May 9, 1985

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC
SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
VIRGINIA ELECTRIC AND POWER COMPANY	)	Docket Nos. 50-338/339-OLA-1
	)	
(North Anna Power Station, Units 1 and 2)	)	

TESTIMONY
OF
ROBERT M. JEFFERSON

I.

Introduction

My name is Robert M. Jefferson. I am a private consultant in the area of the transportation of radioactive materials. I began my consulting activities on April 1, 1985, after being employed by Sandia National Laboratories (Sandia) in Albuquerque, New Mexico for the previous 28 years. During the period from 1978 until my retirement in 1985, I was Manager of the Transportation Technology Center operated by Sandia for the Department of Energy (DOE). For three years prior to that, I managed a variety of transportation and reactor safety programs for the Laboratory.

My direct involvement in transportation of radioactive materials goes back to 1970, when I was responsible for shipping research reactor spent fuel from Sandia to Idaho. Subsequently I was Supervisor of Waste Management and Transportation activities for Sandia until 1975. From 1975 to 1978 I was Manager of Reactor Safety Studies and Transportation Research. As Manager

of the Transportation Technology Center, I have been responsible for the majority of the transportation safety research that has been conducted worldwide for the past 8 years. This includes research designed to assess the ability of spent fuel casks to withstand transportation accidents and hostile attacks. In addition, I have been cognizant of those activities being carried on by other countries and other organizations within the United States, as they related to the safety research being conducted by Sandia. During my years with Sandia I was an active participant in the deliberations of the technical community on the safety of transporting spent fuel and other radioactive materials, both on a domestic basis and on an international basis.

My personal involvement in the area of sabotage and diversion of special nuclear materials, and the possible consequences arising from such acts, began in 1969. At that time I was asked by the Atomic Energy Commission (AEC) to participate in a study, later known as the Rosenbaum Study, to evaluate the susceptibility of uranium and plutonium to diversion into clandestine production of weapons. As the result of that study, I developed an interest in this field that I have maintained since that time. That study was conducted by a team of five people. My area of expertise was physical access, adversary encounters, use of explosives and other weapons, escape, and detection avoidance. I was selected for participation in the study by virtue of my continuing responsibility for the protection of the special nuclear materials utilized by Sandia's

fast burst reactors (an operation which I supervised for approximately 10 years).

Sandia's involvement in spent fuel cask testing began shortly after the 1970 explosive attack on the Mathematics Research Center at the University of Wisconsin. This explosion of 4,000 pounds of ammonium nitrate/fuel oil (ANFO) created concern at AEC over the vulnerability of spent fuel shipping casks to explosive attack. Sandia was asked to undertake a series of experiments to evaluate the effects of various explosive attack methodologies on full scale spent fuel shipping casks. The objectives of that study were to determine what sabotage methodologies were successful, the level of expertise needed to make them successful and the resources needed by a saboteur to mount a successful attack. Because the results of that study provide information that would be of great use to a potential saboteur, the study itself was classified confidential and is unavailable for this proceeding. However, since the work was conducted by my organization within Sandia, I am familiar with the purposes, experiments and results.

Since those early tests were intended to serve only as scoping studies and since they showed that it would be difficult to mount a successful attack, there was no follow-up. However, as an outgrowth of the 1978 "Urban Study," - performed by Sandia for NRC to assess the risk of transporting radioactive materials through urban areas - interest in sabotage was rekindled. That study, based on estimates of release fractions approaching 1% of cask contents, predicted hundreds of early deaths and thousands

of latent cancers should a successful attack be carried out in downtown New York City at rush hour. A series of simple tests was performed in 1979 which indicated that the release fraction would be closer to 0.07% of cask contents. This data point was included in a 1980 "Urban Study," and the consequences dropped to tens of early deaths and hundreds of latent cancers, again in a densely populated, highly urbanized locality. In 1978 the NRC instituted safeguards requirements to protect spent fuel shipments from sabotage with the condition that if research should show that the concern was unjustified, NRC would relax the requirements at a later time. In 1980 two programs were initiated to study explosive attack on shipping casks. One study, funded by NRC, was conducted by Battelle Columbus Laboratories. The other, funded by DOE, was conducted by my organization at Sandia. I shall discuss the results below.

As an outgrowth of the early work, my experience with the study of sabotage and diversion, and this recent experimental work, I have kept in close contact with the rather substantial safeguards activity carried on at Sandia since the mid-1970's. I have participated in that activity as a peer reviewer for reports, and I have been involved in the process of deciding whether special programmatic activities belonged in safety research or in safeguards. My resume is attached to this testimony as Appendix 1.

The purpose of my testimony is to address four primary areas of concern. The first involves the threat that a malevolent act will be attempted against a shipping cask during the process of

transporting spent fuel from Surry to North Anna. The second is the probability that such an attempt, if made, would result in the saboteur's taking possession of the spent fuel cask or reaching it with some attack method. I shall discuss these two areas, which are closely related, in Section III of this testimony. The third area, discussed in Section IV, involves the potential consequences of saboteurs' gaining possession of the cask or reaching it with an attack method. The fourth concerns the emergency responses that could be expected from public and private entities in the highly unlikely event that a successful sabotage attack was to be accomplished against these shipments. This is the subject of Section V.

II.

Description of the Cask

The TN 8L cask to be used for the transport of spent fuel from Surry to North Anna is a NRC-certified shipping cask. As such, it must adhere to certain design criteria imposed on all shipping casks for spent fuel and other high level radiation sources. Unlike the container for any other hazardous material currently being shipped within this country, a shipping cask for spent fuel must be designed to accommodate the severe environments that might be encountered during a serious accident. While the regulations do not require that the casks survive these environments without any change of physical appearance, they do require that the ability of the cask to contain its radioactive contents remain unaffected by the accident.

Further, NRC's regulations require that the radiation shielding, which is an important safety feature of the cask, remain essentially intact, although external radiation levels are allowed to be greater after an accident than before. The regulations contained in 10 C.F.R. Part 71 specify that the cask must be designed to survive a set of engineering criteria specified in the regulations as "hypothetical accident conditions." These design criteria encompass impact, puncture, fire and immersion and, by inference, such other phenomena as crushing and tumbling. Since these design criteria are in effect worldwide, they have been evaluated by a number of research organizations around the world for their adequacy. Studies conducted within the United States indicate that these criteria encompass substantially more than 99% of all accidents encountered in the real world. It is to this kind of standard that the TN 8L cask has been designed.

