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Radiation Laboratory
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March 25, 1957

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SUBJECT: General Concept of a Deep Underground Shot -- Rainier Event -- Operation Plumbbob

Enclosed is a copy of a UCRL paper subject as above. The plans for the tunnel construction and the scientific measurements, while reflecting the best information available at this time, are subject to possible minor changes resulting from current studies of problems connected either with geological characteristics of the test site or with the measurements systems. In addition implementation of certain of the projects depends upon the outcome of formal processing of proposals.

Addressees are invited to submit either comments on the scope of the planned experiments or suggestions concerning additional experiments which might be of particular interest or of peculiar adaptability to a contained nuclear detonation.

G. W. Johnson

G. W. Johnson
Test Division Leader

GWJ/wl

Enclosure: COPG-57-11

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March 25, 1957

GENERAL CONCEPT OF A DEEP UNDERGROUND SHOT

RAINIER EVENT - OPERATION PLUMBBOB

I INTRODUCTION

Following a suggestion by Griggs and Teller[1], the University of California Radiation Laboratory has been considering the feasibility of testing devices by means of completely contained underground explosions. The possibility of eliminating fallout and the expense of weather delays makes such a test method highly attractive. A preliminary study of such questions as earthquake hazard, depth of burial, ground water contamination and yield determination by shock growth measurements, have been carried out by B. Sussholz[2] and G. T. Pelsor[3]. As a result of their favorable conclusions, UCRL has included a deep underground (Rainier) in the forthcoming Operation Plumbbob. Plans are underway for a horizontal tunnel to be driven into the side of a hill in the Nevada Test Site. A low yield bomb will be detonated at the end of the tunnel where the overburden is expected to be sufficient to contain the explosion. This shot is expected to be a precursor for later, higher yield underground shots if the experience gained proves the method feasible. It appears that a substantial saving in dollars could be made if some of the highly instrumented tower shots can be replaced by an underground method of testing. Preliminary estimates indicate that the direct cost per kiloton yield of digging a tunnel is comparable to that of erecting a tower. Following the operation, the costs of the underground test will be evaluated and compared with the costs of conventional methods.

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1. Deep Underground Test Shots by D. T. Griggs and E. Teller
   UCRL-4659 February 1956

2. Memo from B. Sussholz to G. W. Johnson
   Subject: UCRL Underground Explosion Program
   COT-5894 August 24, 1956

3. Memorandum from G. T. Pelsor to G. W. Johnson
   Subject: Underground Test Tunnel Design
   COT-5963 January 23, 1957

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II DATE

The planned readiness date for the underground nuclear test is September 3, 1957.

b(3)

III DEVICE

This choice was based on the following considerations:

b(3)

1.

2. To develop new diagnostic techniques, a device of known d, and yield is needed.

3. The dimensions of the device should be such that it can be easily maneuvered in the limited space of a tunnel.

IV PHYSICAL ENVIRONMENT

A. Description of Site

Fig. 1. shows the tunnel location at N.T.S. A view of the hill section along the tunnel direction is shown in Fig. 2. The hill is capped with 100-200' of ryholite. Beneath this lies a fairly homogeneous formation of tuff (Oak Springs Formation) extending about 3500 ft. to basement rock. The density of the tuff varies from 1.6 to 1.9 gms/cm^3. This material has excellent properties from the standpoint of the cost of mining operations and the amelioration of the off-site earthquake hazard.

B. Depth of Burial

Extensive studies have been carried out by Sussholz[2] and Pelsor[3] on the problem of containment. As a result of their work, the critical depth corresponding to the limit of crater production for a buried nuclear explosion has been estimated to be d_c (ft.) = 2.5 W $^{1/3}$ (lbs.). Due to the pioneering nature of Rainier the depth of burial (d_b) has been taken as

see Fig. 2.

