Need For Increased Management Attention To Certain Laboratory Operating Practices In The Nuclear Weapons Testing Program

B-165546

Atomic Energy Commission

UNITED STATES
GENERAL ACCOUNTING OFFICE

SEPT. 17, 1971

UNITED STATES GENERAL ACCOUNTING OFFICE
WASHINGTON, D.C. 20548

CIVIL DIVISION

B-165546

Dear Dr. Schlesinger:

This is our report on the need for increased management attention by the Atomic Energy Commission to certain laboratory operating practices in the nuclear weapons testing program.

We wish to call your attention to our recommendations and the actions agreed to by the Commission staff as discussed in chapter 4 of the report. Your attention is also invited to section 236 of the Legislative Reorganization Act of 1970 which requires that you submit written statements of the action taken with respect to our recommendations. The statements are to be sent to the House and Senate Committees on Government Operations not later than 60 days after the date of this report and to the House and Senate Committees on Appropriations in connection with the first request for appropriations submitted by your agency more than 60 days after the date of this report. Copies of this report are being sent to these Committees.

Copies of this report are also being sent to the Director, Office of Management and Budget; and to the Chairman, Joint Committee on Atomic Energy.

Sincerely yours,

A. T. Samuelson

Director, Civil Division

The Honorable James R. Schlesinger
Chairman, Atomic Energy Commission

GENERAL ACCOUNTING OFFICE
REPORT TO THE CHAIRMAN
ATOMIC ENERGY COMMISSION

NEED FOR INCREASED MANAGEMENT ATTENTION TO CERTAIN LABORATORY OPERATING PRACTICES IN THE NUCLEAR WEAPONS TESTING PROGRAM
Atomic Energy Commission B-165546

D I G E S T

WHY THE REVIEW WAS MADE

D.1529

The Lawrence Livermore Laboratory at Livermore, California, and the Los Alamos Scientific Laboratory at Los Alamos, New Mexico, conceive, design, and test nuclear weapons for the Atomic Energy Commission (AEC). D2-34

The General Accounting Office (GAO) reviewed operating practices of the two laboratories in nuclear weapons testing--a program estimated to have cost about $214 million in fiscal year 1971--because of indications that they were following different practices.

FINDINGS AND CONCLUSIONS

In three areas the laboratories have followed different practices. These often have resulted in significant variations in costs. In GAO's opinion such cost differences demonstrate a need for AEC to adopt procedures for systematically identifying and evaluating the operating practices adopted by the two laboratories, considering both costs and programmatic results. (See p. 10.)

Hole-depth determinations

Livermore and Los Alamos independently have developed different scaling laws, or guidelines used in arriving at the depth of burial necessary to contain radioactivity undergound satisfactorily. The scaling laws are based on the maximum credible yield expected from a particular nuclear device. Livermore and Los Alamos advised GAO that the scaling laws, developed on the basis of experience, did not dictate the actual depth at which a device would be buried. The laws provide merely a starting point in making such a determination. Other factors, such as the location of the proposed test, are considered in relation to expected maximum credible yield in arriving at the hole depth for a particular test.

Using maximum credible yield, GAO compared tests conducted during fiscal years 1968, 1969, and 1970. The comparison showed that, in most cases, Los Alamos had conducted its tests in holes deeper than had Livermore.

GAO requested cost estimates from AEC's architect-engineer contractor involved in the nuclear test program. These estimates showed that the costs of drilling two 48-inch-diameter cased holes, one at a depth of 900 feet and the other at a depth of 1,100 feet, amounted to about $211,000 and $252,000, respectively, or a difference of about $41,000 for the additional 200 feet. GAO noted many tests conducted by Livermore and

SEPT.17,1971

Los Alamos of about the same maximum credible yield in which Los Alamos' holes were about 200 feet deeper than Livermore's holes.

Los Alamos told GAO that there were three principal reasons that it had tested in holes deeper than had Livermore. Los Alamos could not, however, determine numerically the extent that any of these three reasons had contributed to its determination of individual hole depth. The reasons were:

--Geological differences among the test areas used by the two laboratories existed. Los Alamos, however, did not have any studies documenting such differences.

--Los Alamos' policy was more conservative in determining hole depth to avoid radioactive releases than was Livermore's.

--Los Alamos generally scheduled the drilling of test holes farther in advance than did Livermore, which attempted to tailor its hole depth specifically to the planned event. (See pp. 11 to 15.)

Casing of test holes

In some cases steel casing is cemented to the hole walls to stabilize the hole until the nuclear device is emplaced. During the early years of the undergound nuclear test program, both Livermore and Los Alamos used casing in all test holes.

Beginning in 1966 Livermore adopted the practice of using uncased holes because of the high cost of casing. AEC estimated that the costs of casing a test hole amounted to about one half of the total hole costs.

Los Alamos was reluctant to adopt the uncased-hole practice because of the problem which could be created if an uncased hole were to cave in during device emplacement or if the cables leading to the test device were to break during the backfill of the emplacement hole. In fiscal year 1970, however, it began using uncased holes because of budgetary restrictions and the favorable experience of Livermore in testing in uncased holes. (See p. 16.)

Postshot drilling

Postshot drilling is done to secure a sample to be used in obtaining the most accurate yield measurement and certain other information. Livermore's containment equipment involves a filtering system through which filtered gases are expelled into the atmosphere, whereas Los Alamos' equipment involves a recirculating system in which all radioactive gases are circulated back down the hole where they are sealed off.

AEC advised GAO that Los Alamos had much more elaborate containment equipment than did Livermore. Procurement and maintenance costs for a 2-year period for the Los Alamos containment equipment amounted to about $591,000. The cost for the Livermore containment equipment amounted to about $222,000.