The cask itself is roughly triangular in cross section with heavily rounded corners. It has a vertical dimension of 5 feet, 4 inches, top to bottom, including the copper fins. The cask is of typical steel-lead-steel construction, similar to those tested in the explosive scoping tests conducted in the early 70's and to the later units subjected to attack by conical shaped charges in the Sandia work by Sandoval, et al. which is described below. The cask is roughly 18 feet, 1 inch long including shock absorbing covers and 15 feet, 8 inches long without the covers. The shock absorbing covers are additional cushioning material (balsa wood and steel) placed on either end of the cask during transit to mitigate some of the forces that might be encountered

during severe accidents. These covers are attached by four bolts and are removed prior to handling the system at the reactor pool. The fuel elements are contained in three individual stainless steel ¼" wall square chambers. Two are arranged side by side on the bottom with a third centered above them. Surrounding these stainless steel chambers are boron-loaded copper plates to reduce the thermal neutron flux emitted from the fuel assemblies. The bottom ends of these chambers are closed with stainless steel plates, while the tops are open to the outside of the cask once the lid has been removed.

Surroundir j the three square stainless steel chambers is lead that varies in thickness from a minimum of 5.3 inches to a maximum approaching 9.8 inches. Proceeding out from that point is a layer of wet cement (0.4 inch thick) and a carbon steel outer shell (0.8 inch thick). Attached to this carbon steel shell are 15,800 copper cooling fins or fingers that project outward from the surface of the carbon steel outer shell. In addition, there is a 5.9 inch thick resin coating on the outside of the carbon steel shell which encapsulates the bases of the fins. The entire cask, when empty, weighs 73,600 pounds.

The open end of the cask is closed by a structural assembly known as the lid which serves to complete the shielding at that point and provides the containment seals to prevent escape of gases from the chambers. This lid is approximately 10.6 inches thick, is constructed of stainless steel, carbon steel, lead and resin and weighs approximately 1,875 pounds.

Beneath the balsa wood and steel shock absorbing cover, the lid is held in place by 16 1¼" bolts. There are four lifting eyes on the lid outer surface. Further, there are two centering pins mounted in the body of the cask that act to center the lid onto the cask and to maintain its proper rotational alignment so that it is always placed on the cask in the same orientation.

While this cask has never been subjected to actual test conditions, calculations contained in the Safety Analysis Report for Packaging (SARP) indicate that the cask can survive, without loss of containment and with minor loss of shielding, the regulatory requirements contained in the 10 C.F.R. Part 71 hypothetical accident conditions. While it might suffer some cosmetic damage in an accident (such as the bending of fins) the cask is capable of surviving the prescribed accident conditions with no structural damage.

In addition to holding a Certificate of Compliance from the NRC, this cask holds a certificate from the French Atomic Energy Authority and is being widely used in Europe. The NRC Certificate of Compliance for the TN 8L cask allows Transnuclear and Virginia Electric and Power Company (Virginia Power) to load the cask with no more than 4,840 pounds of spent fuel assemblies, irradiated to a maximum level of 38,500 megawatt days per ton and cooled for a minimum of 150 days, assuming an initial average uranium 235 enrichment of 3.2 weight percent. These requirements define the maximum decay heat and radiation levels of the spent fuel. The decay heat of the fuel assemblies must not exceed 7.9 kilowatts per assembly. The spent fuel to be shipped from Surry to North Anna falls well within these limitations.

The cask is not authorized to ship failed fuel, and the certificate of compliance requires that, on completion of loading, the external radiation level must be less than 17 mrem per hour one meter from the surface of the package. This is considerably below the regulatory limit of 200 mrem per hour at a distance of one meter.

III.

Threat of Sabotage

Malevolent attacks on this kind of transportation system have been virtually nonexistent. In the more than 5,000 shipments of spent fuel that have occurred in the United States since 1964, there has been so far as I know only one case of an attack of any sort. This occurred in the early 1970's on a shipment between Sandia and the Idaho National Engineering Laboratory. The shipment involved a cask carrying four research reactor fuel elements of the Materials Test Reactor type. The cask was the sole cargo in a forty-foot aluminum van-type trailer carried by a trucking company specializing in this kind of material. At the time, the company was having labor difficulties, and in southern Wyoming the trailer was fired upon by unknown assailants using a shotgun. Pellets penetrated the aluminum siding of the trailer but, as one would expect, did absolutely no damage to the cask. Because this event happened on a shipment that I was making, and because of my continuing interest in this subject, I have in the intervening years tried to find other instances of attacks on

shipping casks both in this country and in other western countries. To date, I have discovered no other examples.

On the basis of this experience, then, one can comfortably say that the probability of attack, although it cannot be quantitatively stated either from experience or by modern estimation means, is quite low.

In addition, an analysis of the impediments to sabotage attack, their effects on would-be attackers, and the types of objectives that potential saboteurs might wish to achieve, supports the conclusions that (a) the likelihood that such an attack would occur is small and (b) the likelihood that such an attack would place the saboteurs in position to damage the cask is also small.

A. Impediments to Sabotage.

Section 73.37 of 10 C.F.R. sets out NRC requirements for the physical protection of spent fuel shipments. Virginia Power must comply with this provision. The regulations are designed to minimize the probability of sabotage and to facilitate the location and recovery of spent fuel shipments that may come under the control of unauthorized persons. The utility-shipper must develop a physical protection system that provides for early detection and assessment of attempts to gain unauthorized access to spent fuel shipments, notification to appropriate response forces of any sabotage attempts and plans for resisting sabotage attempts until response forces arrive.

