Dave -

Here is the report that you requested, It appears that I misread this report and that LA-3611 is correct.

Best Regards
George

BIDINGER

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

November 6, 1964

Mr. Harold L. Price
Director of Regulation
U. S. Atomic Energy Commission
Washington 25, D. C.

Dear Mr. Price:

Attached is the final report of the Technical Review Committee, which you appointed to consider the criticality accident on July 24, 1964, at the Wood River Junction, Rhode Island, plant of the United Nuclear Corporation.

Sincerely,

Herbert Kouts

Herbert Kouts
Chairman

Attachment:
Report

REPORT OF THE AEC TECHNICAL REVIEW COMMITTEE*

November 6, 1964

*Committee appointed to report on the criticality incident of July 24, 1964, at the Wood River Junction, Rhode Island, plant of the United Nuclear Corporation. Members:

Dr. C. Wayne Bills
Dr. Richard L. Doan
Dr. Herbert Kouts (Chairman)
Dr. Marvin M. Mann
Dr. Hugh C. Paxton
Dr. Warren E. Winsche

I. Introduction

On July 24, 1964, a criticality incident occurred at the AEC-licensed Wood River Junction (Rhode Island) plant of the United Nuclear Corporation. The incident caused fatal injuries to one United Nuclear employee, and two other employees received moderately high radiation exposures in succeeding events.

In keeping with established procedures of the Atomic Energy Commission, the Director of Regulation appointed a technical review committee to review the results of examinations by the Commission's regulatory staff and by the United Nuclear Corporation. The members of this committee are:

Dr. C. Wayne Bills
Dr. Richard L. Doan
Dr. Herbert Kouts (Chairman)
Dr. Marvin M. Mann
Dr. Hugh C. Paxton
Dr. Warren E. Winsche

The committee was requested to:

a) review the information gathered,

b) advise whether additional information was needed, and if so in what particulars,

c) review and comment on the information developed as a result of the examination with respect to such matters as the nature of the incident, its cause or causes, and matters to be considered in order to minimize or preclude similar incidents, and

d) prepare a report to the Director of Regulation.

The committee has been given access to all information developed in the course of the investigations, including the official report of the investigation conducted by the United Nuclear Corporation. We wish to express our appreciation for the complete cooperation of all concerned.

II. Plant Location

The Wood River Junction Fuels Recovery Plant of the United Nuclear Corporation is located on a 1200 acre site in southwestern Rhode Island. The nearest large population centers are Westerly, Rhode Island, and Providence, Rhode Island. The immediate vicinity of the plant is sparsely populated.

The plant consists of a single building, with one main operations floor and an integral three-story tower. The floor plan of the building, with indicated positions of the major equipment components, are shown in the official report of the United Nuclear Corporation investigation.

III. Staff

On July 24, 1964, the UNC personnel assigned to the

Wood River Junction Plant totaled 22, with duties as generally described below. This number included the plant superintendent, 3 shift supervisors, 9 operators, a health physics technician, a chemist, 2 mechanics, 2 secretaries and 3 security guards contracted from a protection agency. Supplemental technical assistance in health physics and nuclear safety was furnished from UNC's Fuels Division, New Haven, Connecticut, and the Hematite Plant Facility, Hematite, Missouri.

The scrap plant was operated on a three-shift basis, five days a week. The normal shift crews were composed of three operators, a shift supervisor, and a security guard.

Six of the operators had started employment with UNC in February, 1964, and the others joined the staff in April, May, and June, 1964. None had previous experience with nuclear material. In most part, the operators were also inexperienced in chemical operations.

The shift supervisors have B.S. degrees in chemistry or chemical engineering, and two were experienced in operations with nuclear materials, one with the UNC's Hematite plant. One supervisor had no experience with nuclear materials before he began work at the Wood River Junction plant.

