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

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ADDENDUM MATERIAL FOR CLASSIFIED TECHNICAL BRIEFINGS

The attached material is forwarded for review and concurrence. This material, together with the previously forwarded final draft copy of the unclassified technical briefings, constitutes a major portion of the classified briefings to be presented to the Office of Science and Technology ad hoc committee on nuclear underground test safety presently scheduled for November 7 and 8, 1968. Your comments, suggestions and concurrence are requested by memorandum.

Remaining material will be forwarded as received.

CLASSIFICATION CANCELLED
WITH DELETIONS
BY AUTHORITY OF DOE/OC
J. Diaz 1/27/88
REVIEWED BY Carl Wilson DATE 3/29/88

Andrew Boreske Jr.
Andrew Boreske, Jr.
Colonel, USAF
Assistant Director for Tests
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Attachments:
1. Illustration (Cy 10A)
2. Addendum - Off-Site Radiological Safety Program (Cy 10A)
3. Addendum to Attachment 1
4. Seismological Consideration

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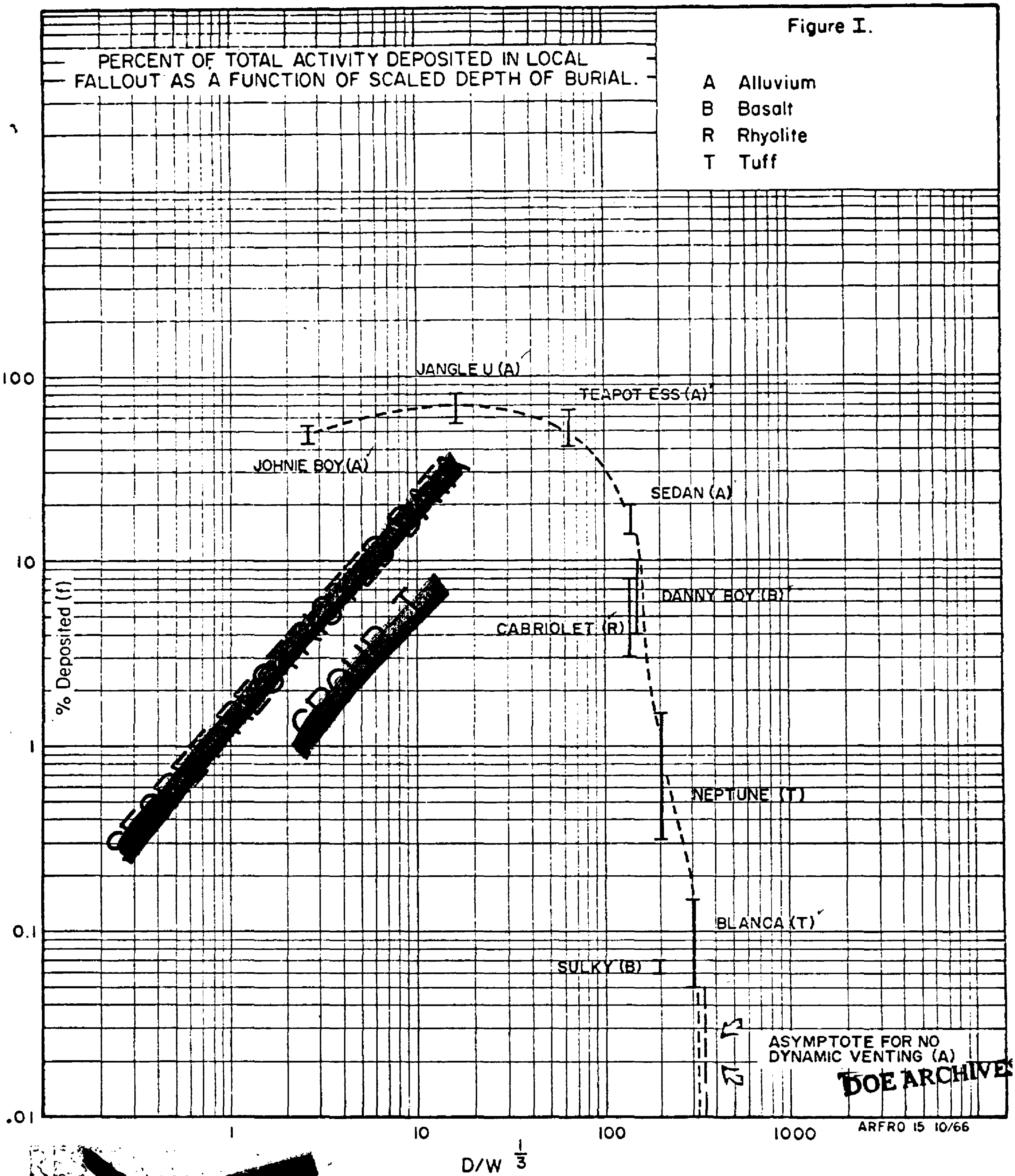
Figure I.