C. Tunnel Design

The tunnel was designed to satisfy two criteria: (1) easy access to device at all times, and (2) the tunnel should close off

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near the point of detonation to contain the radioactive debris. Pelsor[3] has suggested a design that appears to meet these requirements (Fig. 3). On the basis of the Griggs theory, which predicted the shock growth out to 17 ft. of the Jangle U shot, Pelsor[3] has carried out detailed calculations to determine the critical dimensions of this design. The expected sequence of events is as follows: After the detonation, the shock front moves out through the rock and water. Eventually, the shock breaks out of the water tank and takes off down the tunnel. Meanwhile, the shock front moving along the general direction of the 28 ft. dimension pushes compressed rock into the tunnel forming a plug prior to the arrival of the air shock in the tunnel. The water tank thus serves to delay the air shock in the tunnel and results in a considerable saving in tunnel length. It is also to be used as a medium for shock time-of-arrival measurements.

V DIAGNOSTICS

The feasibility of underground testing hinges on the development of yield determination methods of accuracy comparable to present "conventional" methods. In air bursts, yields are usually calculated from early shock growth measurements in air (fireball photography) or from radiochemical analysis of debris. These measurements, in the usual sense, cannot be performed underground. Preliminary studies, however, indicate that these two categories of measurements, suitably adapted to an underground environment, offer the best chance for good yield measurements. Accordingly, the main diagnostic effort will go into measurements of these two classes of phenomena.

The concept of this shot as a development of a new test technique has dictated the use of a device the yield and α of which are well known. The various diagnostic experiments to determine the yield can then be evaluated in terms of either or both of the following viewpoints: (1) obtaining the absolute yield from first principles or, (2) an empirical approach in which this shot would be a normalization.

The Rainier diagnostic experiments that are currently being planned are described below:

<u>Project 22.1</u> - Radiochemistry - R. H. Goeckermann - UCRL

Griggs and Teller[1] have suggested that the yield of an underground burst might be determined by performing radiochemical analysis of core samples obtained by drilling into the disturbed region. The radiochemistry for yield determination is expected to proceed along conventional lines. The securing of the core samples is a specialized problem and will be carried out as

Project 26.1. Obtaining core samples from a region of intense temperature, radioactivity and perhaps pressure, presents a major developmental problem. To meet this, it appeared necessary to draw on technical assistance from the drilling industry and agencies experienced in the handling of radioactive materials. Accordingly, a Radioactive Sampling Committee has been formed. The following members of the committee have been appointed by G. W. Johnson.

Name	Organization	Capacity
E. B. Eckel	USGS	Engineering Geologist
W. P. Huleatt	USGS	Drilling techniques
J. W. Landry	ORNL	Radioactive materials processing
E. R. Parker	UC	Mineral properties
R. G. Preston	UCRL	Program Officer Program 26
L. E. Shaffer	UC	Drilling techniques
C. E. Violet	UCRL	Chairman

The scope of the committee's work consists of the following:

1. To recommend procedures and to set up criteria by which the drilling will be carried out and the samples secured.

2. To supply the AEC with a list of one or more drilling companies that are willing and able to meet the challenge of this project so that a contract can be negotiated.

3. To work with representatives of the drilling company selected in the development of special tools, remote equipment and other specialized hardware.

4. To recommend a candidate to be appointed as project officer of Project 26.1.

5. To give careful consideration of the hazards involved and to follow the design, testing, and procurement of whatever shielding and decontamination equipment is necessary.

6. To act as a technical steering committee and advise the project officer during the course of the planning stages and the actual drilling.

The minutes of the first, second, and third meetings of the Committee have been published and distributed to the cognizant parties.

Project 22.1 - Nuclear Radiation Measurements - W.H. McMaster/ W. W. Knapp - UCRL

This measurement is primarily a check on the performance of the device. If the α agrees with the expected values, the yield

will be known. The measurement of a underground appears to offer no problem. In fact, it is somewhat simplified to the extent that there is an abundance of shielding available and the drilling of horizontal line of sight holes is cheap.

Project 22.4 - Technique Development Experiments - E.A. Soltysik - UCRL

For the Rainier event, these measurements are of two types described below.

(1) Shock growth measurements in aluminum.

It has been proposed that the device be enclosed in a spherical shell of aluminum and that one wall of the chamber be a spherical section of aluminum. The objective here is to measure the shock growth in a medium the properties of which are fairly well known. Evacuated pipes terminating at various depths in the sphere and wall might be brought in as shown in Fig. 3. Light signals produced by the arrival of the shock front will be reflected by a mirror system at the far end Fig. 3 and will be detected by photodiodes at a location yet to be determined. It is estimated that 12-16 light pipes are needed to carry out the experiment. The details of the design of this experiment are currently being studied by W. H. Grasberger, F. L. Adelman, and E. A. Soltysik.