Livermore generally uses airfoam as the circulating fluid in drillback operations. Los Alamos uses mud. The cost for each foot drilled is about the same for the two types of fluids.

AEC advised GAO that mud enhanced containment and that the use of mud was consistent with the Los Alamos philosophy of complete containment, whereas the Livermore philosophy allowed for some leakage. During fiscal years 1969 and 1970, the Livermore post-shot-drilling method resulted in radioactive releases in about one of every three post-shot-drilling operations. The Los Alamos method did not release any radioactivity. AEC advised GAO, however, that none of the releases had constituted a significant health hazard to onsite workers and that none of the releases had been detected outside of the test site. (See pp. 17 to 19.)

Recent developments

On December 18, 1970, Livermore conducted an underground nuclear test designated "Baneberry." This test resulted in the release of significant amounts of radioactivity to the atmosphere. After an investigation AEC made changes in its review process to ensure more complete containment of radioactivity. Also changes were being considered in certain of the laboratory testing practices discussed in this report. (See pp. 20 to 26.)

Conclusions

GAO believes that, because of the complexities involved in underground nuclear testing and because of the significant cost of testing, closer coordination among all responsible parties should be maintained to provide greater assurance that both laboratories use the most appropriate testing practices, cost and other factors considered.

Current AEC procedures do not provide for periodically reviewing and evaluating Livermore's and Los Alamos' operating practices for the purpose of identifying differences. AEC advised GAO that (1) many of the different laboratory practices were direct manifestations of competing laboratory programs and design concepts and (2) design of experiments, including the design for containment of radioactivity, was a responsibility which must remain with the laboratories since it was not feasible to separate experimental design objectives and containment objectives.

Although GAO recognizes that only the nuclear laboratories have the technical expertise for determining the appropriate means for accomplishing their respective technical objectives, it believes that AEC should encourage greater use by both Livermore and Los Alamos of those safe and feasible testing practices that emanate from the competition between the two laboratories, considering the programmatic benefits as well as the costs of the practices. (See pp. 27 and 28.)

RECOMMENDATIONS OR SUGGESTIONS

GAO recommends that AEC:

--Establish procedures for systematically identifying and evaluating significant differences in laboratory practices.

--Solicit formal comments from Livermore and Los Alamos regarding the advantages and disadvantages of the different practices.

--Encourage the laboratories to adopt those practices which appear most appropriate from both a programmatic and an economic standpoint. (See p. 28.)

AGENCY ACTIONS AND UNRESOLVED ISSUES

AEC agreed with GAO's recommendations and plans to take appropriate steps to implement them. (See p. 28.)

Contents

ABBREVIATIONS

AEC	Atomic Energy Commission
CEP	Containment Evaluation Panel
GAO	General Accounting Office
LASL	Los Alamos Scientific Laboratory
LLL	Lawrence Livermore Laboratory
NVOO	Nevada Operations Office
TEP	Test Evaluation Panel

GENERAL ACCOUNTING OFFICE
REPORT TO THE CHAIRMAN
ATOMIC ENERGY COMMISSION

NEED FOR INCREASED MANAGEMENT ATTENTION TO CERTAIN LABORATORY OPERATING PRACTICES IN THE NUCLEAR WEAPONS TESTING PROGRAM
Atomic Energy Commission B-165546

D I G E S T

WHY THE REVIEW WAS MADE

The Lawrence Livermore Laboratory at Livermore, California, and the Los Alamos Scientific Laboratory at Los Alamos, New Mexico, conceive, design, and test nuclear weapons for the Atomic Energy Commission (AEC).

The General Accounting Office (GAO) reviewed operating practices of the two laboratories in nuclear weapons testing--a program estimated to have cost about $214 million in fiscal year 1971--because of indications that they were following different practices.

FINDINGS AND CONCLUSIONS

In three areas the laboratories have followed different practices. These often have resulted in significant variations in costs. In GAO's opinion such cost differences demonstrate a need for AEC to adopt procedures for systematically identifying and evaluating the operating practices adopted by the two laboratories, considering both costs and programmatic results. (See p. 10.)

Hole-depth determinations

Livermore and Los Alamos independently have developed different scaling laws, or guidelines used in arriving at the depth of burial necessary to contain radioactivity undergound satisfactorily. The scaling laws are based on the maximum credible yield expected from a particular nuclear device. Livermore and Los Alamos advised GAO that the scaling laws, developed on the basis of experience, did not dictate the actual depth at which a device would be buried. The laws provide merely a starting point in making such a determination. Other factors, such as the location of the proposed test, are considered in relation to expected maximum credible yield in arriving at the hole depth for a particular test.

Using maximum credible yield, GAO compared tests conducted during fiscal years 1968, 1969, and 1970. The comparison showed that, in most cases, Los Alamos had conducted its tests in holes deeper than had Livermore.

GAO requested cost estimates from AEC's architect-engineer contractor involved in the nuclear test program. These estimates showed that the costs of drilling two 48-inch-diameter cased holes, one at a depth of 900 feet and the other at a depth of 1,100 feet, amounted to about $211,000 and $252,000, respectively, or a difference of about $41,000 for the additional 200 feet. GAO noted many tests conducted by Livermore and

Los Alamos of about the same maximum credible yield in which Los Alamos' holes were about 200 feet deeper than Livermore's holes.

Los Alamos told GAO that there were three principal reasons that it had tested in holes deeper than had Livermore. Los Alamos could not, however, determine numerically the extent that any of these three reasons had contributed to its determination of individual hole depth. The reasons were:

--Geological differences among the test areas used by the two laboratories existed. Los Alamos, however, did not have any studies documenting such differences.

--Los Alamos' policy was more conservative in determining hole depth to avoid radioactive releases than was Livermore's.