The plant superintendent (also called the Scrap Recovery Superintendent) is a chemical engineer with about eighteen years of experience, ten of which were with an AEC-contracted uranium processing plant. He joined the UNC organization in October, 1963, and was responsible for equipping and staffing the plant prior to its initial operation. He also assisted in the preparation of testing, startup, and operating procedures. The plant superintendent reported to the manager, Chemical Operations, in New Haven, Connecticut. The plant superintendent was responsible for production, and for continued safe and efficient plant operation, which includes nuclear safety.

The Health Physics Technician, who has been with UNC for six years, has had some earlier contact with criticality control procedures, specifically for fuel storage at the New Haven Facility. At Wood River Junction, he reported to the plant superintendent but obtained his health physics guidance from the Supervisor, Health Physics, in the New Haven plant. The Health Physics Technician was responsible for monitoring the plant health physics and industrial safety programs. In nuclear safety, his responsibility was limited to the observation of operators' activities and the spacings between containers of nuclear materials. The major health physics concern in a cold scrap plant is alpha contamination.

The chemist, who has the degree of B.S. in chemistry, performed analyses on the day shift. On the other shifts, chemical analyses needed immediately were performed by the shift supervisors.

The Operations Control Manager at Hematite, Missouri, had the responsibility for licensing documents and nuclear safety at the Wood River Junction Plant. He had the responsibility for obtaining approval of the AEC license and its amendments, and for reviewing and approving equipment design to meet the criticality requirements. The Operations Control Manager has a B.S. and M.S. degree in mechanical engineering and nine years' experience in uranium processing with an AEC contractor and with UNC. He also attended the Nuclear Safety course at Oak Ridge in 1959. The Operations Control Manager visited the Wood River Junction plant on two occasions, both in January, 1964, to review progress of construction and to familiarize himself with the site. He apparently did not visit the Wood River Junction plant between the time of startup and the time of the accident.

IV. Process Chemistry

The plant was designed to recover enriched uranium from the wastes and scrap materials generated in fuel fabrication plants. The process equipment can be grouped as 1) feed preparation for solvent extraction, 2) solvent extraction operations for separation of the uranium from other materials in the wastes and fuel scrap, and 3) finishing operations to convert the recovered uranium to solid uranium dioxide, which is the final product. The process steps and type of equipment have been used extensively for similar purposes at other locations. No unusual process operations or equipment were described in the license application.

Only a short summary of the process operations is needed here. The feed preparation area consists of mechanical devices for degreasing solid scrap, removing portions of scrap that do not contain uranium, and for drying and weighing the cleansed solids. Solid scrap was to have been dissolved with appropriate acids in one of the several critically safe dissolvers, and the solution was then to be stored in critically safe storage tanks from which it could be pumped as feed to the solvent extraction operations. No solid scrap had yet been processed. The plant had been operating on aqueous wastes from cleaning fuel materials, known as pickle liquor. This pickle liquor, which contains low concentrations of uranium and other metals, was used as feed to the solvent extraction operations after adjustment of the acidity.

Solvent extraction operations are conducted in a battery of critically-safe pulse columns. Uranium nitrate in the acidified feed solutions is preferentially extracted into a solvent consisting of TBP (tributylphosphate) dissolved in a purified kerosene. The uranium nitrate is then stripped from the solvent into a low-acid aqueous product which is then washed with TCE (trichloroethane) to remove traces of entrained solvent. The TCE-washed solution is the feed material for the finishing operation. In turn, the solvent is washed with a dilute sodium carbonate solution prior to reuse. The sodium carbonate solution is made up in the small tank in which the criticality incident occurred. There appear to have been no original specific procedures for treatment of used TCE, probably because the amounts of TCE to be cleaned were expected to be minor.

As the first step of the finishing operations, the aqueous product from the solvent extraction operation (called O.K. Liquor) is concentrated in a critically safe evaporator to approximately 100 g/1 (at which point it is called concentrated O.K. Liquor). This concentration is required for producing ammonium diuranate in the critically safe precipitators that follow. The ammonium diuranate precipitate is filtered and dried, and then reacted in a furnace to produce UO_2 which is crushed, blended, and packaged for shipment.