PERCENT OF TOTAL ACTIVITY DEPOSITED IN LOCAL FALLOUT AS A FUNCTION OF SCALED DEPTH OF BURIAL.

A Alluvium
B Basalt
R Rhyolite
T Tuff

[redacted]

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ADDENDUM

OFF-SITE RADIOLOGICAL SAFETY PROGRAM

SOUTHWESTERN RADIOLOGICAL HEALTH LABORATORY

CONSUMER PROTECTION AND ENVIRONMENTAL HEALTH SERVICE

This addendum is intended to cover several areas of the PHS-SWRHL program that could not be covered in the unclassified presentation. These areas are:

1. Pre-event evaluation and assessment of potential hazards from individual events.
2. Results for various isotopes that could possibly be evaluated to indicate a boosted or thermonuclear device and to determine the fusion yield.
3. Unannounced events.

Evaluation of the public health aspects of a given event will be affected by the following classified information:

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~~GROUP 1~~
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1. Device characteristics
   - fission/fusion ratio
   - device yield
   - various device incasement methods DELETED

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2. Emplacement methods - stemming material, etc.

3. Experiments associated with the event, for example:
   - tunnel shot with line-of-sight pipe from device chamber to main tunnel shaft.
   - well-type shot with line-of-sight pipe.
   - various emplacements of sampling lines to obtain samples of device residue.

These and other factors affect the potential consequences of a shot. They are all considered in deciding whether an event can be safely conducted and establishing the necessary safety support program. These parameters have a bearing only on the pre-event evaluation or potential hazards analysis, although their analysis determines the type and extent of the SWRHL field program (Chapter IV of the unclassified presentation). The results of our event-related surveillance program, except for certain isotopes (e.g., ^{3}H and [redacted] are not classified. It is the intent of this addendum to show that, under the circumstances of the NTS testing program, these "classified" isotopes are not the critical isotopes for public exposure. If the exposure from the radioiodines is kept below the FRC guidelines, then the exposures due to tritium and [redacted] will be only a fraction of the guideline values.

DEVICE CHARACTERISTICS

This topic, as it affects the safety program, will be discussed primarily by others. It has two effects on our program:

1. It indicates the relative quantity of radioactive material that may be released. DELETED

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2. It indicates what isotopes may be present in the effluent. This information may not be important from the standpoint of public exposure, but is essential for proper analytical techniques. The gamma spectra of many of the tracer or device activation isotopes (^{198}Au, [redacted] ^{126}I)

interfere with normal fission product radioiodine spectra. Their presence, especially if it is not known, prevents accurate quantitation of the radioiodine isotopes.

There is a general policy of announcing all events that are detected on the ground off-site. To date the only event that was detected off-site and was not announced was the Drill Event of December 5, 1964, 1315 PST. The circumstances surrounding the status of this event are unusual. The Crepe Event was conducted without incident on the same day and it, rather than the Drill Event, was announced.

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Following is a summary of the monitoring and surveillance results for the Drill Event (yield 2.7 Kt):

Ground Monitoring:

1. Peak - 0.2 mR/hr at 1830 PST, 5 miles east of Lathrop Wells, Nevada, on Highway 95.

2. The only measured exposure rate above background by a routine station recorder (RM-11) was less than 0.1 mR/hr at 1717 PST at Lathrop Wells, Nevada.

3. Radioiodine was not detected in milk or water samples.

4. The highest air sample result was:

Location	Sampling Period	^{131}I pCi/m^3	^{131}I pCi-sec/m^3	^{133}I pCi/m^3
Shoshone, California	12/5 1000-1630	1.1	2.6×10^4	<1

It should be pointed out that this concentration is marginal with respect to the detection limits of the counting system.