--Los Alamos generally scheduled the drilling of test holes farther in advance than did Livermore, which attempted to tailor its hole depth specifically to the planned event. (See pp. 11 to 15.)

Casing of test holes

In some cases steel casing is cemented to the hole walls to stabilize the hole until the nuclear device is emplaced. During the early years of the undergound nuclear test program, both Livermore and Los Alamos used casing in all test holes.

Beginning in 1966 Livermore adopted the practice of using uncased holes because of the high cost of casing. AEC estimated that the costs of casing a test hole amounted to about one half of the total hole costs.

Los Alamos was reluctant to adopt the uncased-hole practice because of the problem which could be created if an uncased hole were to cave in during device emplacement or if the cables leading to the test device were to break during the backfill of the emplacement hole. In fiscal year 1970, however, it began using uncased holes because of budgetary restrictions and the favorable experience of Livermore in testing in uncased holes. (See p. 16.)

Postshot drilling

Postshot drilling is done to secure a sample to be used in obtaining the most accurate yield measurement and certain other information. Livermore's containment equipment involves a filtering system through which filtered gases are expelled into the atmosphere, whereas Los Alamos' equipment involves a recirculating system in which all radioactive gases are circulated back down the hole where they are sealed off.

AEC advised GAO that Los Alamos had much more elaborate containment equipment than did Livermore. Procurement and maintenance costs for a 2-year period for the Los Alamos containment equipment amounted to about $591,000. The cost for the Livermore containment equipment amounted to about $222,000.

Livermore generally uses airfoam as the circulating fluid in drillback operations. Los Alamos uses mud. The cost for each foot drilled is about the same for the two types of fluids.

AEC advised GAO that mud enhanced containment and that the use of mud was consistent with the Los Alamos philosophy of complete containment, whereas the Livermore philosophy allowed for some leakage. During fiscal years 1969 and 1970, the Livermore post-shot-drilling method resulted in radioactive releases in about one of every three post-shot-drilling operations. The Los Alamos method did not release any radioactivity. AEC advised GAO, however, that none of the releases had constituted a significant health hazard to onsite workers and that none of the releases had been detected outside of the test site. (See pp. 17 to 19.)

Recent developments

On December 18, 1970, Livermore conducted an underground nuclear test designated "Baneberry." This test resulted in the release of significant amounts of radioactivity to the atmosphere. After an investigation AEC made changes in its review process to ensure more complete containment of radioactivity. Also changes were being considered in certain of the laboratory testing practices discussed in this report. (See pp. 20 to 26.)

Conclusions

GAO believes that, because of the complexities involved in underground nuclear testing and because of the significant cost of testing, closer coordination among all responsible parties should be maintained to provide greater assurance that both laboratories use the most appropriate testing practices, cost and other factors considered.

Current AEC procedures do not provide for periodically reviewing and evaluating Livermore's and Los Alamos' operating practices for the purpose of identifying differences. AEC advised GAO that (1) many of the different laboratory practices were direct manifestations of competing laboratory programs and design concepts and (2) design of experiments, including the design for containment of radioactivity, was a responsibility which must remain with the laboratories since it was not feasible to separate experimental design objectives and containment objectives.

Although GAO recognizes that only the nuclear laboratories have the technical expertise for determining the appropriate means for accomplishing their respective technical objectives, it believes that AEC should encourage greater use by both Livermore and Los Alamos of those safe and feasible testing practices that emanate from the competition between the two laboratories, considering the programmatic benefits as well as the costs of the practices. (See pp. 27 and 28.)

RECOMMENDATIONS OR SUGGESTIONS

GAO recommends that AEC:

--Establish procedures for systematically identifying and evaluating significant differences in laboratory practices.

--Solicit formal comments from Livermore and Los Alamos regarding the advantages and disadvantages of the different practices.

--Encourage the laboratories to adopt those practices which appear most appropriate from both a programmatic and an economic standpoint. (See p. 28.)

AGENCY ACTIONS AND UNRESOLVED ISSUES

AEC agreed with GAO's recommendations and plans to take appropriate steps to implement them. (See p. 28.)

CHAPTER 1

INTRODUCTION

The Atomic Energy Commission develops and produces nuclear weapons for the Department of Defense. Overall responsibility for the direction of AEC's weapons program is vested in the Division of Military Application at AEC Headquarters.

In developing nuclear weapons for the Department of Defense, AEC has the authority to conduct tests involving nuclear detonations. Section 91 of the Atomic Energy Act authorizes AEC to conduct experiments and to perform research and development work in the military application of atomic energy. AEC estimated that, for fiscal year 1971, the costs of its nuclear weapons testing program would amount to about $214 million.

AEC implements its nuclear weapons testing program through its Nevada Operations Office (NVOO). Generally NVOO's mission is to coordinate the planning and execution of AEC's nuclear weapons tests and other nuclear explosive-related experiments in the most economical manner while ensuring the safety of the general public.

Most nuclear experiments are conducted by AEC's two nuclear laboratories--the Lawrence Livermore Laboratory (LLL)[1] and the Los Alamos Scientific Laboratory (LASL). Both LLL and LASL are operated for AEC by the University of California. The Sandia Corporation, which operates AEC's non-nuclear-weapons laboratories, and the Defense Nuclear Agency of the Department of Defense conduct a limited number of nuclear tests.

We reviewed selected aspects concerning the underground testing of nuclear weapons at AEC's Nevada Test Site. Our

---

[1] Prior to June 18, 1971, the laboratory was named the Lawrence Radiation Laboratory.

review was directed primarily toward identifying and assessing different operating practices followed by LLL and LASL in carrying out their test programs, and it did not include an overall evaluation of the testing program.

During our examination we interviewed cognizant officials and/or examined pertinent documents at AEC Headquarters, Germantown, Maryland; LLL; LASL; the Nevada Operations Office, Las Vegas, Nevada; and the Nevada Test Site, Nye County, Nevada.