V. Plant Procedures

Contained in the license application is the standard operating procedures manual for the Wood River Junction Plant. This manual, entitled "General Information and Procedures Applicable to the Handling of Special Nuclear Materials", is an abstract of the technical procedures contained in five-volume sets of Standard Operating Procedures used by plant personnel. Three sets were available to the operators. There was one master set.

Detailed procedures based on those developed at the United Nuclear Corporation Plant at Hematite, Missouri, were given for the forty-four processes in the plant. For two items of equipment, SOP's were posted in the appropriate plant areas.

A. Criticality Control Procedures.

Criticality control is based on limitation of one or more of the variables: volume, geometry, mass, concentration. Nuclear safety aspects of processes, process equipment items, and the storage area were evaluated during the pre-license period. The detailed operating procedures included the special nuclear safety requirements of the individual processes, such as limitations of batch size and concentration.

Process safety was based on such limits in conventional ways, and in general, the technical aspects of criticality control seem proper. In some tanks, normal criticality control methods are supplemented by including Raschig rings of borosilicate glass, where solution concentrations are expected not to exceed 5 g/liter of U^{235}, but the nominally safe five inch diameter could not be met. Reasonable tests and frequency of inspections of Raschig rings were specified in the AEC license.

Interim product storage used five-inch diameter plastic bottles of eleven-liter capacity, and four-liter plastic bottles. The latter were used for cleanup liquid and for temporary storage until transfer was made to the eleven-liter bottles. The eleven-liter bottles were normally stored in bird-cage carts providing a minimum of two feet surface-to-surface between bottles. The four-liter bottles were spaced by eye in temporary storage areas delineated on the operating floor, or stored at safe spacing in a permanent shelf area.

Less attention was given to some other aspects of criticality control, as indicated by the following observations. There had been no audit by the Operations Control Manager since operations with U^{235} started on March 16, 1964 (sustained receipts of U^{235} did not occur until the week of May 11).

Labeling practices for U^{235} containers had deteriorated as the result of difficulty with original methods of affixing labels. The plant superintendent was unaware of at least one active operation with fissionable material, namely the treatment of TCE solution in the sodium carbonate makeup tank. These items are mentioned in more detail later in this report.

B. Training Procedures

Although various methods of training have existed, there does not appear to have been a general program or procedure for ensuring the training of all personnel. In specific areas, such as health physics and nuclear safety, the Supervisor, Health Physics, from New Haven, did hold discussions and showed films several months before operation to those personnel employed at that time. Practices provided for new employees to spend a day in general safety indoctrination with the Health Physics Technician shortly after their arrival. The major responsibility for training was assigned to direct line supervision as on-the-job training, with copies of the manual being available for the operators to take home and read. The manual indicates that a safety meeting was to be held each month.

C. Records and Logs.

The responsibility for accountability was vested in the Operations Control Manager at Hematite, Missouri. Procedures provided for verification of the shipper's value for received material by sampling the material as it enters the process. Accountability is balanced by inventory of contents of the various in-process systems and containers. The detailed method of record keeping was not defined in the manual.

Although an operator's log book was provided for passing information from one shift to others, in actual practice, the log had not been used consistently and most items appeared in cryptic form. Operators passed most information verbally to operators who succeeded them on the next shift. The Shift Supervisor's log was used to inform and remind relieving supervisors of plans and problems for the new shift. It is considered to be the best source of information on the state of processing. This log contains no mention of the new TCE washing process.

In addition, there were Operating Report Sheets for recording the operating data for each major operation, and an analytical log of samples for chemical analysis.

D. Identification Procedures.

The original plan of labeling was based on use of color-coded pressure-sensitive gummed labels, attached to the bottles. These did not adhere well, and new tags held on with scotch tape were then tried. These also failed to adhere, because of the presence of organic solvent on the outside of the bottles. Finally, large rubber bands were used to hold the labels on the bottles. It appears that, in some cases, the solvent also led to deterioration of the rubber. The tags themselves did not always bear the information required for identifying the contents of bottles, and specified in the license.