The estimated thyroid dose from radioiodine inhalation at Shoshone was less than 0.1 mrad. The integrated exposure at the location of highest exposure rate, an unpopulated location, was about 0.1 mR. From the available information, the best estimate of the exposures resulting from this event is less than 0.1% of the AEC or FRC Guides.

TRITIUM RESULTS

Increases in tritium concentration in the off-site environment have been noted following several events (e.g., Cabriolet and Buggy I). In addition to these events, the aerial sampling program has detected tritium in the effluents from the Nash and Scroll Events. The intent is not to imply that these are the only events to have released tritium, but rather to use these results to obtain an indication of the potential hazard of exposure of the general population to tritium. Thus, results from on-site and aerial cloud sampling results are used, not because they represent potential exposures of the population, but because they are a conservative upper estimate of potential exposures.

The following tabulations of tritium results are indicative of the concentrations encountered following a few representative events.

1. SCROLL 4/23/68 1130 PST **DELETED** Underground

Aerial Sampling

Midpoint of Sampling Time	Location	Tritium pCi/ml of Moisture	Tritium pCi/m^3 of Air
1407	Over GZ	8.9×10^3	3×10^4
1407	Over GZ	2.9×10^3	9.3×10^3

The first sample was taken over a shorter period of time than the second and thus is averaged over a shorter period of time. Normal background levels of 1 - 2 pCi/ml have been subtracted. All later references to background values for this type of sample will be taken to mean 1-2 pCi/ml of moisture.

2. NASH 1/19/67 0845 PST **DELETED** Underground
(Venting did not start until about 1800 on 1/19/67 and continued until about 1100 on 1/21/67.)

Aerial Sampling

Midpoint of Sampling Time		Location	Tritium pCi/ml of Moisture	Tritium pCi/m^3 of Air
1059	1/20	Over GZ	8.9	42
1214	1/20	Over GZ	7.3	10

The first sample possibly had some moisture in it prior to the sampling run. This moisture would have been at background levels and would affect the pCi/ml result, but not the pCi/m^3 result. Results include normal background levels.

3. CABRIOLET 1/20/68 0800 PST 2.6 Kt Cratering

Aerial sampling not available.

Air Samples

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Water Samples

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Aerial Results

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Snow Samples

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DISCUSSION

Few, if any, of these results represent actual population exposures. They are the maximum tritium results obtained from the various events and are an indication of the upper level of potential exposures.

The radiation protection guides from AEC-MC 0524 for individuals in the population are:

$$\text{Air} = 2 \times 10^{-7}\ \mu\text{Ci/cc} = 2 \times 10^{5}\ \text{pCi/m}^3$$

$$\text{Water} = 3 \times 10^{-3}\ \mu\text{Ci/cc} = \overset{3}{2} \times 10^{6}\ \text{pCi/l}$$

Integrating these over a period of ~~one~~ Year day gives: 3.15 x 10^7 sec →

$$\text{Air} = 1.7 \times 10^{10}\ \text{pCi-sec/m}^3$$

~~Water = 2.0 x 10^6 pCi-day/m^3~~

These guides are for yearly average exposures, thus they should not be directly applied as an upper limit on a daily basis.

[redacted]

An estimate of the potential tritium exposure can be obtained by comparing the tritium concentration in water condensed from the cloud. Reviewing the previous results from this standpoint, water from the highest ground level air sample result (~~Buggy A~~ Cabriolet at 20 miles) is only 7.5 times the continuous exposure guide. It should be noted that (1) this location was on-site; and (2) it would be very hard, in fact impossible, for enough water to be removed during cloud passage (unnaturally or naturally by rain, etc.) to amount to more than several days drinking supply. A similar statement can be made for water from aerial samples; even those collected over GZ.

Taking a more reasonable approach, all the air samples, even the aerial ones collected over GZ, are ~~less than one-hundreth~~ only a fraction of the daily average protection guides. Also, all the water results, including snow samples, are less than 1/30 of the daily concentration guides. None of these water samples represents human drinking water supplies. It is evident that the actual exposures of the population to environmental levels of tritium were considerably below the guides.