The shipper's physical protection system must provide for (a) notification of NRC in advance of each shipment, (b)

procedures for coping with circumstances that threaten deliberate damage to a shipment, (c) instructions to shipment escorts for analyzing and dealing with threatening situations, (d) establishment of a communications center staffed continuously during shipments to monitor the progress of the shipments and notify appropriate agencies if an emergency should arise, (e) prior arrangements with local law enforcement agencies for response to emergencies, (f) training of shipment escorts and (g) calls from escorts to the communications center at least every two hours.

With respect to shipments by road, the regulation requires that the spent fuel transport vehicle be accompanied by an escort and specifies that in heavily populated areas, the vehicle be accompanied by an armed local law enforcement agent or by escort vehicles front and rear, each with an armed escort. It also requires that escorts have the capability of communicating with the shipper's communications center, local law enforcement agencies, the transport vehicle and one another through the use of various types of communications equipment. The regulations require that the transportation vehicle be equipped with an NRC-approved method for immobilizing the cab or trailer in the event of a sabotage attempt.

All of these requirements are designed to increase the complexity of an attack for a would-be saboteur, the number of hurdles to be overcome and the time the attack would take.

In addition to the impediments posed by 10 C.F.R. § 73.37, the saboteurs would confront significant obstacles simply by

virtue of the bulk, weight and design of the cask, the perilous nature of its contents and its ability to withstand explosive and other attacks, which I will discuss in the next section of this testimony.

What effect would the impediments I have described have on persons considering sabotage of a spent fuel shipment? It is generally conceded that the probability of an attack is inversely proportional to the difficulties involved in the attack. Thus, the more resources or skill a successful attack would require, the lower the probability that the attack would be attempted. Plainly, a saboteur considering an attack on a spent fuel shipment would face a formidable array of difficulties or, put the other way, would require a formidable array of resources and skills.

In the first place, the potential saboteur would run a serious risk of death or injury, given that armed escorts or law enforcement agencies will accompany these shipments and that others would be called to the scene promptly in the event of a threat. This risk, I should add, is in addition to the threats of harm he will face if he should gain possession of the cask and attempt one of the damage scenarios I describe in the following section. Although not true in the Middle East, studies of terrorist activities to date in the United States have indicated that the probability of an attack is drastically reduced if the attack requires the sacrifice of the attacking team's lives.

The physical dangers inherent in such an attack are accentuated by virtue of the fact that the saboteur would face significant

time pressures. Transport and escort vehicles will be equipped with communications equipment - at least citizens' band radios and radiotelephones - and will be in contact as a matter of course with the shipper's communications center. The communications center will check periodically with the convoy. The vehicles, and in turn the communications center, will also be able to communicate with local law enforcement agencies, who will be aware of each planned shipment before it begins. The transport and escort vehicles can summon help quickly. This consideration, along with the likelihood that the transport vehicle immobilization device would be used, would make it extremely difficult to carry out a successful hijacking attack. Thus, it would be particularly difficult to mount an attack that contemplates securing possession of a cask in a remote area and transporting it to another destination.

In short, from the terrorist's standpoint, the longer the period of time involved from the initiation of his action until its completion, the higher the probability that society will take countermeasures and that his attempt will fail. Further, the higher the apparent probability that his effort will fail, the lower the probability that the saboteur will attempt it. Thus, when one studies the probability of terrorist attack on the shipping cask it becomes important to examine the scenarios involved and the risk to the saboteur (including the length of time each imagined scenario would involve).

Moreover, the very impediments that will discourage a sabotage attempt will tend to insure that if it is nevertheless

carried out, it will fail. Studies conducted of the battlefield methodologies employed in Vietnam indicate that in small group encounters, such as the kind that would be involved in a terrorist attack, the aggressor usually breaks off contact at the first indication of the loss of his ability to control the situation. Thus, I would anticipate that unless the terrorist was very, very dedicated (even to the point of death) he would likely terminate the attempt when the situation had approached the point where he might risk capture or death (e.g., due to response by local law enforcement agencies). A saboteur's ability to control all of the variables surrounding a spent fuel shipment would be severely limited.

With the impediments I have discussed in mind, it is important to consider what objective an attacker might have in mind if he were to consider attacking one of the Surry-to-North Anna shipments.

B. Sabotage Objectives.

One obvious objective might be to attempt to divert special nuclear material for weapons purposes. If that were a saboteur's intent, however, he would have far more promising targets. Materials for weapons use could be extracted from spent reactor fuel only by reprocessing, and it is difficult to imagine how a saboteur, even if he could gain possession of a cask and its contents in the first place, could manage to have it reprocessed.

Another objective, of course, might be to make a "political statement." Historically, the underground movement in this country has staged its attacks in order to embarrass the

political establishment or commercial activity involved. Their attacks, however, have been carefully planned and mounted at times and locations so as to minimize the possibility of public injury. The "political statement" is intended to draw attention to "the cause" and to rally public support for the terrorist's objectives. Attacks which harm innocent bystanders do not develop sympathy or public support for the terrorist's cause but instead arouse outrage and demands for his removal as a threat. As long as this continues to be the case in this country, and I see no reason for it to change, then an attack for the purpose of making a statement would take the form of harassment rather than an attempt to breach a cask with its potential dangers to the public. Given the danger to saboteurs that I have described and the likelihood of failure, a spent fuel shipment simply would not be an inviting target.

A third purpose of attacking a shipment of this nature would be to cause direct harm to the public. If the attacker intends harm to the public, he could try to accomplish it by one of two broadly defined approaches. Either he could attack the cask directly as it travels along its intended route (for example, by a projectile fired from a weapon) or he could attempt to divert the shipment (i.e., hijack it) for use at a time and location of his choosing. The direct attack has the advantage of minimizing his time involvement and therefore minimizing the probability that he might be detected and prevented from completing his attack, but it also poses the possibility of producing inconsequential results. For example, in order to stage a successful attack he

would probably have to interdict and strike the cask along a remote part of the shipping route in order to minimize the chance of early detection. If he does, however, the consequences of breaching the cask, even if he can accomplish it, would be far less than if the attack were carried out in a heavily populated area.

In contrast, a diversion would require the terrorist to hide his hijacked possession, or to transport it to a point where he might cause more damage, and would therefore increase the time span required and the likelihood of his detection prior to the time that he could produce significant public damage. As I indicated above, this time trade-off is important, since the more time involved, the greater the probability of the terrorist's detection and subsequent capture or destruction.