Procedures specified that the bottle tag and the sample tag were to contain information as to the source or origin of the solution. This information was first recorded in the analytical log and a number was assigned to the sample. When analysis was complete, the number of the bottle and the tag were to be checked and the analysis recorded on the bottle tag.

VI. Narrative of Incident and Subsequent Events

From its study of information available from the United Nuclear Corporation, from individuals, and from the team of AEC investigators, the Committee has not been able to construct a completely factual account of some events involved in the incident. This difficulty arises from two sources. First, as is always the case in accidents, persons involved found themselves under stress, and a certain amount of confusion seemed to occur. Under such conditions, persons do not remember all details and occurrences clearly. Second, some technical data have been difficult to reconstruct in an unambiguous way. With the foregoing qualifications, the Committee believes that the following narrative is reasonably correct.

At the time of the incident, the plant was being operated by four employees comprising the 4 P.M. to 12 P.M. shift. One of the employees was designated as shift supervisor and was in charge of the plant. In addition to the operating employees, one guard was on duty. The operators were assigned as follows: one to the evaporator and precipitator area, one to the pulse column area, and one to the dissolver area. The dissolvers, the precipitators, and the extraction columns were all in operation at the beginning of the shift.

At about 6:06 P.M., Mr. Peabody, the operator who had been assigned to the extraction column area, poured the contents of an 11-liter bottle into the sodium carbonate makeup tank on the third floor of the extraction column (tower) area. This tank had not been meant for use with fissionable material. When he had almost emptied the bottle, the nuclear chain reaction occurred. Mr. Peabody saw a bluish-white light at the time of the nuclear excursion and observed that some of the tank's (liquid) contents were ejected at that time. The excursion caused some of the solution in the tank to splash up to the ceiling of the room, which is approximately 12 feet above. Mr. Peabody fell to the floor, dazed but not unconscious. He immediately rose and ran down 3 flights of steps to the first floor and out of the building, leaving the immediate plant area through an escape gate in the fence on the south side of the plant and proceeding to the emergency shack some 500 feet southwest of the plant. The shift supervisor, the remaining two operators, and the guard also went immediately to the emergency shack, having been alerted by the sounding of the nuclear (radiation) alarm.

After arrival at the shack, the shift supervisor notified the plant superintendent and the other Company officials of the accident, and requested an ambulance and medical help for Mr. Peabody. Meanwhile, the other personnel were caring for Mr. Peabody, who had within a few minutes begun to exhibit signs of discomfort and shock. The ambulance arrived at about 7:00 P.M. It started with Mr. Peabody for the Westerly, Rhode Island Hospital, but was diverted to the Rhode Island Hospital in Providence, Rhode Island, when it was established by police radio that no facilities for treating radiation injury cases existed at the Westerly Hospital. One of the plant operators accompanied Mr. Peabody.

The hospital had been notified that an accident had occurred and that one injured employee was enroute in the ambulance. Mr. Peabody was brought into the hospital at about 7:45 P.M. Partial decontamination was performed, and he was then placed in the emergency ward where medical care and radiation control procedures were instituted.

The employee accompanying Mr. Peabody in the ambulance was found to have low-level contamination on his hands and on his clothes. He was cleaned and discharged from the hospital.

In the early morning of July 25, personnel experienced in treatment of radiation exposure arrived at the hospital to assist the hospital staff. Mr. Peabody's condition deteriorated through Saturday and Sunday, and he expired at 7:20 P.M. on Sunday, July 26, 1964. An autopsy was performed early in the morning of July 27 by the hospital staff with the assistance of medical experts from the Oak Ridge National Laboratory.

Shortly after officials had been notified of the accident, the plant superintendent arrived at the emergency shack. He used a portable radiation measurement instrument taken from the emergency shack for two radiation surveys separated in time by about one hour. These showed that radiation levels exceeded the meter limit of 100 mr/hour only near the extraction column tower in which the accident had taken place.