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Under a national administration policy announced at the White House level in 1961 after the Soviet Union broke the three-year nuclear test moratorium, we do not publicly announce all tests. The fact that a test has been conducted which has not been announced is classified. The current policy is that we announce almost all tests DELETED

DELETED unless there are reasons for a public statement such as a venting, or experiments associated with the test that will be discussed later in unclassified publications. The current policy is that all peaceful purposes tests are announced, and their general purpose described in the announcement.

During the years when tests were conducted in the atmosphere, weapons laboratory researchers wished often that some sort of steady rate of testing could be achieved. In those years, tests bunched up to be performed in a series every year or two in Nevada or the Pacific.

The slide shows that a steady rate has been achieved to a reasonable degree since underground testing became the basic policy. The totals relate to tests during a fiscal year. The rises and declines per year reflect fiscal policy at the national nevel, the basic requirements of the military in terms of effort needed, and a few other factors. The difference in number of tests year to year is not great, as you can see.

[redacted]

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[redacted]

However, when total yield of individual test devices is considered, there have been changes of considerable magnitude in the program since 1961. The changes upward have been dictated by need, and were made as experience was gained. The slide shows in a general way the step-up in maximum yields of underground test devices by fiscal years.

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we moved upward in 1964 to Bilby with a yield of about 235 kilotons, then on to Halfbeak in 1966 with about 350 kilotons, to Greeley in 1967 with about 870 kilotons, and to Boxcar in 1968 with about 1300 kilotons. The yield figures must be approximations where any appreciable fusion contribution is concerned, since post-shot radiochemistry analysis to determine thermonuclear yield is very difficult.

It has been the Commission's policy to step up yields on a careful and prudent basis so ground motion effects, in particular, can be extrapolated on a reasonable basis to future events, rather than take a chance of some unexpected and possibly damaging effect coming along with any radical escalation of yield.

Obviously, as yields have increased, depths required for containment have increased also. The first underground tests designed for containment were in mined horizontal shafts. A little later, some so-called safety experiments were conducted in drilled vertical shafts not designed for containment, but to increase earth capture of radionuclides. This history goes back to 1957 and 1958.

[redacted]

The next slide gives an indication of increasing hole depth with time, and of course is not too different from the trend in the slide on yield escalation. However, it may be of interest that the depth of burial of the Boxcar device [redacted] was 3,800 feet. This was somewhat less than that of the Greeley device, which [redacted] was buried at 3,990 feet. The current estimates of actual yields, as noted previously, are 870 kilotons for Greeley and something like 1300 kilotons for Boxcar. At the Greeley location in the igneous formations of the Pahute Mesa area of the Nevada Test Site, it took about nine months for the resulting chimney of broken rock to fall in all the way to the surface, and that is not a desirable phenomenon at such a late date because of on-site safety considerations. This slide illustrates why--the hole was about 300 feet wide and 150 feet deep with essentially vertical side walls. Boxcar was placed at a shallower depth in the same type of formation so chimneying could continue to the surface soon because of the cracking radius, and surface collapse did occur in about an hour and 45 minutes. This slide shows the result-- much like subsidences in the alluvium of Yucca Flat. The subsidence is about 900 feet wide and 275 feet deep.

~~This material contains information affecting the national defense of the United States within the meaning of the espionage laws, Title 18, U. S. C., Secs. 793 and 794, the transmission or revelation of which in any manner to an unauthorized person is~~

