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PUBLIC HEALTH ASPECTS OF THE CIVILIAN APPLICATIONS OF NUCLEAR EXPLOSIVES (PLOWSHARE) PROGRAM

by

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ABSTRACT

A brief discussion of the work being carried on within the PLOWSHARE Program is presented. This includes an introduction to studies in the categories of research and development, excavation experiments, scientific research experiments and underground engineering experiments. Particular attention is devoted to public health aspects of the excavation and the underground engineering applications. Potential hazards which may be associated with ground shock as well as those related to nuclear radiation are discussed in general terms. An inventory of some radionuclide activities expected to be released from nuclear cratering events of useful magnitude is presented.

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Before discussing public health aspects of the PLOWSHARE Program I believe it appropriate to spend some time discussing the PLOWSHARE Program itself. The work being carried on under this program may be divided into four categories [(1)] research and development, excavation experiments, scientific research experiments and underground engineering experiments.

The principal effort in the research and development category is directed toward "obtaining a fundamental understanding of nuclear explosive design, explosion phenomenology and uses of nuclear explosions for civil, industrial and scientific purposes." [(1)] The E. O. Lawrence Radiation Laboratory (LRL) in Livermore, California, which is operated for the U. S. Atomic Energy Commission by the University of California, is the major location for this work. Investigations are proceeding in four major areas: "(1) development of the theory of nuclear explosion effects in a variety of underground environments; (2) development of a predictive capability for ground motion, acoustic waves and radioactivity; (3) measurement and evaluation of physical data to support the theoretical studies; and (4) feasibility studies and cooperative work with other groups on the use of nuclear explosives in potential applications." [(1)]

The principal effort in the category of excavation experiments has been directed toward providing adequate information to the Atlantic-Pacific Interoceanic Canal Study Commission in order that the feasibility of nuclear excavation may be considered in its final report to the President. In transmitting the Third Annual Report of the Study Commission to Congress, President Johnson stated:

"There is little doubt that the construction of a sea-level canal is technically feasible. The major questions to be resolved are:
--when it will be needed,
--whether it would be financially feasible, and
--where and how it should be constructed."[2]

Because of unavoidable delays in starting field work in Panama and Columbia and because the PLOWSHARE nuclear cratering experiments needed to determine the technical feasibility of nuclear excavation have experienced temporary postponement, the Study Commission has requested that its final report due date be changed from June 30, 1968, to December 1, 1970. This request is now pending before the Congress.

The nuclear cratering experiments planned for the future include Projects CABRIOLET, BUGGY I, BUGGY II, AND SCHOONER. CABRIOLET, possibly to be conducted in FY 68, is planned to be a 2.5 kiloton explosion at a depth of 170 feet in hard rock at the Nevada Test Site. "The explosion is intended to produce a crater with an expected depth in the range of from 115 to 145 feet, and a diameter of from 425 to 460 feet. The project will be an important step in providing essential data on basic cratering effects from a nuclear explosion occurring at the apparent optimum depth in hard, dry rock."[1]

BUGGY I, planned for FY 68, "involves the simultaneous underground detonation of five low yield nuclear explosives in even terrain at the Nevada Test Site and is designed to produce a smooth ditch-like crater. After BUGGY I, a second nuclear row charge, BUGGY II, is planned. The experiment is planned to be performed adjacent to the BUGGY I crater and will be designed to produce a second ditch-like crater which will connect with the BUGGY I crater. This experiment is also very important because the current concept of nuclear excavation of canals and mountain passes calls for such inter-connecting of a series of nuclear row charge craters."[1]

SCHOONER "which is presently conceived to be a 10's to 100 KT nuclear point charge in hard rock, possibly in the Bruneau River area of southwestern Idaho, would provide the basis on which to extrapolate to the higher yields needed for practical large-scale, nuclear excavation." (1) This experiment may be conducted in FY 69.