While the second survey was in progress, state civil defense authorities arrived, equipped with high-range radiation instruments. Upon learning of the availability of these high-range instruments, the plant superintendent and the shift supervisor borrowed the instruments and made a third entry of the plant, intending to transfer the contents of the sodium carbonate makeup tank into containers of safe geometry, so that no further chain reaction could take place. This was to be done via a flexible hose draining into the sodium carbonate process column, which extends from the first to the third floor. When the superintendent and the supervisor reached the third floor of the extraction tower, they found the stirrer in the sodium carbonate tank still running. The superintendent turned off the power switch to the stirrer, and the two men went to the first floor to drain the column of sodium carbonate solution before draining the tank. The solution was drained into four-liter bottles. It was found that the tank would not drain, and the superintendent concluded that the drain was plugged with precipitate. He restarted the stirrer, and the supervisor, who had remained below, drained the liquid from the tank through the extraction column into additional four-liter bottles. The preceding action consumed an estimated twenty minutes. Another twenty to twenty-five minutes were consumed in other areas of the plant.

Between 8:45 and 9:00 P.M., personnel entered the plant, this time to turn off the radiation alarms and to determine more accurately the radiation level in the column area. It was found that the radiation level in the first floor area of the column room was about 50 r per hour.

There was another entry of the plant during this period on the night of July 24 and early morning of July 25. Shortly after 4:00 A.M., a Company supervisor went into the evaporator area to stop the flow of uranium solution from the storage tank to the evaporator. This particular solution, however, was not involved in the incident.

One more brief entry, on the morning of July 25 at about 9:00 A.M., was made for a radiation survey of the process area. No areas in which radiation levels exceeded 100 mr per hour were entered.

The office and locker room areas of the plant were decontaminated during the morning of July 25. Following this action, which was completed early in the afternoon of July 25, it was decided that the process area would not be reentered until specific plans had been formulated.

On Monday, July 27, 1964, United Nuclear officials organized an investigating committee. The committee was instructed by the Company to examine and analyze all aspects of the incident. This committee's efforts culminated in the Company's report dated August 24, 1964.

Beginning with an entry of the process area during the afternoon of July 27, all actions within the plant until August 13 were subject to the direction and approval of the Company's investigating committee. By this latter date, with the exception of a very few localized areas, the plant had been decontaminated to the cleanliness criteria established by the Company committee. Since that time, the remaining areas have been satisfactorily decontaminated.

While decontamination of the plant was a major objective of the Company, the controlling problem for the Company's investigating committee was that of determining how and why the accident occurred and the characteristics of the nuclear excursion. With these purposes in mind, the Company committee formulated a detailed plan for sampling solutions residing in process equipment and in bottles, and for the careful mapping of the location of bottles and other portable equipment, as they existed after the accident. Decontamination in each location was effected only after samples of equipment and materials necessary for the study were obtained.

It is clear that some conditions immediately following the accident were disturbed as a result of the several entries into the process area during the evening of July 24 and the morning of July 25. These actions have been taken into account insofar as is possible, but it cannot be said that the facts are fully known.

VII. Discussion and Comment

This accident occurred in a new plant, in operation for only a few months.

While neither the process nor the equipment are wholly new in themselves, it is not uncommon that unforeseen problems arise in the operation of any new plant. Furthermore, with the exception of the plant superintendent and two supervisors, the operating organization in this instance was not experienced in the kind of operations performed. With these considerations in mind, and upon detailed review of the facts and circumstances in this case, the Committee feels that some discussion of four points peculiar to this incident is in order. These are:

1) The stripping column had not functioned as well as planned, and more than normal amounts of entrained uranium-

bearing solvent were carried through to the TCE. The TCE thus had to be treated to remove uranium more often than had been planned.

2) Difficulties were experienced with the evaporator, starting with the 12 P.M. - 8 A.M. shift on July 23, the day before the accident. This led to the generation of several bottles of high-uranium-concentration solution and slurry.

3) Uncertainties had been created by the methods used to tag the geometrically safe storage containers and to identify their contents.

4) Procedural methods and controls had not been updated to accommodate process and equipment problems arising from initial operations.