(2) Shock growth in rock.

Soltysik has suggested the following experiment. If an array of metal rods are embedded in the rock aligned in a radial direction such that the near ends terminate at various radial distances, then the shock front moving through the rock would shock each rod at a time corresponding to the radial distances. The shock in the rods would travel somewhat faster and independent of the shock in the rock. The pressure pulses in the rods would be converted into electrical signals by means of transducers and displayed on scopes. This system is a means of measuring the shock time-of-arrival in the rock. The feasibility of this experiment is currently being studied by E. A. Soltysik.

Program 25 - Shock Growth Measurements, Underground Shot - F. B. Porzel - Armour Research Foundation.

Project 25.1 - Hydrodynamic Yield Measurements

Upon a request of UCRL, F. B. Porzel of Armour Research Foundation has proposed an experiment to measure the shock growth in the rock and water gate. The techniques outlined in the proposal follow closely those used in the APF Wigwam blast measurements. (WT-1034).

Following the recommendations of the ARF proposal, we have tentatively located three horizontal holes as shown in Fig. 3. Two of these are for strings of blast switches and the third is for doppler cable. In addition, there will be a string of switches in the water tank.

These measurements may afford a better measure of the yield than those in rock. To learn something about the closure behavior of the tunnel, measurements of the air shock in the tunnel between the water gate and the plug and also beyond the plug will be made. ARF has been asked to provide the former, and ERDL will provide the latter. Sandia Corporation has been asked to instrument both walls of the tunnel at the point expected to plug, the instruments to indicate the beginning and completion of the plugging action.

Program 26 - Effects of Underground Shot - R. G. Preston - UCRL

The projects in this program have been planned with four principal objectives in mind:

a. To furnish information required for planning the safe containment of larger detonations in the same or other geological formations.

b. To furnish information required for effective use of nuclear weapons against underground targets or as demolition explosives.

c. To furnish information required for reassuring the public regarding the effects of testing of nuclear weapons detonated deep underground.

d. To obtain samples of occluded radioactive debris for a radiochemical yield determination.

Additional minor objectives of this program are listed as follows:

a. To obtain samples for studies of geophysical significance.

b. To furnish information for estimation of the detonation energy couples into seismic waves for use in seismological calibrations and other geophysical investigations.

c. To obtain samples of occluded radioactive debris for analysis by collaborators in Project MICE.

Project work under Program 26 has been divided up, tentatively, as follows:

Project 26.1 - Core Sampling - L. E. Shaffer - UCRL

This project, to be accomplished by UCRL, with contractor assistance, provides for all activities incidental to obtaining radioactive samples from the cavity after detonation and for drilling activities both for emplacement of instruments and for mapping the zone disturbed by the detonation.

Project 26.2 - Geophysical Measurements - Unknown - USGS

This project, to be accomplished by USGS, provides for mapping the zone disturbed by the detonation, for appropriate physical and chemical tests of core samples, for determining the penetration of radioactive products and for studies of specific geophysical significance.

Project 26.3 - Temperature and Static Pressure Measurements

This project, to be accomplished by BRD, provides for measurements of temperatures in and near the cavity as a function of time after the detonation and for determining the static pressure within the cavity following detonation prior to penetration by sampling equipment.

Project 26.4a through 26.4f (except 26.4e) - Close-in Earth Motion Measurements

These five projects represent an integrated effort to study the earth motions resulting from the detonation at locations between minimum distances for survival of instruments and distances where the predominate effect is seismic. Acceleration and strain measurements will be accomplished by SC, SRI and ERDL (under Projects 26.4a, 26.4b and 26.4e) on the basis of pooling the instrument capabilities of the three agencies. Acceleration and displacement measurements in the strong seismic region (less than 2 miles from GZ) and on the alluvial fill of Yucca Flat will be accomplished by the USC & GS (under Project 26.4d). Examination and documentation as well as a portion of the transient measurements, as just noted, of the physical effects of the detonation will be accomplished by ERDL (under Project 26.4e). Finally, timed technical photography of earth surface disturbances will be accomplished by EG&G (under Project 26.4f).