The contents of this report have been discussed with representatives of AEC, and their comments have been incorporated into the report.

REVIEWS TO ENSURE CONTAINMENT OF RADIOACTIVITY

On August 5, 1963, representatives of the United States, the United Kingdom, and the Union of Soviet Socialist Republics entered into a treaty, commonly referred to as the Limited Test Ban Treaty. The Limited Test Ban Treaty prohibits nuclear explosive tests in the atmosphere, outer space, and underwater but permits underground nuclear detonations unless they cause radioactive debris to be present outside the territorial limits of the nation conducting the test.

In giving its advice and consent to the ratification of the Limited Test Ban Treaty, the Senate insisted on assurance by the President that four safeguards would be implemented under the joint responsibility of AEC and the Department of Defense. One of the safeguards was the continuation of a comprehensive, aggressive, underground nuclear test program.

In carrying out the testing program, LLL, LASL, and AEC conduct a series of reviews to ensure that each proposed test will be conducted safely and within the constraints of the Limited Test Ban Treaty. In planning for a particular experiment, LLL and LASL determine, among other things, (1) the hole depth needed to conduct the test, (2) the stemming plan (method used to fill the emplacement hole), and (3) the effect of the explosion on the surrounding geology and the emplaced hardware. LLL and LASL evaluate and assess those conditions which influence containment of the explosion and

advise AEC of the results of such assessments. At the time of our review, each planned test was then reviewed by a Test Evaluation Panel (TEP) at NVOO.

TEP was established by the Manager, NVOO, on December 16, 1963, shortly after the Limited Ban Treaty was ratified. Creation of TEP stemmed from AEC policy guidance concerning the continuation of weapons development testing and concerning the establishment of formal review procedures designed to reduce the possibility of an individual test's violating, or being regarded as a violation of, the Limited Test Ban Treaty.

TEP was chaired by the NVOO Test Manager and comprised individuals having considerable experience in nuclear testing. Members of TEP included representatives of LLL, LASL, the Department of Defense, Sandia Laboratories, the National Oceanic and Atmospheric Administration, and the Environmental Protection Agency and independent consultants.

The primary purpose of TEP was to review all data pertinent to containment aspects of each planned nuclear test and to report the results of its deliberations and conclusions to the Manager, NVOO, for his review and for further transmittal to the Assistant General Manager for Military Application at AEC Headquarters.

In making recommendations to the Manager, NVOO, TEP classified each planned test into one of the following categories.

> Category A--Underground nuclear tests which, on the basis of experience, should not release a significant amount of radioactive material. It must be understood that, even in this category, unforeseen conditions may develop which result in the release of detectable levels of radioactivity at the U.S. border.
>
> Category B--Underground nuclear tests which are designed to not release a significant amount of radioactive materials but for which design configurations have not been proved by experience.

Category C--Underground nuclear tests which are expected to release a significant amount of radioactive material.

During each TEP meeting presentations normally were made by representatives of the sponsoring laboratory regarding the technical data associated with the test and by representatives of NVOO regarding the construction of the emplacement facility. After all data was presented, members of TEP were requested individually to make a voice vote as to their assignment to a category. In some cases a unanimous vote was not obtained; the Chairman then either instructed the sponsoring laboratory to produce additional data at the next meeting or accepted the majority vote for categorization, his choice depending on the pertinence of the topic of nonagreement.

On occasion TEP assigned a test to a conditional categorization because technical data was not complete and/or an emplacement facility was incomplete. If the test were scheduled for detonation prior to the next scheduled TEP meeting, this data was furnished to TEP by mail or teletype for its review with a request for a vote to remove the conditional categorization.

After each meeting the Chairman of TEP transmitted the recommendations arrived at by TEP to the Manager, NVOO. The Manager, NVOO, in turn, requested execution authority from the Division of Military Application at AEC Headquarters.

The Division of Military Application and the AEC Commissioners reviewed each proposed test, and the Commissioners granted final authority for the execution of each test.

As of June 30, 1971, 233 announced underground nuclear tests had been conducted after the Limited Test Ban Treaty was signed in August 1963. The majority of these tests were conducted at the Nevada Test Site. For operational flexibility each laboratory has been allocated separate areas for conducting its tests at the test site.

- - - -

On December 18, 1970, an underground nuclear test, designated "Baneberry," was conducted at the Nevada Test Site, which resulted in the release of significant amounts of radioactivity to the atmosphere. As a result of this test, AEC has revised certain operating policies and procedures. The discussion in chapter 2, however, is concerned with those differences in laboratory practices which we identified during our review before the Baneberry test was executed.

On March 19, 1971, TEP was renamed the Containment Evaluation Panel (CEP) and its functions and procedures were redefined and reemphasized. The purpose of this change was to emphasize the containment review responsibilities of the principal organizations involved in underground nuclear testing and to strengthen the panel membership in the areas of geology, hydrology, and underground nuclear phenomenology. The CEP and the differences in laboratory practices, as affected by changes made in the testing program resulting from the Baneberry test, are discussed in chapter 3.

CHAPTER 2

DIFFERENCES IN LABORATORY PRACTICES

Our review showed that LLL and LASL had followed different practices with respect to (1) hole-depth determinations, (2) casing of test holes, and (3) postshot drilling, in conducting nuclear tests at the Nevada Test Site. These practices often have resulted in significant differences in costs. In our opinion such cost differences demonstrate a need for AEC to adopt procedures for systematically identifying and evaluating the differing operating practices adopted by LLL and LASL, considering both costs and programmatic results.