"The nuclear excavation experimental program in later years depends on the results obtained from the experiments just described. It is expected that at least one higher yield nuclear row charge in varying terrain and a major experiment or demonstration project combining several experimental objectives would be required for purposes of the canal studies." (1)

"Reduction of the amount of radioactivity released from nuclear cratering explosions has always been recognized as crucial to the ultimate success of the nuclear excavation program." (1)

Low-fission explosives, improved emplacement techniques and decreases in radioactivity by shielding the nuclear explosive with neutron-absorbing material have all been achieved. All of the above add to the natural scavenging process which occurs during nuclear cratering. "The combination of all these factors now allows the prediction that, in cratering explosions of useful yields, the sum of fission products airborne in the radioactive cloud and in the close-in fallout should be about 100-150 times less than the amount estimated to have been released from the 1962 SEDAN cratering experiment." (1)

In the category of scientific research applications, attention to date has been in two areas: heavy element experiments and neutron physics experiments. Data collected to date indicate that "increased neutron flux levels do not produce increasingly heavy nuclei as easily as was originally believed." (1) Theoretical and experimental work in this area is continuing. In the neutron physics experiments work is continuing to develop the "techniques and equipment necessary to conduct particularly neutron fission and capture cross-section experiments, using a nuclear explosion as a source of neutrons." (1) All experiments in the above two areas are conducted with completely contained underground nuclear explosions.

In the category of underground engineering experiments, several interesting projects are under study. All of these involve the use of completely contained deep underground nuclear explosions to develop and manage natural resources. "For example, a nuclear chimney and related fracture zone located underground in natural gas bearing rock formations of low permeability could act as a highly effective well bore which may make it possible to recover natural gas which is now economically unproducible. Located in oil shale or a low-grade copper ore body, a nuclear chimney might also be used as an underground area from which the oil, or copper, could be extracted. Situated in an area regionally near, but locally remote from major population centers, such a chimney could be used to store natural gas near the consumer-end of gas transmission lines." (1)

"The U. S. Bureau of Mines estimates that if nuclear gas stimulation is successful, U. S. recoverable gas reserves would more than double from under 300 trillion cubic feet to about 600 trillion cubic feet. The USBM also estimates that if in-place retorting of domestic oil shale in nuclear chimneys proves feasible, 160 billion barrels of oil might be recovered. Similarly, nuclear chimneys might lead to the recovery of millions of tons of copper which are not presently economically recoverable and could provide needed storage for billions of cubic feet of natural gas." (1)

Project GASBUGGY, a joint AEC-U. S. Bureau of Mines - El Paso Natural Gas Company project in Rio Arriba County, New Mexico, which will be the first in a proposed series of natural gas stimulation experiments, is currently scheduled for November 14, 1967.

The Continental Oil Company in conjunction with CER Geonuclear, Inc., Las Vegas, Nevada, has proposed Project DRAGON TRAIL which recommends using a 40 KT nuclear explosive at a depth of 2,700 feet in the Mancos B Formation in Rio Blanco County, Colorado. This project would seek data similar to that which will be gathered in GASBUGGY, but in a gas-bearing formation with different geological characteristics.

The Austral Oil Company in conjunction with CER Geonuclear, Inc., Las Vegas, Nevada, has proposed Project RULISON which would involve the use of two simultaneous nuclear explosions, at depths of 7,500 and 8,500 feet, to create a nuclear chimney extending vertically almost the entire height of the gas-bearing strata of the Mesa Verde formation at the proposed site near Rifle, Colorado.

"The Columbia Gas System Service Corporation, Columbus, Ohio, the U. S. Bureau of Mines, AEC and LRL, Livermore, are now completing a feasibility study of the use of nuclear explosions to create underground storage area for natural gas. For the purpose of studying an actual location, a site in central Pennsylvania is being used in the feasibility study."(1) This study has been given the name Project KETCH.

The Kennecott Copper Corporation, Salt Lake City, Utah, AEC and LRL, Livermore, have completed a joint feasibility study, Project SLOOP, to evaluate the use of nuclear explosions for breaking copper ore bodies to prepare them for in-situ leaching. A site in Kennecott's Safford, Arizona, ore body has been considered in the study and would probably be used as the location for any experiment. The quality of the ore there is such that it cannot be economically mined and treated by presently known and proved methods.

Project BRONCO is the name given to a joint AEC, CER Geonuclear, U. S. Bureau of Mines, and LRL, Livermore, feasibility study of the use of nuclear explosions to break up oil shale deposits for subsequent in-situ retorting. This study was begun in February, 1967.