As I shall discuss below, the cask is a rugged system requiring more than simple explosive techniques to create a release. The requirements of 10 C.F.R. § 73.37 for communications and escorts reduce the attractiveness of this target a great deal. Furthermore, the fact that the tractor will be equipped with a device to immobilize it should the driver decide that he is under attack makes it necessary that an attack be a highly coordinated event. If the element of surprise to the driver and escort are not sufficient to prevent their notification of appropriate authorities, or if surprise is not sufficient to prevent the driver from disabling the tractor, the potential saboteur is faced with the task of uncoupling the crippled tractor from a very heavy

trailer and recoupling another tractor to pull the load away. All of these activities would take place in full public view and would take long periods of time, again reducing the potential saboteur's likelihood of success. The requirement for a highly coordinated attack reduces the likelihood of success as attested to by certain operations carried out by this country in support of rescue attempts overseas.

Furthermore, should the attacker be successful in hijacking the shipment he must find a place to hide it while he awaits the optimum conditions for the second stage of his activity. Since the cask emits radiation that is detectable at very, very low levels, it is well within the capability of existing equipment to search for and find the diverted shipping cask, thus increasing the time pressure felt by the attacker. The searching can be carried out using helicopters or fixed-wing aircraft carrying low-level radiation detection equipment. Such equipment is available to the Commonwealth of Virginia on short notice from Andrews Air Force Base. Again, diversion is not an attractive alternative.

In summary, then, it is doubtful whether spent fuel is an attractive target for a terrorist at all. It is a poor target for one who wishes to divert weapons grade material. If the saboteur's purpose is embarrassment of the Company or the political system, there are certainly more attractive targets available that are less protected, require less skill, involve less probability of detection and capture, and provide sufficiently spectacular results to produce acceptable press

coverage. In any event, adequate political effect could be achieved in an attack on the cask without attempting to breach the cask and thus risk harm to the public. Finally, if it is harm to the public that the saboteur has in mind, there are many other less risky targets that can, in fact, provide far greater risk of harm to the public than the sabotage of a spent fuel shipping cask with far less risk of failure and possible injury or death to the saboteur. In short, there is no compelling reason to select spent fuel as a target of opportunity, whatever the saboteur's motivation. There are too many dangers involved, too much time is required, too many things can go wrong. The likelihood of failure is very high.

Thus, I believe the likelihood that such an effort will be made, or that if made it will succeed, is correspondingly low.

IV.

Consequences of a Successful Attack

In spite of the low probability that a terrorist will undertake an attack on a spent fuel shipping cask, and in spite of the impediments to the success of such an attack if attempted, the question remains, what if the attack itself were successful. What sort of consequences might be the result? It is important to understand that there are three very different approaches to a successful sabotage, each with different consequences.

A. Mechanical Damage.

One approach that has been suggested is to mechanically disassemble the cask and remove a fuel element from the cask for subsequent dispersion using explosives. While this is possible,

it would be an extraordinarily difficult, dangerous and time-consuming undertaking. First of all, the cask has been designed for vertical loading and unloading, but it is carried by truck in a horizontal position. The cask weighs approximately 37 tons, so in order for a terrorist to erect the cask to the vertical position, he would have to have access to a 50-ton crane with adequate hook height, or he would have to devise some sort of alternative erection system for this purpose.

Most scenarios would have the terrorist remove the lid of the cask while the cask is still mounted in the horizontal position and then remove a spent fuel assembly. This activity is not impossible, but it would require a time consuming and difficult process. First, he must remove the shock absorbing cover, which weighs 900 pounds and is held on by four bolts. Subsequently he must withdraw sixteen 1¼ inch diameter bolts. Even with the bolts removed, the lid of the cask, which weighs nearly a ton, would remain in place. The fit of the lid to the cask body is very close, making it doubtful that the saboteur could remove the heavy lid without it binding during the process. Further, there is a vertical steel wall welded across the front of the trailer that would make is impossible to do such things as attach cables to the lid in order to pull it out. It is also important to note that once the lid is removed the terrorist has no way to put it back on the cask, so he must carry the situation he has created through to some conclusion. The opened cask, minus its lid, would project an intense beam of radiation along the cask axis. The radiation beam would decrease in intensity with distance, but

the intensity close to the open lid of the cask would be high enough to deliver a lethal dose in a very short period of time.

Assuming that the cask lid were somehow removed, the next task facing the terrorists is to remove the spent fuel elements from the cask, which some say can be quite easily done by simply grappling for a "handle" on the fuel bundle and extracting the fuel elements one at a time. The fuel elements being shipped do not have a "handle" or bail but are normally picked up by a special tool that fits inside the top nozzle and uses actuating pins to engage small holes in the nozzle wall. If a saboteur was to plan to use such a tool, he would have to have it manufactured in advance and then face using it without the benefit of proving it works. Moreover, there is no spot on the top of a fuel assembly that could be easily hooked, certainly not by a person who cannot look at the object he is trying to hook. For example, the leaf springs at the top of the assemblies would accommodate a hook or grapple if the assemblies were free standing. But when the assemblies are in the square chambers of the cask the leaf springs (the only parts that might be grasped) lie flush against the chamber walls, so that a hook could not be attached to them. Furthermore, in order to attach a special tool or grapple for a hold on the fuel assembly, one must place part of his body, at least his arm, into the high radiation field. When one sticks his arm into a high radiation field, the ionization on the skin and the hair causes all the hair on the arm to stand up and gives one a tingling sensation. Thus, the terrorist involved in this sort of activity would be very conscious of the fact that he was

receiving a high dose of radiation to his arm. This dose would indeed be quite high since the saboteur would be required to grapple for this difficult-to-grasp fuel element in a blind fashion.

