated there that 2 to 3 such containers will be carried per truck shipment. So we can say that on the average, there will be approximately 63 kilograms of plutonium per shipment. For a total of 8110 kilograms of plutonium, this means $\frac{8110}{63}$, or about 125 separate shipments per year out of Barnwell.

Each shipment represents enough plutonium for about 9 atom bombs (Nagasaki size). Can such shipments be hijacked? Before answering this question, it is worthwhile asking another question. If, two years ago, one had been asked about the liklihood that three huge airliners would be successfully hijacked to the Middle East <u>within</u> <u>one</u> <u>week</u> by terrorists, I am sure the probability estimate would have been vanishingly small. Until it happened. Anyone who <u>underestimates</u> the ingenuity of determined terrorists and underworld operators does so at grave peril. The probability that a plutonium shipment will be hijacked successfully will be estimated as very low until the first shipment is hijacked.

<u>The Toxicity of Plutonium</u>

There is a great deal in the Barnwell Report about the irradiation of bone by plutonium. I am more concerned about the production of lung cancer by plutonium. My colleague, Donald Geesaman,* has published estimates that the inhalation of 10,000 particles of plutonium dioxide may produce one fatal human lung cancer. It doesn't require that <u>one</u> person inhale <u>all</u> 10,000 particles - this is a statistical problem, and it means that for every 10,000 particles inhaled into human lungs, there will be one lung cancer. Ten people inhaling 1000 particles each will produce the same effect as one person inhaling 10,000 particles.

* GT-121-70. Plutonium and Public Health. Presented at Univ of Colorado, Boulder, Colorado, April 19, 1970.

Let us go through the arithmetic relating to these plutonium shipments. For example, let us suppose that some terrorists were desirous of spreading plutonium oxide around near a major metropolitan center. Let us suppose that that one container with 25 kilograms of plutonium were exploded open by bombing or by some combination of bombing and fire. With high temperatures, much of the plutonium nitrate would be probably converted to plutonium oxide. We can explore the worst case, namely <u>all</u> 25 kilograms converted to particles averaging one micron in diameter.

1 micron diameter means each particle has a volume of 5×10^{-13} cc. The density of plutonium dioxide is 11.46 gms/cc. So each such particle has $(11.46)(5\times10^{-13})$ or 5.7×10^{-12} grams of plutonium oxide.*

So, for 25 kilograms, we get $\frac{25,000}{5.7 \times 10^{-12}}$ or 4.4×10^{15} particles. If all these particles ultimately found their way into human lungs, that represents

$$\frac{4.4\times10^{15}}{10^{4}} = 4.4 \times 10^{11}$$ lung cancers, Enough plutonium for 440 billion human lung cancers. Now, there are only 3 billion people on earth, so we <u>aren't</u> going to get 440 billion lung cancers in any hurry. So, let us suppose there are a number of inefficiencies in this whole process, and as a result, only one particle out of ten million potential plutonium oxide particles finds its way into human inhalation pathways. That still means 44000 lung cancers could be produced as a result of this terrorist act. That's a lot of diplomatic leverage for terrorists. Please note that all the inhalation needn't occur right away. The plutonium oxide particles can settle to the ground, be resuspended and carried by winds over and over, even to very great distances from the point of original dispersal. With a half-life of 24,000 years, such plutonium will be around to produce cases of lung cancer for periods of more than fifty times as long as world history from the birth of Christ to the present time. Every 10,000 particles inhaled can represent one fatal human cancer, wherever and for all practical

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*Barnwell Plutonium is even worse than Pu^{239}, because of contamination with Pu^{238} and Pu^{240}.

purposes, whenever the plutonium is inhaled.

We spread plutonium around Palomares, Spain when one of our bombers crashed there. A massive clean-up campaign was carried through and shiploads of contaminated soil were collected to be returned to the USA. But people in Palomares are not too convinced all is well. Palomares is reported to be a ghost town area now. How many people will enjoy living near a site of a massive plutonium dispersal? If we ship enough plutonium on our highways, there are going to be some terrorist explosions and dispersal, and I would suspect there are going to be ghost towns in addition to old mining towns in Nevada and California.

The Barnwell Facility points up some good reasons for the widespread concern over diversion of plutonium into the hands of terrorists and the underworld. One small atom bomb, properly placed on the Barnwell Facility could, I would suspect, release a good deal more than one percent of the radioactivity inventory there. And we have already discussed the catastrophic potential consequences of a one percent release.

Recommendations

We can all hope that neither the 1% release or the 0.01% release accidents ever occur at Barnwell. But hope alone is not enough. As stated at the outset, I am in no position to estimate the probability of either accident, from sabotage, from cooling equipment failure, from earthquake, or from hostile action. Certainly the Barnwell Environmental Report provides nothing in the way of reassurance that such accidents cannot occur. Everything hinges on the probability that such releases may occur. I doubt that anyone can seriously challenge the possible consequences if the releases of this magnitude occur. Depending upon the weather, the precise magnitude of the disaster, and its form, can vary, but the broad outlines are not overstated.