AEC officials stated that NVOO was responsible for containment and that such responsibility had been defined in the General Manager's planning directives, which are NVOO's annual operating instructions. The planning directive for fiscal year 1971 stated that the Manager, NVOO, was directed, among other things, to:

1. Assume overall responsibility for the conduct of the nuclear testing operation.

2. Ensure that device emplacement and the firing of test devices, as well as postshot operations, are conducted in a manner consistent with the Limited Test Bank Treaty.

3. Take every precaution necessary to reduce to a minimum the hazards, both to the public and to onsite employees, of a nuclear detonation and any subsequent postshot operation.

With respect to the different practices followed by LLL and LASL, NVOO advised us, in a letter dated May 17, 1971, that:

> "*** NVOO has not conducted formal studies of the different practices of each Laboratory as these practices affect containment. Through our reviews to assure safe detonations and to avoid violation of the Partial Test Ban Treaty we have

always been aware of the different practices and of the new techniques as developed and introduced by each testing organization. The Laboratories efforts in containment prior to Baneberry were treated as an integral part of their experimental efforts and it was never envisioned that the same approach would be used any more than in any other areas of their experimentation."

The major differences in laboratory practices that we identified are discussed below.

HOLE-DEPTH DETERMINATION

In a public document entitled "Safety of Underground Nuclear Testing," dated April 1969, NVOO stated that:

"Containment and venting are reasonably well understood. A very substantial amount of data is in hand on the containment of nuclear explosions over a broad range of yields. Scaling laws have been developed whereby the depth of burial required to contain an underground explosion of yields in the ranges of interest can be calculated with a high degree of confidence. Test emplacement practices that are used today assure comfortable margins of containment safety ***."

AEC advised us in July 1971 that, as a result of experience gained through the conduct of tests subsequent to the above quote, AEC was in the process of revising the document to show a position consistent with this experience. AEC explained that the mechanics of event containment were well understood only from an empirical point of view and that additional investigations needed to be accomplished before the theoretical mechanisms could be fully understood. In addition, AEC said that scaling laws had not been developed for use with a high degree of confidence but that scaling laws had been developed and were being used as a rule of thumb. AEC said also that complete containment design required that each event be sited by considering its individual characteristics.

We were advised by LLL and LASL that the scaling laws referred to above were a function of the maximum credible yield expected from a particular device.

During our review we noted that the two nuclear laboratories had not used similar scaling laws for determining hole depths and that, for tests having comparable maximum credible yields, LLL generally had used hole depths shallower than had LASL.

LLL and LASL officials advised us that the development of the scaling laws for determining hole depths had been an empirical process. They stated, however, that the hole depth indicated by the scaling laws was not the actual working-point depth used for device emplacement but provided merely a starting point in determining the actual depth at which a test would be conducted. We were informed, for example, that the hole depth indicated by the scaling laws normally was increased for more complex diagnostic experiments which required more experimental equipment in the hole. In addition, other factors, such as the location of the proposed test in relation to past events or nearby holes, must be considered.

AEC advised us that both LLL and LASL believed that high-yield tests could be conducted at shallower depths scaled in relation to yield than could low-yield tests. Once the proper depth has been selected, even further increases in depth may be required. For example, the test experiment may call for a mined room at the bottom of the hole. For this type of experiment, the hole depth may be dictated partially by the need for a competent rock formation.

Because both LLL and LASL advised us that the hole depths calculated by their scaling laws were not the actual working-point depths used, we compared the actual hole depths used for LLL and LASL tests conducted during fiscal years 1968, 1969, and 1970. Our review of those tests by maximum credible yield showed that, generally, LASL had used holes deeper than had LLL.

AEC advised us that each laboratory considered the differences in the geology of its test areas in determining

depth of burial. AEC stated, however, that, in many areas, the geology was uniform enough so that changes for containment reasons might not be required.

To obtain an indication of the magnitude of the cost difference in drilling test holes at various depths, we requested estimates of drilling costs from NVOO. Fenix and Scission, Inc., NVOO's architect-engineer contractor, prepared cost estimates for drilling two 48-inch-diameter cased holes, one at a depth of 900 feet and the other at a depth of 1,100 feet. These estimates showed that the costs of drilling the 900-foot hole and the 1,100-foot hole amounted to about $211,000 and $252,000, respectively, or a difference of about $41,000 for the additional 200 feet. We noted many tests conducted by LASL and LLL of about the same maximum credible yield in which LASL's holes were about 200 feet deeper than LLL's holes.

Because of the different scaling laws and different hole depths used by the laboratories for tests having similar maximum credible yields and because of the significance in drilling costs, we discussed with LLL and LASL the reasons that accounted for the disparity in hole depths. The principal reasons presented by LASL for using holes deeper than LLL used for tests in the same yield range follow.

1. Geologic differences of the LLL and LASL test areas--LASL explained that the geology of its test area was different from the geology of LLL's test area. According to LASL the composition of its area's geology is less compact than that of the LLL area. LASL stated that its experience, due to this geologic difference, had indicated that its hole depths should be deeper. LASL, however, did not have any documented studies on the basic geological differences between the LLL and LASL test areas.

2. Conservatism--LASL advised us that it was more conservative than LLL in determining hole depths to avoid radioactive releases.

3. Scheduling differences--LLL schedules the drilling of its test holes 60 to 90 days before a test hole is needed and attempts to tailor its hole depth specifically to the planned event. LASL, however, provides NVOO with a drilling schedule for an

entire year. Under LASL's method test holes may not be utilized to the maximum extent possible because requirements may change during the year. LASL advised us, however, that it did update its drilling schedule periodically and that no significant inefficiency resulted from its scheduling method.

We discussed the above-mentioned factors with LASL to determine the extent to which each contributed to the specific depths for individual test holes. LASL advised us, however, that it could not quantify the extent to which these factors affected hole depths.