Assuming, nonetheless, that the saboteur could secure and maintain a firm hold on one of the fuel bundles with his grapple, he might attach the grapple to a long line and attempt to use some motive means to extract the fuel bundle from the spent fuel shipping cask, but the steel wall welded to the front of the trailer would prohibit this approach. In addition, as long as the steel wall remains in place at the front of the trailer, he could not in any event extract the assembly all the way from the cask. Even if he can remove the wall and take the assembly all the way out of the cask, he is now faced with the fact that he has an exposed fuel bundle giving off a very high signal to those searching with aircraft-carried radiation detectors, and furthermore, that it will prevent him from removing the other fuel from the cask.

The remaining problem is how he is to go about placing the explosives along the fuel element. There are several means possible, but all of these involve high radiation doses to those involved in placing the explosives. Because of the time and difficulty involved, it might be argued that the saboteur would instead simply remove the lid of the cask and place explosives in the mouth of the cask in order to disrupt the fuel on the inside. While this might sound more plausible, again the saboteur faces a trade-off since the amount of spent fuel that would be disrupted

by the explosive in this manner is considerably less than in the previous scenario.

To be sure, if this type of attack could be executed successfully, it could result in significant release of respirable material. Simply describing the process, however, emphasizes the tremendous time constraints and extraordinary difficulties that would face the saboteur. My view is that this type of attack is the one a saboteur is least likely to try. To remove the fuel from the cask involves high risks for the saboteur, both radiological and in terms of interdiction. Moreover, one may assume that this type of effort would have to be attempted in some remote location. A great deal of time would be required to remove the shock absorbing cover, the 16 1¼ inch diameter bolts in the lid and the lid itself. There would be risk enough of detection in a remote area. If this operation were carried out along the outskirts of Richmond, it would greatly increase the probability that before the operation could be completed, it would be prevented by local law enforcement agencies. If the attack must be carried out in a remote area, on the other hand, the potential consequences will be decreased significantly.

Thus, with these mechanical attacks on a cask, the saboteur is faced with a very high risk scenario that is likely to produce minimal results even if successful. I repeat, there are simply more attractive targets involving less risk and higher pay-offs.

B. Projectiles

Since mechanical disassembly involves such a high risk to a potential saboteur, he might consider using projectiles to attack

the shipment, since they would permit him to attack quickly and from a distance. During the mid-1970's, Sandia tested the use of devices such as light antitank weapons (LAW) or other projectiles that could be launched from firing tubes, such as bazookas. These projectiles use shaped charges to penetrate armor plating, and therefore could theoretically be used to penetrate a shipping cask. As a result of the tests, it was concluded that this type of armament would be ineffective against spent fuel shipping casks for two primary reasons: First of all, the aiming had to be extremely accurate, which is not to be expected by persons who are not using this type of weapon on a continuing basis. Second, the conical-shaped charge used in these devices is simply not large enough to be effective against the wall thicknesses found among typical spent fuel shipping casks including the TN 8L.

We also considered armor-piercing projectiles that use impact shock waves to create spall on the inside of the armor against which they are used. These devices normally require a cannon for their firing, and therefore were not considered broadly available to potential saboteurs. In addition, most shipping casks used today -- and certainly the TN 8L -- utilize lead shielding, which is not an effective medium for transmitting spalling-type shock waves.

Thus, I conclude that "stand-off" type weapons, such as the bazooka-fired LAW devices, would not be effective for use by saboteurs in attacking spent fuel shipping casks.

C. Explosives

A third methodology would be the use of explosives. As I indicated earlier, Sandia, at the request of the Department of Energy, has evaluated a number of types of explosives, both theoretically and through the conduct of a series of experiments. Taking a cue from the 1970 attack against the Math Research Center at the University of Wisconsin, Madison, Sandia conducted a test utilizing a 4,000-pound charge of ANFO, placed ten feet away from a spent fuel shipping container. The resulting explosion hurled the shipping cask approximately 150 yards and bent the cask, but did not breach its containment. Similar evaluations were carried out using breaching charges which consisted of large quantities of material placed in intimate contact with the shipping cask. The TN 8L is a particularly effective cask in resisting the use of this kind of explosive.

Another attack methodology evaluated was the use of a platter charge. Here a circular steel plate is mated with an appropriate mass of high explosives and detonated such that the platter becomes the projectile. It was found that, in spite of their apparent simplicity, these are difficult to construct and even more difficult to aim.

One of the most obvious of the explosive attack methodologies, and one that is widely available, is the conical-shaped charge. In contrast to the small and somewhat ineffective LAW, it is possible to place larger charges at appropriate locations to create damage on a spent fuel shipping cask. A variety of sizes and configurations of shaped charges was tested.

The final unit used in this series of tests conducted by Sandia was a burn bar, in which an oxygen-lance type of device could be used by a saboteur to burn a hole in a shipping cask. This particular approach has the difficulty of being suicidal on the part of the saboteur, since burning through to the spent fuel would expose the individual to very high levels of radiation.

Each of these attack methodologies was evaluated from the standpoint of its relative degree of success, the availability of the explosive devices and the time required for their use. From this group of attack methodologies, it was concluded that the conical-shaped charge meets most of the requirements that a saboteur might consider when mounting his attack. While the conical-shaped charge does require some skill, both in selecting the proper charge for the job and in using it, it was considered that the probability of success using this method is higher than the other methods available.

In analytical studies conducted in 1977 and 1979 (published in 1978 and 1980 as the "Urban Study"), it was estimated that a successful attack upon a spent fuel shipping cask, using a conical-shaped charge, could possibly disrupt as much as 10% of the contents of the shipping cask. It was further estimated that, of the 10% disrupted, approximately 10% could be mechanically fractured into respirable-size particles. This would result in a release fraction from the shipping cask, as the result of a successful sabotage attack, of approximately 1% of the cask contents. Very early explosive tests indicated that this value should probably drop to 0.7%, and that was the value

used in the first Sandia "Urban Study" (SAND77-1927). In the interval between that study and a subsequent revision of the Urban Study published in 1980 (NUREG/CR 0743), additional testing by Sandia indicated that the most likely release fraction would approach 0.07% of the contents.