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FISCAL YEAR

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NUMBER OF SHOTS WITH INCREASING HOLE DEPTH

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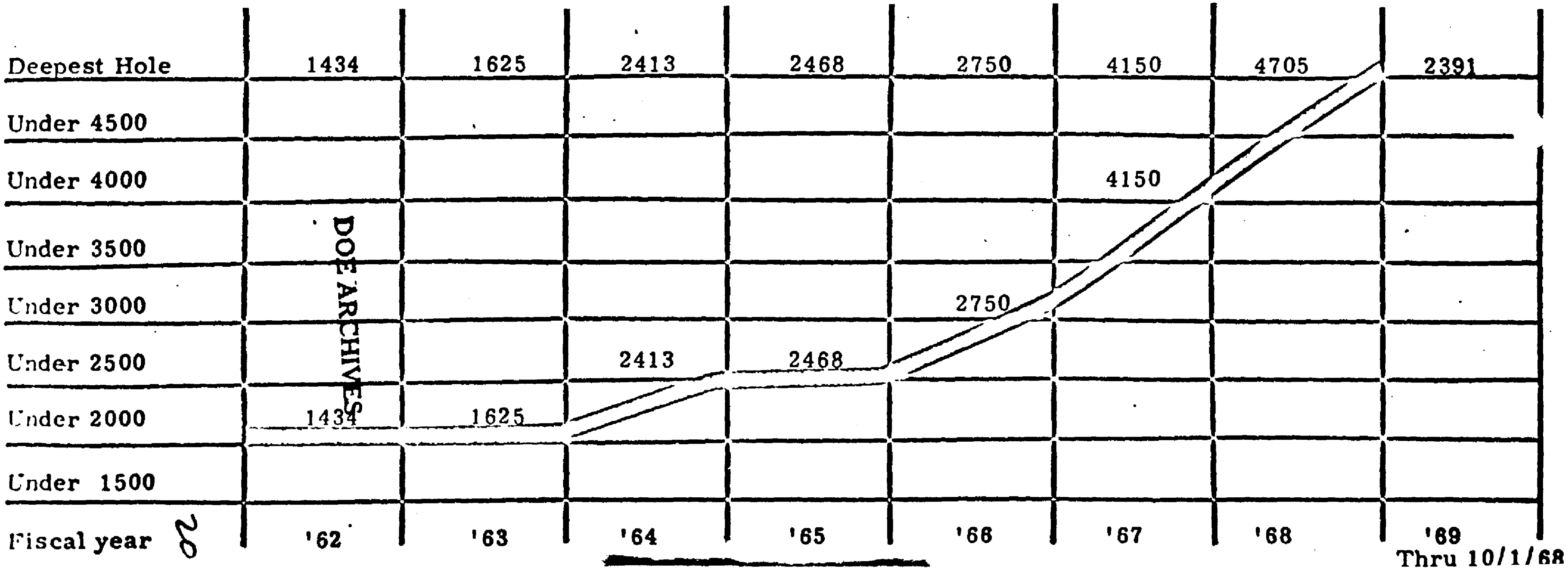

Deepest Hole	1434	1625	2413	2468	2750	4150	4705	2391
Under 4500								
Under 4000						4150		
Under 3500								
Under 3000					2750			
Under 2500			2413	2468				
Under 2000	1434	1625						
Under 1500								
Fiscal year	'62	'63	'64	'65	'66	'67	'68	'69 Thru 10/1/68

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SEISMOLOGICAL CONSIDERATION

BY ROLAND F. BEERS

October 8, 1968

INTRODUCTION

Some of you may be surprised to hear me say that the science of seismology is a relatively young science, even though observation of earthquakes and their effects has drawn the attention of man since the earliest civilization. We realize that until nearly the end of the nineteenth century data collected from earthquakes was mainly qualitative. Moreover, because of the spectacular nature of large earthquakes and their effects on human beings, these observations without instruments were unreliable and strongly colored with emotion.

It is important to recognize that even now, in the twentieth century, popular accounts of earthquakes and their effects are not wholly reliable sources of information. The literature is full of interesting tales of seismic effects, some of which are legendary. Attempts to explain causes of earthquakes, even to predict them from these qualitative observations have led to widespread fallacies, superstitions and much folklore.

THE SCIENCE OF SEISMOLOGY

I make these preliminary remarks in order to give you some of the facts of seismology which have developed in the twentieth century. By systematic, scientific methods measurements have been made of the effects of earthquakes using highly specialized seismograph instruments, improved methods of data collection, processing and analysis. A result of these developments is a more reliable and comprehensive understanding of the mechanisms, not only of earthquakes, but also all other kinds of seismic disturbances.

The principles used in scientific studies of earthquakes are the basic principles of physics and mechanics. With reliable determinations of physical properties and the laws governing generation of seismic disturbances, their propagation, attenuation and effects, applications in seismology have been extended to many other areas of usefulness to mankind.