Because LLL generally conducted its tests in holes shallower than did LASL, we selected all LLL tests, conducted from January 1968 through October 1970, in which significant amounts of radioactive releases had been measured, to determine whether the releases had been attributed to inadequate depths of burial. We considered a significant release to be 100 curies or more. According to AEC records release of radioactivity generally must go well above 100 curies before it is detected offsite. In reviewing LLL's records of these releases, we found that none of the causes had been attributed by LLL to inadequate depths of burial.

During our review, however, LLL conducted a test designated "Baneberry." This test resulted in the release of significant amounts of radioactivity to the atmosphere. The Baneberry Summary Report, which resulted from a technical investigation of the failure of the Baneberry test to be contained underground, concluded that the primary cause of the release was:

"*** an unexpected and abnormally high water content in the medium surrounding the detonation point. This increased the coupling of energy into the earth and also extended the duration of high pressures in the cavity. The end result was the shot's behaving as if it were of higher effective yield and <u>therefore emplaced at too shallow a depth</u>. <u>The nature of the eventual release</u>

is what could be expected for an underburied test." (Underscoring supplied.)

This particular test is discussed in detail in chapter 3.

CASING OF TEST HOLES

During the early years of the underground nuclear test program, both LLL and LASL used casing in their test holes. According to LLL the primary function of casing is to stabilize the test hole until the nuclear device is emplaced. NVOO advised us that the costs of casing a test hole amounted to about one half of the total hole costs. (See p. 13.)

LLL advised us that, in August 1966, it adopted the practice of using uncased holes for its tests because of the high costs of casing. LLL reasoned that, if a hole stood long enough to complete the drilling, it would stand long enough to emplace the nuclear device. LLL further explained that this method was workable because its test holes usually were drilled for specific events and did not stand long once completed. In addition, LLL expressed the opinion that casing did not enhance the capabilities for containing radioactivity. We were informed, however, that LLL would use casing in certain situations, such as:

1. Holes that are drilled below the static water table.

2. Experiments that use mined rooms. Safety precautions will not permit anyone to go down a hole unless it has been cased.

LASL advised us that it had been reluctant to adopt the uncased-hole practice because of the problems which could be created if an uncased hole were to cave in during device emplacement or if the cables leading to the test device were to break during the backfill of the emplacement hole. LASL explained that a man could be sent down a cased hole to repair broken cables but that it would be very difficult and dangerous in an uncased hole.

LASL advised us that, nevertheless, it began using uncased holes in fiscal year 1970 because of budgetary restrictions and the favorable experience of LLL in testing in uncased holes. During fiscal year 1970 only three of a total of 22 holes drilled for LASL were uncased. In October 1970 LASL's drilling schedule for fiscal year 1971 showed that, of a total of 26 holes, 21 would be uncased.

POSTSHOT DRILLING

Postshot drilling is a drillback technique used to obtain a sample from the immediate vicinity of the test cavity for the purpose of obtaining the most accurate yield measurement and certain other diagnostic information. LLL and LASL used different techniques to accomplish their postshot-drilling operations. These differences involve primarily the type of circulating fluid and the containment equipment used.

In a letter dated December 17, 1970, NVOO provided us with a list of LLL and LASL tests performed during fiscal years 1969 and 1970 on which postshot drilling was conducted. This information showed that, during the 2-year period, LLL's post-shot-drilling method had resulted in radioactive releases in about one of every three drillbacks and that LASL's post-shot-drilling method had not resulted in radioactive releases.

AEC advised us that none of the releases had constituted a significant health hazard to onsite workers and that none of the releases had been detected outside of the test site. The different post-shot-drilling methods used by LLL and LASL are discussed below.

Circulating fluid

Generally, LLL uses airfoam as the circulating fluid in drillback operations and LASL uses drilling mud.[1] LLL officials have expressed the opinion that airfoam is cheaper than mud because a considerable amount of mud is lost downhole. LLL maintains that drilling with airfoam has a faster penetration rate and that there are fewer hole problems, such as drilling equipment's sticking in the hole.

LASL explained that it used mud for the circulating fluid in postshot drilling for several reasons, including:

---

[1]Drilling mud is a liquid, usually water, which carries various solids, such as barite, in suspension to thicken it. The formulation is carefully controlled according to the current drilling situation.

1. Mud provided a more stable hole; therefore less holes were lost.

2 Mud provided a barricade to radioactive gases.

3. Mud acted as a coolant.

4. Mud acted as a better lubricant for the drill bit.

NVOO officials advised us that mud enhanced containment and that the use of mud for postshot drilling was consistent with LASL's philosophy of complete containment, whereas LLL's philosophy allowed some leakage. These officials also stated that, although mud cost more than airfoam, the cost for each foot drilled was about the same because mud allowed for a lower maintenance cost for the drill bit.

Containment equipment

In the past Fenix and Scisson, Inc., made trend analyses of post-shot-drilling costs for NVOO. These trend analyses showed that the costs for each foot in postshot drilling were about the same for LLL and LASL. We noted, however, that the costs of containment equipment had not been included in such analyses.

NVOO has defined containment equipment as that equipment which is used to control radioactivity release during postshot reentry activity with a drill rig. According to NVOO, LASL has much more elaborate containment equipment than has LLL. NVOO provided us with the following costs of procurement and maintenance for containment equipment over a 2-year period.

Procurement and Maintenance Costs of Postshot Containment Equipment

	Fiscal year 1969	Fiscal year 1970	Total
	(000 omitted)		
LASL:			
Procurement	$ 95	$102	$197
Maintenance	219	175	394
Total	$314	$277	$591
LLL:			
Procurement	$ 36	$ 38	$ 74
Maintenance	67	81	148
Total	$103	$119	$222

LLL informed us that it used only that amount of containment equipment which it believed necessary but that safety was the primary consideration. LLL uses a filtering system that expels filtered gases into the atmosphere.