This series of explosive tests on spent fuel shipping casks carried out at Sandia culminated in an experimental attack using a full-scale conical-shaped charge against a full-scale spent fuel cask containing a typical fuel assembly (although not spent). This final test in the series was conducted inside a chamber so that all of the resulting debris could be collected. The conical-shaped charge managed to punch a hole through one side of the cask, which at its narrowest point was 0.6 inch in diameter. The resulting explosion and intrusion into the cavity of the cask disrupted the equivalent of 10.4% of the fuel. That means that a little over 10% of the fuel pellets contained in the zirconium tubes in a fuel assembly inside a cask attacked by this means would be broken into more than two pieces.

As a result of the disruption of this fuel, slightly over 1% of the fuel was ejected from the cask. While this was very close to the original estimate, most of that 1% was in the form of large particles that would be deposited in the immediate vicinity of the cask. Only about 0.0034% of the fuel in the cask was released in respirable form and therefore available to cause biological harm to the general public. Since that test was conducted on a single fuel element cask, additional studies were done to evaluate what might happen with a three-element cask such

as the TN 8L. Since the respirable fission product release is proportional to the amount of fuel disrupted, and since not all three fuel elements are in line (so that the same jet can go through a proportional amount of all three of them) the actual release is something less than three times the amount that would be released from a single fuel element cask. Calculations using data obtained in these tests indicated that the release from the TN 8L-type cask would be on the order of 0.0024% (while the percentage released is smaller for the three-element cask the actual amount is larger).

It is comforting to see that the percentage of release is constantly going down as more and more is discovered about what actually happens as a result of an explosive attack, but our ultimate concern is the potential effect on the the public of such an attack. In the first Urban Study where this sabotage problem was addressed, it was calculated that the result of a successful sabotage conducted in a location in downtown New York during rush hour could create hundreds of early fatalities and thousands of latent cancers. The 1980 Urban Study, utilizing a release fraction of 0.07%, reduced those public impacts to tens of early fatalities and hundreds of latent cancers. It should be noted that the explosion itself was estimated to kill at least 140 people in the vicinity of the blast.

Utilizing the results of the full-scale tests that I discussed above, and including results from parallel testing conducted for NRC by Battelle Laboratories in Columbus, Ohio, it has now been calculated that the consequences of a successful

explosive attack on a spent fuel shipping cask, again in downtown New York, would be one expected early fatality (that is, a death occurring within one year of the time of the sabotage). If all of the uncertainties were pushed to their limits, it might be possible to achieve a maximum of three early fatalities. Using the same analytical models, one would calculate an expected consequence of four latent cancers, with a maximum possible of 14 (these are cancers occurring anytime following the event and include the early fatalities).

The experimental work and conclusion are described in An Assessment of the Safety of Spent Fuel Transportation in Urban Environs, R.P. Sandoval et al., SAND 82-2365 (June 1983), which will be introduced as an exhibit in this proceeding. These consequences were calculated using very specific assumptions as to the spent fuel involved and the population density immediately surrounding the event. For instance, the New York City case involved an average population density of 101,500 persons per square mile. Data from the County Road Map Atlas of the Commonwealth of Virginia, published by the Department of Highways and Transportation in January 1981, using preliminary 1980 census data that match those used for the New York City study, indicated that the average population density of Louisa County was 32.4 persons per square mile. In fact, the highest population density along any route between Surry and North Anna is the City of Richmond, which the County Road Map Atlas states has an average population density of 3508 persons per square mile. Since the consequences of a release are directly proportional to the number

of people exposed, which is in turn directly proportional to the population density, a simple ratio between the population densities along the route and those in the study would give a ratio of the effects as well.

For the highest population density in Richmond, Virginia, that ratio turns out to be 3.5%. Applying that percentage to the figures previously stated would result in zero early fatalities and zero expected latent cancers although, using the limiting error bounds, one might expect a maximum of one-half a latent cancer as the result of a successful sabotage attack in Richmond, Virginia. Should the attack be successful but occur in the rural portions of the state, those figures would drop to zero across the board.

Further, the consequences are reduced by the age of the fuel being transported. The fuel considered in the Urban Study upon which the figures above were based was 150-day-old fuel that had been burned to a level of 33,000 megawatt days per ton. Using calculations for the fuel that Virginia Power intends to transport, and the additional decay time between 150 days and the approximately 5-year-old fuel that will be transported, the consequences can be further reduced by at least a factor of 10.

Should a saboteur be successful in blowing a hole in a cask, the cleanup operation would be complicated only slightly by the resulting beam that would be emitted from this penetration. The very fact that a shaped charge was used to produce the penetration and subsequently disrupt the fuel beneath the hole would indicate that the source inside the cask for irradiating through the hole has been reduced as a result of the explosive

attack. Even if it had not been reduced, what would come out of this conical hole would be a beam of radiation which, by the time one got 500-600 feet away, would have dropped to a level of little concern. The recovery operation, therefore, is complicated only by the fact that there is a beam which must be avoided. Furthermore, the beam can be rather easily plugged in the early phases of the recovery operation. Since the beam itself would in all likelihood be pointing up in the air, it would be a simple matter to take molten metal such as Cerrobend (which melts at 150-250° F.) and pour it into the opening, thus forming a temporary shield over the hole. Other materials could also be used, such as lead shot or even earth. All that is needed is to close the hole to prevent additional escape of particulates and to provide some sort of shield in the opening created by the blast. Once this closure is accomplished, the cask can be handled using conventional means.

On these bases, I have concluded that the consequences of a successful sabotage attack within the Commonwealth of Virginia upon the TN 8L cask would be minimal in terms of public health.

Since these calculations address just the fission products, the question reasonably arises, what about other radioactive materials within the cask? One of the other products would be fission-product gases, which, by the time fuel is two years old, would have decayed to rather negligible values. Further, since this group of fission products consists of noble gases that would not chemically combine with other materials, their possible release

from the cask would simply result in their dissipation in the atmosphere, and they would have little effect upon the public.

Another material inside the cask would be the crud or corrosion products that collect in the crevices on the fuel assemblies. This material could be dislodged as the result of an explosive attack, but it represents a small portion of the total radioactivity involved within the cask and would be released in roughly the same proportion as the other radioactive material or fission products. Thus, it too would contribute insignificantly to the release accomplished.