APPLICATIONS OF SEISMOLOGY

The most general application of the principles of seismology and one of the first to be accomplished has been determination of the internal constitution of the earth. With increased amounts of seismic measurements of improved accuracy, models of the earth have been successfully devised and tested. In general terms, we now think of the earth as a spheroid with three unequal axes, comprised of a central core, surrounded by a concentric thick mantle and covered on the outside with a thin crust. Details of the interior of the earth are still subjects of discussion and form the basis of continuing programs of worldwide seismic investigations.

A second area in which applications of seismology have been fruitful employs chemical explosives to generate seismic disturbances. These are propagated to various depths in the crust and used as yardsticks for measurements of crustal features. The principal elements of the crust are physical properties, geologic structure, stratigraphy and the distribution of these features throughout the total crustal thickness.

The economic benefits of exploration seismology are unprecedented. With modern seismographic tools and procedures, the future reserves of oil and gas of the world are now being discovered. Since 1926, surveys for these goals have covered most of the continental areas of the world and are now reaching into marine environments where valuable fuel deposits have been developed beneath the oceans. Other applications are being made in the search for mineral commodities and ground water. The seismograph has become a major, indispensable tool of industry over the entire world.

Without the incentive of these immediate economic goals, use of the seismograph with explosives has also led to solution of complex geological problems throughout the world. By interchange of information among various disciplines such as earthquake seismology, exploration seismology and geologic mapping, many geological details of the earth's crust have been determined which provide valuable scientific resources for future developments of many kinds.

THE AEC NUCLEAR TESTING PROGRAM

Of immediate interest to you who are assembled here today is the use of underground nuclear explosives to reach the goals of the Atomic Energy Commission and other agencies of the United States Government. The testing program at the Nevada Test Site and elsewhere has provided the world with an unprecedented amount of reliable accurate seismic data. These data have been provided by the Commission in such form that their use has become widespread in the solution of major earth science problems. Improvements in understanding the complex structure of the earth, the mechanisms of seismic wave generation and propagation have been accomplished through better instrumentation systems, the collection and interpretation of data in a scientific manner.

The history of the Atomic Energy Commission nuclear explosion program since 1945 shows a steadily growing fund of seismic data whose precision and reliability are incomparably superior to any data collected prior to that date. For example, a direct result of applying these data to earthquake problems has been improvement in the knowledge and accuracy of seismic travel times from source to observatories throughout the world. Let me give you an example.

When an earthquake occurs in California, stations throughout the world record the seismic wave arrivals with an accuracy of about 0.1 seconds. Data of this kind from several large nets of seismic observatories in various parts of the world have been compiled and afford the basis of improved travel time tables. These cover major segments of the earth's crust. Compilation of the data and their publication are performed by a number of contributing organizations. The International Seismological Summary is one repository of these data. The U. S. Coast and Geodetic Survey at Washington, the International Central Seismological Office at Strasbourg, France, are other examples of international cooperation among seismologists. During the International Geophysical Year, 1957-1958, worldwide cooperative programs were conducted. These data have been published and form a further contribution to the science of seismology and solution of earth problems.

These data are mainly derived from observations of earthquakes. Although travel times may be measured to an accuracy of 0.1 seconds, there is always some uncertainty regarding the location of an earthquake, the epicenter. By statistical methods using data from many stations an epicenter may be measured with an uncertainty expressed in terms of standard deviation.

This uncertainty of location does not accompany measurements of seismic disturbances from nuclear explosives. Moreover, the exact time of detonation is generally provided by the Commission, thus resulting increased accuracy of measurement.

A recent publication of results in the Bulletin of Seismological Society of America provides large benefits to the seismic aspects of the AEC underground nuclear explosives program.

Measurements of this kind lead not only to better evaluation of the earth's structure but also form the basis of theoretical and analytical studies in earth sciences. Prior to the advent of testing, no data of this kind were available. The present situation amounts to a major milestone in the science of seismology and brings to the AEC benefits which could not have been anticipated at the outset. The Commission shares these benefits with the scientific community and with other agencies of the United States Government.