LASL informed us that its equipment was designed for complete containment. LASL uses a recirculating system in which all radioactive gases are circulated back down the hole where they are sealed off. LASL agreed that its containment equipment was much more sophisticated and costly than LLL's but explained that the use of such equipment was in agreement with LASL's philosophy of complete containment.

CHAPTER 3

ACTIONS TAKEN BY AEC AS A RESULT OF RADIOACTIVE RELEASE FROM BANEBERRY TEST

During our review LLL conducted a test designated "Baneberry," which resulted in the release of significant amounts of radioactivity to the atmosphere. Because of this release, which amounted to about 3 million curies,[1] AEC initiated a self-imposed moratorium on testing; conducted a technical investigation of Baneberry; and revised its current operating policies and procedures to ensure proper and clear assignment of responsibilities, adequacy of documentation, and appropriate dissemination of information.

An ad hoc committee was appointed by the Manager, NVOO, to investigate the Baneberry test. The committee concluded that the primary cause of the Baneberry release was an unexpected and abnormally high water content in a relatively limited area around the Baneberry site. (See p. 14.) According to AEC this geological environment was unique in relation to AEC's previous test experience.

According to AEC records there was an insufficient recognition of material properties in the immediate vicinity of the Baneberry site before the test was executed. In particular, certain unknown water-saturated clay layers were not recognized in selecting the depth of burial. LLL officials advised us that LLL had been aware of the high water content in samples taken from a nearby exploratory hole. They stated, however, that the hole had been drilled with water as the circulating medium and that this factor was considered by LLL to be the cause of the high water content in the sample taken.

---

[1] Calculated at 12 hours after release. The gross fission products released amounted to about 700 million curies.

According to AEC the following actions will be taken to minimize the possibility of such an occurrence in the future.

1. Since the proper depth is dependent on the physical properties of the medium in which the experiment is conducted, these properties will be determined in all geologically complex regions or in new media to allow proper determination of the depth of burial for the experiment. This will require exploratory drilling sufficient to know the geology from the surface to the working point.

2. Construction activities, particularly those which introduce large quantities of water during drilling operations, can change the preexisting properties of the medium. Such activities will be monitored, and any significant modifications will be incorporated in the determination of a proper depth of burial.

3. Increased theoretical attention will be given to the hydrodynamic problems associated with ground response and to the determination of a proper depth of burial for each specific medium.

As pointed out on page 10, AEC officials advised us that the annual planning directives defined NVOO's responsibility with respect to containment. Subsequent to the Baneberry investigation, the Assistant General Manager for Military Application, on February 26, 1971, issued the following policy statement concerning the responsibilities for containment.

> "The Director of the weapons laboratory sponsoring a test at the Nevada Test Site is responsible to the Manager, Nevada Operations Office, for the proper containment of that test. The Manager, Nevada Operations Office, in turn is responsible to the General Manager through the Assistant General Manager for Military Application for the overall safe conduct of the test and for the review of the test through the Test Evaluation Panel."

In addition, on March 26, 1971, the Assistant General Manager for Military Application transmitted the following information.

> "To ensure a clearer and more precise understanding of the intent of the policy guidance provided in the [February 26, 1971] message, the policy statement has been changed to read as follows:
>
> > 'The Manager, Nevada Operations Office, is responsible to the General Manager through the Assistant General Manager for Military Application for the proper containment and safe conduct of tests and for the review of tests through the Test Evaluation Panel. The Director of the weapons laboratory sponsoring a test is responsible to the Manager, Nevada Operations Office, for the design of systems to provide such proper containment of the test.' " (Underscoring supplied.)

After the Baneberry test NVOO restructured TEP under a new charter and renamed it CEP. For CEP the mix of voting members was changed to emphasize factors affecting complete containment of proposed tests rather than to emphasize consideration of conditions affecting safety if a release did occur. Therefore several TEP voting members, including (1) a medical doctor, (2) a representative from the Environmental Protection Agency, and (3) a representative from the National Oceanic and Atmospheric Administration, were to become nonvoting advisers to CEP. Also experts in the fields of geology and hydrology were to be added as voting members of CEP. [6]

The purpose of CEP is to assist the Manager, NVOO, in the review of proposed nuclear tests to ensure that:

> "*** the containment design is one which will (a) provide reasonable assurance of satisfactory containment; or (b) release radioactivity under controlled conditions and/or within the guidelines established by the General Manager."

As previously discussed (see pp. 7 and 8), TEP was created to establish formal review procedures designed to reduce the possibility of an individual test's violating, or being regarded as a violation of, the Limited Test Ban Treaty. In essence a violation of the Limited Test Ban Treaty would be indicated by the detection of radioactive debris outside the territorial limits of the United States.

AEC advised us that the formation of CEP had added further emphasis on containment in contrast to TEP which had emphasized the review and evaluation of data associated with proposed tests to determine the possibility of such tests' resulting in violation of the Limited Test Ban Treaty.

As defined in the new charter for CEP, the policy of AEC is that, except for specific tests approved for release of radioactivity, all nuclear tests shall be planned and conducted in such a manner as to be contained satisfactorily. AEC defines satisfactory containment as that which will result in no radioactivity measurable offsite by normal monitoring equipment and in no unanticipated release of radioactivity onsite.

As described in its charter, CEP will be responsible to the Manager, NVOO, for the review of the containment plan of each test. The proposing laboratory will be responsible for such plans. Specifically CEP will:

"a. Review the containment design and those experimental features which affect containment of each test. When appropriate, recommend to the laboratory which proposes the test changes to enhance containment such as changes in siting, burial depth, etc. When needed, request additional information to clarify and verify conditions which affect containment.