As a part of the studies conducted by Sandia, analyses were performed on the behavior of certain representative and volatile fission products. The concern was that since some of these fission products may be vaporized at fairly low temperatures, they might behave differently as a result of an explosive attack. The finding was that, in fact, most of the materials which are volatile at the temperatures involved in the explosive attack do behave quite uniformly. Cesium, for example, is volatile at the temperatures involved, but is very active chemically and condenses very rapidly on any cold surface. Since the entire inside of the cask is not heated, but only subjected to a pulse of high temperature, any cesium produced during the attack quickly condenses on the cold surfaces of the inside of the cask, and on the cold surfaces immediately outside the cask, so that almost none of the cesium would escape the cask itself.

One of the interesting results of the sabotage tests conducted on spent fuel casks was the electron microscope analysis

of the products produced by the explosion. Those materials were found to contain lead, which had condensed from the vapor state, stainless steel and zirconium cladding, which had solidified from the molten state, but no evidence whatsoever that any of the fuel material (UO_2) had suffered anything more than mechanical fracturing. Since the melting point of UO_2 is on the order of 5000° F., this finding is consistent with expectations. Furthermore, it means that in order to produce respirable-size particles, they must be created as the result of the shock waves and not the temperature involved in the explosive attack. This significantly reduces the quantity of respirable fines produced.

V.

Emergency Response

Response to an emergency occurring during the transport of radioactive material generally occurs in three phases with different personnel being involved in each phase. Obviously, the first phase begins when the first person of authority comes upon the scene. This is usually a local policeman or fireman but frequently will be a state police officer. These people have a simple set of responses in the case of any hazardous material accident (e.g., radioactive materials, gasoline, propane or other such threats to the public health and safety). First they will typically cordon off the area to prevent bystanders from getting involved in the accident by being too close. Second, they will notify the appropriate personnel, who then notify the authorities about the event. For example, the local policemen, the state policemen or the fire crew responding to such an accident would

notify their dispatcher, who in turn would notify the carrier, the shipper and emergency response personnel within the state or locality in which the accident occurred. These first responders are authorized to attempt to save life, but they are not usually trained or equipped to make decisions concerning recovery from the situation, although this is not uniformly the case in the Commonwealth of Virginia.

The second phase is stabilization. It consists of the collection of more knowledgeable people at the accident site who can evaluate what has happened and determine what steps are necessary to stabilize the situation to prevent the accident from creating progressively worsening problems or continued involvement of the public. In the case of a radioactive accident, this phase would involve the use of radiation detectors of various types to define the extent of the accident, to decide upon the most appropriate response measures on the part of the responders and the public and to formulate long-term response plans for the incident.

The third phase of the recovery is cleanup. It involves commercial organizations who come in to clean up and restore the site and decontaminate the area to its original condition. These companies generally respond to all sorts of accidents involving hazardous materials and are equipped to address the situation in such a way as to prevent further public involvement and to expeditiously return the accident site to normal conditions.

This same response pattern would hold true whether the accident was created by chance or deliberate intent.

It is important to note that there are capabilities at various levels for addressing the first two of these three phases.

In my travels around the country and talks with emergency response personnel and state police, sheriff's departments and local fire departments, I have yet to find a police chief or fire chief or sheriff who did not know the proper procedures for this first level response. Further, they all know the appropriate persons to contact in case of an accident involving hazardous materials including radioactive materials. Without exception, for example, every emergency response person I have run into knows the phone number for Chemtrec. Chemtrec is a commercial organization sponsored by the Chemical Manufacturers Association that provides information to first responders on the nature of the hazard involved so they may more appropriately tailor their response to the situation. In the case of radioactive materials the Chemtrec response will be supplemented by consultation with the Interagency Radiological Assistance Program headquartered in Germantown, Maryland. All that is required is that the U.N. hazardous material number on the placard be given to the Chemtrec operator. Chemtrec is manned 24 hours a day, 7 days a week, and can in fact give quite accurate information on what to do in the initial phase. Further, Chemtrec automatically notifies several groups of people if information on the shipper, carrier or consignee is available to them from the first responder. For example, they will notify the carrier, the shipper and under some circumstances the Joint Nuclear Accident Coordinating Center (JNACC).

JNACC is composed of a group of federal agencies who jointly support the response centers in six geographical areas around the country. The response center for the Virginia area would be in Washington, D.C. This system, which was designed solely for response to nuclear accidents, can provide a variety of services ranging from simple information transmitted over the telephone to the dispatch of teams of personnel and supporting equipment for aiding in the second or stabilization phase of the response. Perhaps the best known illustration of their response capabilities is that a team from Albuquerque, New Mexico was on site in Polomaris, Spain, within 23 hours after four nuclear weapons were lost from a U.S. Air Force bomber as the result of a midair collision in that locality. Their capability includes complete monitoring systems mounted in light vehicles that are capable of being transported by air to any air field capable of handling a C-141 aircraft. Furthermore, they have available to them, in computerized form, a list of all air field facilities in the country such that, given the location of an accident, an inquiry to the computer will tell them which air field is the nearest to the accident scene.

In addition to these capabilities, there are a host of other personnel and equipment available to the first responder should he feel the need for this additional help. For example, all hospitals accredited by the American Hospital Association must have a nuclear medicine department and must therefore employ a health

physicist. This health physicist must be provided with the proper instrumentation for carrying out his job. Thus, the first responder could call upon any local hospital for support in evaluating the magnitude and extent of an accident involving radioactive materials.

A similar capability is available from many state universities, including the University of Virginia and Virginia Polytechnic Institute and State University. Perhaps the strongest support in the case of the shipments under consideration would be the utility itself. Virginia Power has a staff of health physicists and a broad range of instrumentation capabilities that would enable them to participate in the second phase to define the appropriate response mechanisms and otherwise to advise those responsible for both the first and second phases of the operation. One additional capability available from Virginia Power is a helicopter which could be used along with appropriate instrumentation to track or otherwise find the shipment should it have been hijacked and diverted (although it is more likely that equipment available at Andrews Air Force Base would be used). As indicated before, this tracking from the air is quite feasible because of the radiation signature given by the cask. Finally, the Commonwealth of Virginia has in place a well-trained cadre of personnel in the Bureau of Radiological Health and the Department of Emergency Services to deal with any possible sabotage-induced radiological incident. The second phase response would be coordinated by the Department of Emergency Services. Even the initial response would be augmented by the fact that many Virginia law enforcement officers

and fire department personnel have already been trained by the Commonwealth in handling such emergencies. Thus, there are in place both the techniques for responding to an accident of the type of concern here as well as a well-established cadre of response personnel.