Project 26.5 - On-Site Seismic Measurements

This project, to be accomplished by the USGS, provides for on-site seismic measurements commencing a few miles from GZ and extending throughout the test area to include locations of geophysical significance and of interest from the standpoint of safety.

The program as outlined envisions the development of sufficient data on earth motion (i.e. acceleration, strain and displacement in the medium and on the surface and seismic disturbances on the surface) to permit extrapolation of the test results to nuclear detonations of other yields under different test or employment conditions.

Program 27 - Contained Nuclear Detonation as a Research Tool - UCRL

Project 27.1 - Diamond Production - W. I. Linlor - UCRL

The possibility of producing diamonds from graphite exposed to a contained nuclear detonation has been advanced. The suggestion provides for attaining the required high temperatures in the graphite sample by incorporating boron in some fashion with the graphite so as to derive heat from the neutron capture process. At the same time, the high pressures required for stabilizing the diamond phase of carbon would be available within the room housing the device shortly after detonation.

W. I. Linlor is presently investigating the feasibility of the suggested method for diamond production.

Appendix A - Hydronuclear and One-Point Safety Tests.

A problem closely related to the Rainier concept is that of carrying out one-point safety tests underground. The advantage here of containing the radioactive debris is obvious. It is also possible that the recovery of the SF material by some kind of mining operation may be feasible.

UCRL is currently planning to shoot two devices of this type in Operation Plumbbob.

Fig. 4 shows the present tunnel design for these shots. This tunnel will be located near the Rainier tunnel. The upper limit on the yield is 1 ton. The overburden criterion is again taken to be 2 x d_c. Taking a yield of 1 ton, d_b=65 ft. The length of the tunnel will be adjusted to this overburden. There will be an additional tunnel dug nearby similar to that shown in Fig. 1. This is available for the second shot if necessary or for use in a future test series.

It is possible that these shots may be useful to the drilling contractor to test the special equipment designed to accomplish the radioactive core sampling.

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Appendix B - USGS Activities

In addition to the on-site measurements which will be carried out as Projects 26.2 and 26.5 the USGS is undertaking the following work associated with Rainier.

(1) Feasibility Study for AEC.

The USGS, under a contract with the AEC, is currently carrying out a feasibility study and an associated test program with the following primary objectives in mind.

(1) Geological assessment of the underground area (Area 12) to aid in the selection of a site for the Rainier tunnel.

(2) Determination of safe cover for complete containment of explosives (HE) of known yield, and the scaling thereof.

(3) Determination of the degree and extent of compression and fracturing of the rock.

(4) Prediction of the expected seismic signals from the Rainier event.

(5) Prediction of the hazard of ground water contamination.

With regard to (2) and (3), the USGS is carrying out a series of HE tests including a 10-ton and a 50-ton shot at the U-12 tunnel. In addition there will be a series of smaller charges detonated in drilled holes in the tuff and basement rock.

The 10-ton shot was fired Feb. 21 and the seismic and other measurements are currently being evaluated. The 50-ton shot will include about 300 curies of La^{140} and a highly odoriferous gas to aid in evaluating the fracturing mechanism.

With regard to (4) and (5), the AEC has invited a number of seismologists and ground water experts to make an independent evaluation of these problems and of the USGS feasibility study.

(2) Off-Site Measurements

The USGS will record all tests in the series to determine whether ground motions are sufficient to cause damage at representative distances. The primary objectives for these measurements are (1) to advise the AEC on the probability of Rainier triggering an earthquake (2) and if an earthquake does occur, to determine whether it was natural or caused by Rainier.

Accordingly, the USGS will operate about 20 seismic stations during Plumbbob and coordinate the operation of stations of other agencies in the area of interest.

Appendix C - Rad-Safe Procedures

Due to the pioneering nature of the Rainier testing technique and also the probability that there will be cracks or fissures available to provide paths for a fraction of the fission products to escape into the atmosphere, it appears advisable to set up a procedure for monitoring the mesa after the shot. In addition there will be a number of detectors placed in the tunnel to monitor remotely the radioactivity at various locations after the shot.