And we can all hope that plutonium diversion or dispersal into the environment will not occur.

I am completely convinced that Allied-Gulf Nuclear Services feels it is doing its very best to make such accidents remote. But that is not sufficient assurance. That the AEC or its advisory committees have reviewed the project is also not good enough.

No one of totally independent stature has been assigned the specific job, of figuring out how such releases could occur, what all the vulnerabilities are, and what the chances are of such occurrence. And it is the absence of such critical engineering adversary review that is precisely what has been missing from every aspect of the entire nuclear power industry.

The Board of Directors of the Allied Chemical Corporation should be demanding such an independent review.

The Board of Directors of Gulf Oil Corporation should be demanding this review.

The Legislature of the State of South Carolina should be demanding this review.

The health and fate of ten million or more Americans may depend upon the answers.

Perhaps this discussion may help clarify why an increasing body of opinion expresses concern over the development of the nuclear power industry. The morality of going ahead with the nuclear power industry deserves serious questioning. Especially is this true when the prospects are so bright for alternatives, such as generation of all the electricity we could ever require from solar energy.

South Carolina, and Barnwell County in particular, needs industry and needs jobs. How much brighter our discussions today would be if Allied Chemical and Gulf Oil Corporations were proposing a major solar electricity research and development program at Barnwell. Such a facility providing 3000 jobs, not 300, would make excellent sense for the Corporations, for South Carolina, and for the world. Sooner or later, this is inevitable. Why not sooner, and in South Carolina? Why not A.G.S.F. - Allied-Gulf Solar Facility? Toward a bright future, rather than a radioactive one.

SUMMARY RECOMMENDATIONS

TO

THE NUCLEAR STUDY COMMITTEE

OF

THE LEGISLATURE OF THE STATE OF SOUTH CAROLINA

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A Supplement

to

Detailed Testimony

January 7, 1972

Summary Recommendations

In the accompanying testimony I have estimated for you the potential consequences of certain releases of part of the radioactivity inventory at the Barnwell Fuel Reprocessing Facility, at full operation. Those consequences can be summarized in three very brief statements:

(a) The possible evacuation of millions of humans because of the rendering of such cities as Washington, D.C., Philadelphia, Pennsylvania, or New York City uninhabitable.

(b) Possible damages in the neighborhood of 10-Billion Dollars from a single such release.

(c) Diversion of plutonium for black market atom bombs or plutonium poisoning.

These estimates are, of course, a bit disturbing. I have carefully avoided estimating the <u>chance</u> of such an occurrence, because such an estimate is outside my area of expertise.

But the South Carolina Legislature and the Boards of Directors of both Allied Chemical and Gulf Oil cannot avoid, and must not avoid, acquisition of <u>reliable</u>, independent assessment of such probabilities. It is, of course, human nature to shy away from having to think about the unthinkable. And, hence, there is every reason to expect that, from several quarters, the kinds of accidents discussed in the full testimony will be dismissed out of hand.

I have a constructive suggestion to propose to you as a simple and rapid method for elimination of obfuscation and cobweb-adorned thinking on such matters.

I. Let us assume that the Allied-Gulf Nuclear Services Corporation deems the prospect of such accidents to be ridiculously small.

II. If that should be the case, AGNS and the parent corporations would assuredly be happy to back that opinion with a full assurance of financial liability. At present, since liability is limited to 560-million dollars, it is clear that 95% of damages from a 10-billion dollar accident would necessarily be uncompensable.

Therefore, I propose that the Legislature of South Carolina consider proposing to Allied Chemical and Gulf Oil the provision of a legal contract as follows:

> "In the event of an accident at the Barnwell Facility, the full financial resources of Allied Chemical and Gulf Oil Corporations will be available for compensation claims, over and above those covered by the Price-Anderson Act insurance."

Such a simple contractual document will provide an enormously effective fog-cutter on these matters. If, by any chance, the question is raised that such a contract conflicts in any way with Federal pre-emption, then I offer a second suggestion.

> That suggestion is that the Legislature of South Carolina will defer consideration of permitting fuel reprocessing in South Carolina until the Price-Anderson Act is repealed, and financial responsibility is thereby restored to the nuclear power industry.

The Allied Chemical Corporation, the Gulf Oil Corporation, and the Electric Utility Industry all should, of course, be in the forefront of a National demand for repeal of the Price-Anderson Act. These great industries have so often expressed their full confidence in the safety of the nuclear power industry. The time has arrived for them, therefore, to take the lead in removing those ominous clouds of doubt occasioned by the absence of adequate financial responsibility for this industry.