A. Problems Caused by Contaminated TCE

Difficulties with the stripping columns began in March and April, and the uranium-bearing TCE which was generated had to be treated to remove the uranium. No detailed procedure for this removal had been written, and a method was devised which involved mixing the contaminated TCE with a sodium carbonate solution in an eleven-liter bottle, and manually agitating the mixture. Because of the weight, an operator usually placed the bottle across his shoulders, and rocked it back and forth. The practice was slow and laborious.

During May and June, the rate of generation of contaminated TCE was reduced considerably, possibly because of greater experience in control of the column operating variables. Starting in July, solution resulting from dissolving off-specification UO_2 was being fed to the extraction operation. This appeared to cause a resumption of the high entrainment from the stripping column, with the requirement for frequent changes of the TCE wash.

On July 17, one operator proposed to his supervisor that the cleaning of contaminated TCE could be done much more efficiently in the stirrer-equipped sodium-carbonate preparation tank 1-D-11 on the third floor of the extraction tower. The supervisor concurred with the proposal if the uranium concentration of the TCE so treated was kept below 800 ppm (a safe concentration). The operator tried the process, found that it was indeed more efficient, and informed his replacement on the next shift, who was Mr. Peabody. With the concurrence of his supervisor, Peabody began to use the new method to remove the uranium from large amounts of TCE. The use of the sodium carbonate tank to wash TCE was mentioned by the first operator in the operator's log at the close of the shift during which he devised it. It was not noted in the supervisors' log. Apparently, it was not communicated to the other supervisor or to the plant superintendent.

New equipment for decontaminating the TCE, which had been designed on safe geometry principles by the third supervisor, was on hand, but was not yet installed.

B. Problems Caused by Evaporator Plugging

The evaporator is normally used to concentrate the uranium solution prior to uranium precipitation. Flow into the evaporator stopped during the 12 P.M. - 8 A.M. shift on July 23, and it was found that the inlet was plugged with uranyl nitrate crystals. Clearing the inlet leg required most of this shift and the following one. The uranyl nitrate, which was removed as solution and slurry through the use of steam, was placed in several bottles. Two of these were eleven-liter bottles labeled "Bottle X, Concentrated Liquor from the Evaporator" and "Bottle Y, Concentrated Liquor from the Evaporator". It has not been established how a third eleven-liter bottle was labeled, and some concentrated material may have been stored in four-liter bottles. The confusion exists because most if not all of the concentrated material except that in bottles X and Y had been reprocessed by the time the accident took place.

This was the first concentrated material stored in the plant in such bottles. The next evening, Mr. Peabody produced the nuclear incident by pouring the contents of bottle Y into the sodium carbonate wash tank.

C. Labeling Problems

The deterioration of labeling practices has been mentioned earlier. Although the use of label designation such as "Bottle Y, Concentrated Liquor from the Evaporator" was a violation of the established plant procedures, the role, if any, that labeling practices played in contributing to the accident is not clear.

Peabody had mentioned to his supervisor shortly before the accident that some eleven-liter bottles were mislabeled. He later said that before the accident he had been looking for an empty eleven-liter bottle, and had gone to the storage area and found none. He said that he then decided to empty a bottle by washing contaminated TCE as he had done before and that he selected a bottle which he believed to contain TCE. In fact, it is known that he took bottle Y. It seems well-established that bottle Y was isolated on a safe cart by ropes and stanchions and that it was labeled as described previously. To get at this bottle, he would have had to move the ropes and stanchions.

The Committee has found no way to resolve the contradiction posed by these statements and facts.

D. Methods Used in Abnormal Situations

While the written procedures in existence, when followed, may have been adequate for routine operations, it would appear from the preceding discussion of the TCE and evaporator problems that emergency procedures for use in non-routine situations had not been provided prior to plant startup, nor had such been adopted before the accident.

It may be surmised that audits of procedural practices and criticality control by qualified personnel would have led to improvement of safety practices and the development of procedures for the non-routine situations that existed, but there had been no audit by the Operations Control Manager or other technically qualified personnel after plant startup. In a few instances, changes such as in equipment or in batch sizes had been cleared by teletype communication between Wood River Junction and Hematite, Missouri.