NUCLEAR DETECTION PROGRAM

One of the most comprehensive programs of seismic investigations has resulted from the surveillance of clandestine underground nuclear explosions under the terms of the limited Test Ban Treaty. On both sides of the world, free and communist, elaborate systems for seismic detection have been developed and are now in constant use. These systems range from individual stations with small arrays of seismographs to very large aperture seismic arrays (LASA) in which 500 or more seismometers are located. The objective of these arrays is to discover clandestine underground nuclear explosions anywhere in the world. The quantity of seismic data recorded on both sides of the world is prodigious. The United States successfully detected the first Soviet nuclear explosion by methods of this kind in 1949. Many subsequent events in East and West have also been recorded.

In a constant effort to improve detection capability, systems of instrumentation have been developed which exceed all former performance characteristics. Moreover, the continual examination of huge quantities of data by machine methods has led to reliable determinations of the location and yield of these events.

These programs of nuclear detection have provided the seismologists of the world with opportunities to solve problems in seismology hitherto regarded as impossible. The net result has been an expansion in knowledge and understanding of the principles of seismology throughout the world. From this improved position have arisen further applications to other areas of seismology, e.g., exploration, earthquakes and effects of seismic disturbances.

AEC SAFETY PROGRAM

A principal consideration of the Atomic Energy Commission is the safety of life and property from effects of underground nuclear detonations I have portrayed for you the extremely comprehensive background on which all considerations of safety are now based. The goal of safety for each event has been a guiding principle in the establishment and conduct of long range scientific studies in seismology for the particular benefit of safety.

In approaching the question of safety from the effects of underground nuclear explosions, one is easily tempted to think in terms of the effects of earthquakes. Much of the popular reaction to proposed test events by AEC arises from popular older reports of catastrophic natural events where losses in life and property are great. This popular reaction is not unnatural. Public opinion is influenced by these considerations and difficult to change with hard facts, logic and reason. Understanding of the principles of seismology is not easy to come by. The problem of those responsible for safety at AEC is thus to present images, models and pictures which are readily grasped by the public, which give a high degree of assurance that the planners at AEC know what they are doing, that they are able to say with reliability and assurance that no planned event will endanger the lives and property of people. These assurances are made from time to time by the Nevada Operations Office of the Commission, expressed in terms understood by the public and based upon the most exhaustive array of deductions that can be made.

A brief account of these procedures will bring us to the end of this discussion and the papers to follow. The safety of live is not really a big problem. No nuclear detonation underground has ever shaken people so much that it injured or could injure a human being or animal. If the predicted motion of the ground is great enough that some such possibility exists the manager of the test event makes sure that everyone is evacuated from the area. Such an area is extremely limited and normally not accessible by members of the public.

The consideration of safety of persons thus revolves about what happens to buildings and other structures which may be set into vibration by motion of the ground nearby. We approach this problem from the beginning, namely, the source of the explosion. A definite quantity of energy concentrated within a small spherical volume is suddenly released into the crust of the earth. We take account of the total energy and partition it into fractions for which specific effects will be predicted. Within micro-seconds a predictable volume of earth materials will be heated to the point of melting and vaporization. This volume and the associated pressures are predictable for a given yield and given earth materials. Very quickly the spherical cavity expands in all directions, pressing the outgoing walls against surrounding rock. A zone of plastic deformation follows, outside of which there is a zone of cracking. Each of these zones consumes large fractions of the total energy. About 50% is deposited at the source. Another fraction is consumed in plastic deformation and cracking. Finally, the pressure has fallen so low it can no longer push out the walls of the sphere and the remaining energy is the source of a seismic disturbance, less than 5% of the total.

Following the laws of scientific seismology, this spherical source radiates seismic waves in all directions. The paths of propagation can be predicted in terms of the rock properties and their distributions. In some respects this event now resembles a very small earthquake. The difference is the small size and spheroidal shape of the source as contrasted with the usual extended linear nature of an earthquake source.

Near the source the pattern of seismic radiation can be measured by appropriate instrumentation. At greater distances, the seismic waves result in vibrations or motion of the ground, the objective of concern by safety. To determine the probable effect of these ground motions upon buildings and other structures, the characteristics of the structure are determined by engineers skilled in the interpretation of spectral response. Each building vibrates in response to ground motion at characteristic frequencies. For some of these frequencies, the motions of the building are larger than others. The task of the structural engineer is to relate the natural frequencies of a structure to the spectral content of ground motion and thereby determine the probability whether the structure will vibrate to a dangerous degree or not. You will hear more about these details in the papers which follow.