In summary, all peaceful applications of nuclear explosives can be broken down into two types--those in which the effects and products of the explosion are fully contained underground, and those in which the effects, and therefore to a limited degree some of the products of an underground nuclear explosion, are apparent on the surface. This latter type constitutes the field of nuclear excavation.

After that rather lengthy introduction we now arrive at the major topic to be considered in this presentation--public health aspects. Potential public health problems associated with the PLOWSHARE Program are concerned with releases of radioactivity to man's environment and with ground motion or ground shock. Since the latter is much easier to evaluate it will be taken up first.

Abundant data have accumulated from the underground testing program to date to allow reasonably accurate prediction of ground motion to be expected as a function of distance from a given yield nuclear explosion in a given medium. The prediction capability in this field is adequate to determine how far out it will be necessary to evacuate people to assure no health hazards will result. The prediction capability, however, is not good enough yet to predict with confidence the distances to which minor damage to structures may result.

A question which is invariably asked in this regard is whether or not an underground nuclear explosion could trigger a major earthquake. The Nevada Operations Office of the AEC has a group of engineering and scientific authorities, which form a subcommittee of their Panel of Consultants, who have considered this question in some detail.(3) It is their unanimous opinion that an underground nuclear explosion would not start an earthquake. "The authorities point out that an earthquake results when tens of years of accumulated strain is suddenly released. Since it is impossible to have a natural earthquake without having prior storage of energy--something that occurs over a period of years--a man-made explosion could not "cause" a natural earthquake. Theoretically, if a nuclear explosion were large enough, if the immediate area were seismically active, and if the strain had built up to a great enough degree in the near vicinity, there is a remote possibility that the detonation might be followed immediately by an earthquake which was on the verge of occurring anyway. However, there is no known instance of a natural earthquake being triggered by a man-made explosion. It would be necessary to conduct the explosion miles deep and in an earthquake-susceptible area to get near a zone where the stress was great enough for an incipient earthquake to be triggered by the explosion." [3]

The assessment of potential public health problems which may result from releases of radioactivity to man's environment is a much more difficult matter. A complete determination in this regard requires, in the beginning, a precise description of the source term (inventory of amounts of each radionuclide released to the environment). Following that, knowledge of the initial deposition and interaction of the radionuclides with terrestrial, aquatic and marine environments is required and particularly knowledge of the interactions of the radionuclides in the food web of man. In brief, one needs to know the fate in the biosphere of each radioactive atom. Finally, knowledge of the effects on man of low levels of radiation dose of different types delivered over long periods of time is another area of uncertainty.

Obviously if one were to wait until all these answers were known accurately, there would be no nuclear excavations performed in our lifetimes and probably not in those of our immediate descendants. It should be pointed out, however, that had such rigid standards been imposed in the past we would probably not now have such things as electricity, automobiles, atomic energy, airplanes, TNT and a host of other things.

Potential radiation hazards of nuclear excavations must be realistically placed in perspective with other accepted human hazards.

We must base our radiation safety decisions in this matter on a careful and cautious evaluation of the best information available today, together with a balance of known benefit vs. probable risk as reflected in accepted radiation protection standards. Is this not the same safety decision-making process followed in every other industry? Of course, when new pertinent information comes to light, past safety decisions must necessarily be re-evaluated in view of the new knowledge.

The remainder of this presentation will consider what is known at this time concerning the total knowledge which is required. We are not in as bad shape as some would have us believe.

A recent document from LRL (4) has given a statement of considerable interest concerning the source term.

"In order to plan for major excavation projects, the following factors relative to release of radioactive debris should be taken into account: The amount of radioactivity airborne in the cloud and in the fallout is minimized by scavenging during the venting process, by special emplacement techniques, by utilizing minimum fission explosives, and by employing extensive neutron shielding. Based on reasonable assumptions about these factors, the following information can be used in planning for cratering events of useful magnitude. For each individual nuclear explosive detonated, the sum of fission products airborne in the radioactive cloud and in the fallout can be expected to be as low as the equivalent of 20 tons. The tritium release may be less than 20 kilocuries per kiloton of total yield. The sum of activation products airborne in the radioactive cloud and in the fallout may be expected to be as low as the amounts shown in the following table:

REPRESENTATIVE SET OF INDUCED RADIOACTIVITIES
AT DETONATION TIME
(Total in Cloud and Fallout)

Nuclide Production, Kilocurie for Yield of

Nuclide	100KT	1MT	10MT
^{24}Na	200	800	2,000
^{32}P	0.1	0.4	0.8
^{45}Ca	0.01	0.03	0.06
^{54}Mn	0.1	0.3	0.7
^{56}Mn	600	2,000	5,000
^{55}Fe	0.04	0.15	0.3
^{59}Fe	0.04	0.15	0.3
^{185}W	6	10	14
^{187}W	300	500	700
^{203}Pb	1,000	7,000	20,000
Other	15	20	40 "(4)

A listing of fission products to be expected from 20 tons equivalent of fission can be found in various references in the unclassified literature. Reference 5 is one such reference.

With the source terms in view, the next step in determining potential human hazards is to identify the critical radionuclides by comparing predicted amounts to accepted radiation protection standards. Since maximum permissible concentrations are based on air, water and sometimes milk levels, it is first necessary to calculate probable distributions of the radionuclides based on diffusion models and meterological parameters. Various ecological concentration processes must also be taken into consideration. A complete radiation safety analysis must consider radiation dose to humans resulting from external gamma radiation together with dose from internal emitters, including both ingested and inhaled radionuclides. The critical radionuclides may be different for each type of human dose. To calculate dose from ingested radionuclides it is essential to identify the critical material in the human food web.

Suffice it to say that considerable data have accumulated over the years in the above areas. In addition, experiments are under way to generate missing pieces of data. An extensive bioenvironmental evaluation of the areas under consideration for a sea level canal is currently under way by Battelle Memorial Institute, Columbus, Ohio, under contract to the AEC. Results of this study will be available in time for them to be evaluated by the Canal Study Commission prior to the submission of their final report to the President. In particular Battelle has studies under way in the following general research areas: dose estimation, human ecology, agricultural ecology, terrestrial ecology, hydrology and radionuclide distribution, freshwater ecology, physicochemical oceanography and marine ecology and resources [6].

The problems are many and varied but they are not insurmountable if we are willing to settle for somewhat less than the ideal which, of course, would be complete knowledge of all the factors previously mentioned.

The Battelle program will not shed any new light on potential effects on humans of low levels of radiation delivered over a long period of time. Under the linear concept of damage there is a small but finite risk in this area which must be accepted if benefits are to be derived. It should be pointed out that, at this time, it is just as impossible to prove that there is <u>any</u> risk in this regard as it is to prove that there is <u>no</u> risk.

Some comment should be made here concerning potential radiation problems which may be associated even with completely contained underground explosion applications such as the natural gas stimulation and the petroleum and copper recovery proposals. Natural gas, petroleum and copper resulting from these experiments would be contaminated to some extent with radioactive materials for some time. Determination of the magnitude of the problems which this will pose to these applications must await successful experiments in each area. However, proposals are already being made for methods to reduce the radioactive contamination of natural gas, petroleum or copper which may result from these applications.

This discussion has probably raised more questions in your mind than it has provided answers. The day of applications of nuclear explosives to peacetime problems is just beginning to dawn. No one really knows what it holds in store for us. Without doubt, however, success in presently planned experiments will inevitably lead state, national and international health agencies into an entirely new era of public health actions which, at this time, can only be partially defined.

An International Symposium with the same subject as this paper is currently being planned for fall, 1968, in Las Vegas, Nevada, under the sponsorship of the U. S. Public Health Service. It is expected that this Symposium will shed much more light on this subject area than has been possible today.

In summary I would like to quote from a speech made by Dr. Glenn T. Seaborg, Chairman, U. S. Atomic Energy Commission at Rio de Janeiro, Brazil, on July 3, 1967. [7] ". . . the United States has indicated its readiness to enter into international arrangements to furnish peaceful nuclear explosive services which can be safely undertaken, whenever appropriate devices and technology are available. These services would be supplied on a non-discriminatory basis, on attractive terms identical for both United States and overseas customers. Moreover, when those devices and their applications become feasible, there will be no scarcity of the necessary units and all proper uses can be accommodated without delay."

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