VI.

Conclusions

The likelihood that a sabotage attempt bent on injury to the public will be aimed at the Surry-to-North Anna shipments is quite small. To my knowledge, no such serious attempt has ever been launched against any of the more than 5,000 shipments of spent fuel that have been made in this country. This is not surprising. The threat of injury or death to the saboteurs, the terrible time constraints affecting the attack and the small chance of success are significant deterrents.

If the objective is weapons-grade material, the saboteur will recognize that spent fuel is a poor source of such material. If the objective is to make a "political statement," he is likely to conclude that there are far safer and easier ways to make that statement, and, in any event, such attacks are unlikely to have as their purpose significant injury to the health and safety of the public. If the objective is to injure the public, he is likely to conclude what common sense tells us, namely that there are far more accessible targets that will produce much greater levels of the damage he wishes to inflict.

Even if the saboteur should elect to make the effort, he faces severe impediments in gaining access to or control over the

cask. He may face armed escorts in multiple vehicles. He must deal with a sophisticated communication system among the vehicles, the shipper and law enforcement officials and thus the prospect of bringing large retaliatory forces down on his effort. He will face the prospect that the tractor will be immobilized and an awareness that the spent fuel shipment is not a cargo that he can successfully hide. Finally, even if he can gain possession of the cask, the maximum damage he could reasonably be expected to inflict has been shown to be quite small.

When I consider (a) the small probability that an attack will be launched, (b) the small probability that an attack will successfully breach the cask, and (c) the fact that even if an attack is successful the public health risk is almost non-existent, I conclude that the sabotage risk associated with the proposed shipments is insignificant.

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EXPERTISE:

Technical aspects of the transportation of radioactive and other hazardous materials including: The regulations (both domestic and international), their interpretation, their adequacy and the technical impact of any proposed changes; the technology as has been developed by the various R&D programs worldwide since 1978 and applied to design concepts, materials, interfaces, testing and sabotage; the risks surrounding the transportation of radioactive materials both real (as quantified in technical risk assessment methodologies) and institutional (as defined by activists, political bodies and media); emergency response techniques, capabilities and agreements.

In addition, as a recognized authority in the field, I am well known by activists, state personnel, carriers, industry people and U.S. government personnel.

This capability is augmented by well developed communication skills that make it possible to adapt information to specific audiences.

More details and additional expertise available upon request.

EMPLOYMENT:

1957 to present Sandia National Laboratories
Albuquerque, New Mexico

Since 1978 Manager Nuclear Materials Transportation
Technology Department (Transportation Technology Center)

Responsible for the operation of the full range of Transportation R&D programs sponsored by the DOE to asure that there are safe, effective, economical, and publically acceptable means of transporting radioactive materials in support of DOE programs.

1975-1978 Manager Nuclear Fuel Cycle Technology Department

Responsible for R&D on the safety of commercial nuclear power plants including effects of fire, radiation, and aging on the reliability of safety systems.

1973-1975 Supervisor of Waste Management and Transportation Division

Responsible for R&D programs in waste technologies and in the equipment for transporting radioactive materials.

1965-1973 Supervisor of Radiation Applications Division

Responsible for the design, development, operation, and utilization of five research reactors (both steady state and pulsed) and eleven electron beam machines.

1962-1965 Supervisor of Research Support Section

Responsible for the design, construction, installation, and initial operation of special apparatus for conducting research in the interaction of radiation with matter.

1957-1962 Staff Member
Involved in nuclear reactor design and field experimentation in radiation effects.

1954-1957 U.S. Air Force - Sandia Base, Albuquerque, New Mexico
Instructor in nuclear physics, health physics and weapons systems.

1953-1954 Convair - Ft. Worth, TX.
Junior Engineer designing kinematic systems for aircraft landing gear and similar actuating mechanisms.

1964-1980 University of New Mexico
Nuclear Engineering Department - Albuquerque, New Mexico
Adjunct Professor of Nuclear Engineering (part time) teaching courses at MS & PhD level.

EDUCATION:

BS ME	Michigan Technological University 1953 (with Honors)
MBA	University of New Mexico 1964 (with Honors)

CURRENT PROFESSIONAL ACTIVITIES:

- Member National Research Council, Transportation Research Board, Committee on Transportation of Hazardous Materials (A3 C10)
- Member - Sandia Reactor Safeguards Committee
- Chairman - University of New Mexico Reactor Safety Advisory Committee
- Member Publications Steering Committee of the American Nuclear Society
- Instructor for Energy Education Programs; a continuing eduction seminar for high school school science teachers in Illinois
- Speaker in Media Information Program conducted by $(SE)^2$
- Speaker for American Nuclear Society on topic of Transportation of Radioactive Materials

PAST PROFESSIONAL ACTIVITIES:

- Member National Academy of Science Committee on Nuclear and Alternative Energy Sources
- Chairman Fifth International Symposium on Packaging and Transportation of Radioactive Materials PATRAM (5/78)
- Chairman Ad Hoc Committee on Transportation of the International Atomic Energy Agency (5/78)

- American Nuclear Society

  Chairman - Special Publications Books (76-79)

  Chairman - National Publication Committee (71-76)

  Chairman - Remote Systems Technology Division (73-74)

  Chairman - Trinity Section (New Mexico) (70-71)

AWARDS:

- Exceptional Service Award - American Nuclear Society, November 1980
- Nuclear Public Communication Award - American Nuclear Society, November 1983 (First Recipient)

PUBLIC SERVICE ACTIVITIES:

- Teaching leader - Bible Study Fellowship (1980-Present)
- Past Show Coodinator - Southwest Arts & Crafts Festival 1975
- Past President New Mexico Arts & Crafts Fair 1973

PUBLICATIONS:

Available upon request