"b. Categorize each proposed test as follows:

Category I - Underground nuclear tests which, on the basis of experience and judgment, will be contained satisfactorily.

Category II - Underground nuclear tests which are designed to be contained satisfactorily but which in the judgment of the CEP cannot be assigned to Category I because of location, configuration or other factors. It is expected that experiments in this category will require special consideration and approval before being conducted.

Category III - Underground nuclear tests which are expected to release a significant amount of radioactive material. Experiments in this category will require special consideration and approval before being conducted.

"c. After the detonation of a test which releases radioactivity, review the circumstances and assess the reason for the release of radioactivity, its extent and remedial measures which should be considered in the design of future tests and/or recommend additional investigations.

"d. When requested, evaluate predictions of amounts of radiation that may be expected off-site and the expected concentrations at border exits."

In contrast to the procedures of TEP, in which only the majority vote was summarized, the procedures of CEP require that categorization be made individually by each panel member with a written statement as to the reasons for the assignment. These categorizations, written conclusions, meeting minutes, and whatever further explanation as is appropriate constitute a recommendation to the Manager, NVOO, that each test can or cannot be detonated with satisfactory containment.

Because of the significant release from the Baneberry test and because of its effect on the testing program, we asked LLL and LASL officials whether any changes would be made in their testing practices. These discussions are summarized below.

HOLE-DEPTH DETERMINATION

According to LLL Baneberry has emphasized that standard formulas for computing hole depths cannot be applied for all nuclear tests and that past experiences with containment cannot be used as the primary criteria for determining future hole depths. LLL stressed that more information now must be known about the geology, hydrology, etc., of the immediate vicinity of each proposed test location.

LLL had not determined, at the time of our review, what its new criteria would be. LLL stated, however, that, in the future, deeper holes probably would be used by LLL for lower yield tests and that both LLL and LASL probably would be using similar criteria. No decision with respect to this matter had yet been made.

LASL advised us that, after a careful examination of its past experience, it had concluded that its criteria for determining hole depths were adequate and would not change. LASL advised us also that, in the future, more information concerning the immediate area of each test location would be obtained; however, it did not know how the information would be used or to what extent each factor would be weighed in hole-depth determinations.

CASING OF TEST HOLES

LLL advised us that, because CEP might require that all actions associated with a test be completed before CEP reviewed a proposed test, LLL might be required to schedule the drilling of its test holes further in advance of planned tests than it had previously. LLL stated that, because this practice of scheduling usually would result in holes' standing longer before they were used, it probably would have to use more cased holes. We noted, however, that the first three LLL tests proposed to CEP were planned to be executed in uncased holes.

LASL stated that it had always had some reservations regarding radioactive containment within an uncased hole. LASL also advised us that, as a result of the Baneberry test, in the immediate future it would use only cased holes to

provide a greater assurance of containment. Subsequently AEC advised us that both LLL and LASL would use a mix of cased and uncased holes, depending on site geology and experiment design.

POSTSHOT DRILLING

LLL advised us that, as a result of the Baneberry test, AEC was placing more emphasis on improving containment. Because of this increased emphasis, LLL did not know whether it would be required to change its post-shot-drilling method.

LASL advised us that it did not plan to change its method of postshot drilling.

CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS

The primary purposes of conducting nuclear tests underground are to obtain the desired diagnostic information and to avoid the release of radioactivity to the atmosphere. We believe that, because of the complexities involved in underground nuclear testing and because of the significant cost of testing, closer coordination among all responsible parties should be maintained to provide greater assurance that both laboratories use the most appropriate testing practices, considering the costs and benefits involved.

LLL and LASL have been following different practices with respect to (1) hole-depth determinations, (2) casing of test holes, and (3) postshot drilling, in conducting nuclear tests at the Nevada Test Site. Such practices often have resulted in significant differences in costs.

As pointed out in chapter 3, AEC has revised its procedures for reviewing proposed nuclear tests and, in addition, has more clearly defined NVOO's responsibility for ensuring containment of radioactivity in underground nuclear tests. It appears that such actions will increase NVOO's awareness regarding its responsibilities for ensuring containment of nuclear tests and that the increased emphasis placed on CEP will increase the probability of containment on individual tests.

Current NVOO procedures do not provide for periodically reviewing and evaluating LLL's and LASL's operating practices for the purpose of identifying differences. AEC advised us that (1) many of the different laboratory practices were direct manifestations of competing laboratory programs and design concepts and (2) design of experiments, including the design for containment of radioactivity, was a responsibility which must remain with LLL and LASL since it was not feasible to separate experimental design objectives and containment objectives.

Although we recognize that only the nuclear laboratories have the technical expertise for determining the appropriate means for accomplishing their respective technical objectives, we believe that AEC should encourage greater use by both LLL and LASL of those safe and feasible testing practices that emanate from the competition between the two laboratories, considering the programmatic benefits as well as the costs of the practices.

RECOMMENDATIONS

We recommend that, in view of the different practices followed by LLL and LASL in the past with respect to underground nuclear testing, AEC:

1. Establish procedures for systematically identifying and evaluating significant differences in laboratory practices.

2. Solicit formal comments from LLL and LASL regarding the advantages and disadvantages of the different practices.

3. Encourage the laboratories to adopt those practices which appear most appropriate from both a programmatic and an economic standpoint.

AEC agreed with our recommendations and advised us that it would take the action necessary to ensure implementation.

Copies of this report are available from the U. S. General Accounting Office, Room 6417, 441 G Street, N W., Washington, D.C., 20548.

Copies are provided without charge to Members of Congress, congressional committee staff members, Government officials, members of the press, college libraries, faculty members and students. The price to the general public is $1.00 a copy. Orders should be accompanied by cash or check.