VIII. <u>Quantitative Aspects of the Accident</u>

In summary, the criticality incident occurred in an 18-inch-diameter open-top tank (26-in. deep, dished bottom) of 1/8-inch-thick stainless steel. The tank stood above a 6-inch-high concrete pad such that its lip was 60 inches above the floor; separation from a concrete-block wall was about

15 inches. An agitator was mounted in the tank. Evidence leads to the following picture of the incident.

According to the most plausible reconstruction of events, two excursions occurred, which were separated by a period of 1-3/4 hours. The first took place while about 2.6 kg U^{235} as about 11 liters of uranyl-nitrate solution was being poured in the tank that already contained approximately 41 liters of 0.54 molar sodium-carbonate solution. The agitator was on at the time. This excursion, which is believed to have occurred when about 10 liters of the solution had been added, splashed about one-fifth of the liquid out of the tank. The victim, who ran out of the building after having fallen to the floor, received an estimated exposure of about 8000 rem.

It appears that the loss of fluid (not necessarily of the average composition of the contents of the tank) was such that the vortex and small bubbles from agitation were sufficient to maintain a subcritical state. Although the final content of the tank, 41-42 liters containing 2.1 kg U^{235}, is known better than conditions before the first excursion, a criticality evaluation is complicated by the quick formation of a uranium precipitate (supposed to be $Na_4UO_2(CO_3)_3 \cdot 2H_2O$). As an abnormal proportion of this precipitate may have settled into a Tygon tube that was connected to the bottom of the tank, the actual quantity and distribution of uranium within the vessel is uncertain. The overall uncertainty of conditions during agitation masks any calculated conclusions about criticality at that time.

The evidence for a second excursion comes from neutron exposures of the two persons who emptied the tank 1-3/4 hours after the first event. Actions immediately before drainage were to turn the agitator off, then on again when it became apparent that the line from the tank was plugged. It is most likely that the second excursion occurred after the agitator was turned off, while the vortex and bubbles disappeared but before gross settling of the uranium precipitate occurred. This interpretation is supported by criticality calculations. No visible evidence of the later excursion is reported. The few seconds required for the vortex to subside, and the chain reaction to be reestablished in the absence of a neutron source, would be sufficient time for the superintendent who turned off the agitator to have left the immediate area, and could account for the observation that his neutron dose seems to have been smaller than that of the supervisor with him, who did not approach the tank as closely. The report of these people that the solution did not feel warm while being drained supports this second-excursion hypothesis instead of a recurring reaction while the agitator was active.

According to radiochemical analyses of the material from the tank, the total number of fissions was $1.2 - 1.3 \times 10^{17}$. A less reliable subdivision based on exposures, is that the yield of the first excursion was about 10^{17} fissions. The violence of this event suggests a single fission spike, whereas the second excursion may have been a sequence of small bursts.

The Committee considers it to be important that actions taken after the first excursion could well have caused a second excursion, even though the evidence for this as the particular cause of the neutron irradiation of the two persons involved is not definitive.

2nd nuclear excursion

IX. <u>Conclusions</u>

The accident that took place at the United Nuclear Corporation plant at Wood River Junction, Rhode Island, posed no threat to the surrounding population. Viewed in this light alone, there would be no reason to consider this particular accident in any different way from other industrial accidents. However, the Review Committee believes that it has been appropriate to consider this accident in some detail, to aid in implementing the high standards needed in the nuclear industry for protecting employees as well as the public.

It does not appear that any single factor was solely responsible for the accident. The Committee's conclusions on principal contributions are as follows:

A. Technical Factors Contributing to the Accident

1. Early in the operation of the plant, unforeseen process difficulties arose. Some of these led to generation of a large amount of uranium-bearing trichloroethane stored in eleven-liter bottles. No written operating procedure for removing the uranium from this material had been prepared.

2. A manual wash method to treat the contaminated TCE was developed on an ad hoc basis. This method was cumbersome and invited modification.

3. A new wash method devised by an operator made use of a stirrer-equipped tank that was never meant for use with fissionable material. The tank was of critically unsafe size and shape. With the concurrence of two shift supervisors,

this new method was used in place of the manual method previously mentioned.

4. Because of other process difficulties, several bottles containing large amounts of uranium were generated. Within less than two days, the content of one of these bottles found its way into the new TCE wash method, causing the accident.

5. After the initial accident, two supervisory employees reentered the building and took action that apparently caused a second nuclear excursion.

B. Procedural Matters

1. There appear to have been gaps in communication among plant operating personnel, and between the plant and company management and technical personnel. The plant manager apparently was not made aware of important changes in procedures, and no evidence has appeared that thorough review of logs and problems occurred.

2. It appears that review of process difficulties by management and technical personnel, and

formulation of approved changes in procedure to cope with such difficulties, did not occur at times, although procedures for such review and audit existed. Such practices permitted the informal resolution of the "TCE problem".

3. The Committee believes that the indoctrination of plant personnel in operating procedures and safety practices deserved more emphasis than seems to have been given.

4. In the opinion of the Committee, the control of and access to fissionable material was not commensurate with the hazards involved.

C. Other Conclusions

1. The identification of fissionable material stored in the eleven-liter bottles was rendered difficult by the methods employed in labeling the bottles, and the fact that the labels were not always suitably descriptive of the contents. While labeling practices may not have contributed directly to this accident, they appear to warrant improvement so as to reduce the chance of other accidents.

2. Evacuation of the facility after the accident was prompt and adequate. Notification of company and medical personnel was efficiently performed.
3. Instrumentation on hand was not appropriate for survey following a nuclear incident.
4. The building was reentered without informed assessment of the situation that existed, and without special clothing and other equipment. Information on the presence of possible neutron flux would have been particularly appropriate following an accident of this type.

X. Observations

The Committee believes it appropriate to conclude with a few observations of a general nature. It believes that these can be helpful in reducing the probability of incidents in nuclear fuel processing plants, and in minimizing the consequences if incidents do occur.

1. Control and review of criticality by non-resident personnel are likely to be ineffective unless supplemented by reasonably frequent contact with operations. Day-to-day surveillance of operations by personnel informed on criticality

rules, added to periodic thoughtful audit by competent observers independent of the line operating organization, has been recognized as good practice in most organizations.

2. Plant startup periods are particularly sensitive, and this and other accidents suggest that the vulnerability extends to any period in which activities are unusual. Startups should be recognized as a shakedown of organization, equipment, processes, and procedures. For this reason, operational checkout with unenriched uranium is often considered desirable for new plants and new processes.

3. Training and procedures should provide for coping with process abnormalities, and the ability to modify written procedures after appropriate review should be maintained.

4. Criticality incidents are usually caused by combinations of circumstances, each of which may seem to be minor. Similarly, combinations of inexpensive aids can go far toward preventing such accidents. Examples are signs that act as reminders, and aids that make the proper procedures easy and the improper ones difficult to follow.

5. Training in nuclear plants should be recognized as being needed on a continuous basis, because severe emergency situations will exist so infrequently as to require memory

freshening. There should be means of establishing how well the personnel remember aspects of criticality and health physics practices. The training should continue to emphasize the need for adherence to approved procedures, and the practical non-theoretical aspects of the subject matter.

6. In plants where several forms of concentrations of fissionable material exist, there is always a danger of confusion of material. Identification practices should be clear, unambiguous, and reliable. Those lots of fissionable material that require special geometry or similar treatment to avoid criticality should be specially identified, stored, and controlled, in ways commensurate with their greater potential hazard.

7. A system which has undergone a criticality accident should be left undisturbed until competent review has produced a plan to cope with the situation. Reentry to the immediate area of the accident prior to this time is warranted only if believed necessary to save human life. If there is reentry for this reason, every effort should be made to ascertain the pertinent facts, and for this reason portable high level radiation instruments should be maintained as emergency equipment.