CLOSING REMARKS* BY DOCTOR GLENN C. WERTH

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AT THE

AMERICAN NUCLEAR SOCIETY-ATOMIC ENERGY COMMISSION

SPONSORED SYMPOSIUM

ON

"ENGINEERING WITH NUCLEAR EXPLOSIVES"

DUNES HOTEL

LAS VEGAS, NEVADA

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All 112 papers have been presented, and the 17 technical sessions are over. If single sessions had been scheduled instead of parallel sessions, we would have been here for two weeks. The Organizing Committee is to be congratulated for a job well done. But in all due respect, it really hasn't been the ideal technical meeting I'd like to go to someday. That would be the meeting where you could somehow absorb all the papers that were presented, yet you could also spend all your time out in the corridor talking with the individual scientists and finding out what the real problems are.

Obviously I didn't hear all of the papers, so I make no claims that the following technical highlights are the optimum set. I have divided my comments into three parts: the highlights of the data from nuclear events, highlights from the broader research papers, and a discussion of some of the application papers.

PART I: NUCLEAR EVENT DATA

The final set of Gasbuggy papers has been presented. The formation was thoroughly fractured beyond the chimney, and gas production is up. But, on

*Work performed under the auspices of the U.S. Atomic Energy Commission

careful examination, we find that the production should have been up even more if these fractures had really played the role that was anticipated. Why wasn't it? Was it because Gasbuggy was in a predominantly fracture-controlled reservoir and we failed to tap into a new fracture system? Or was it because the fractures have partially healed? We don't know the answer, but it does point up that in Plowshare, as in any new scientific area, while the first pioneering experiment answers a great many questions, new problems are opened up as well.

We are anticipating with considerable technical excitement the production tests on Rulison. A better explosive was used in regard to its diameter, handling in the field, and a simpler firing system. Rulison will clearly take its place among the significant events of the Plowshare Program.

We have heard the final summary report of the 31-kt Schooner cratering event. It is unfortunate that there isn't time on the Nevada Test Site tour to see this crater, for it is an impressive sight. A most remarkable explosive with very special minimum radioactive characteristics was used. Some day we hope to be able to give complete information on radioactivity from cratering events. Should this happen, I think you will be duly impressed.

Perhaps not many of you attended the Scientific Applications section in which the Hutch experiment was described. A very specially designed nuclear explosive was used to produce a concentrated neutron flux that impinged on a target with the objective of making heavy isotopes. The neutron flux achieved was 35 moles/cm^2. No fermium-259 or heavier isotopes were made, and the reason remains a mystery. It could possibly be that the half-lives are too short or too long to be observed in the recovery and data analysis. On the other hand, there may be some very fundamental physics that nature is trying to tell us about that we are not quite sharp enough to understand. Our physicists and chemists are anxious to repeat the experiment with larger recovery operations so that targets can be made for use in accelerators and Van de Graaff machines. Fundamental physics experiments could be done to learn more about heavy elements and perhaps make new isotopes of element 104. Another interesting result of that session on Scientific Applications was the report on the use of nuclear explosives to produce spin-polarized neutrons.

We are very pleased that the French scientists were able to be here to present data on their nuclear events. This French data is technically exciting. Being based on thirteen events in granite, it is far more complete than the U.S. data, which is based on three events. A very careful job has been done in preshot geologic work, postshot drilling, mineralization studies, chemistry studies, and so on, and it is very refreshing to see something besides the Hardhat chimney used in application concepts. A most significant apparent contradiction is the fact that the cavity radii from the Sahara events are only about half as long as those of the Nevada test events. We don't know the answer to this problem, but perhaps we have some clues. It may have to do with the Hoggar Massif being very dry, very hard, and unfractured. The differences between the nuclear effects are quite substantial, and it's going to take considerably more interaction between scientists of the two countries to unravel this technical problem.

We have heard data presented on two Soviet experiments, and we are sorry that the Soviet scientists couldn't be here to present their own data -- I refer, of course, to the 1.1-kt contained event in salt that produced the

elliptical cavity, and the 1-kt cratering experiment in sandstone. The data and analysis of the radioactivity from the cratering event are quite extensive; they are very well done technically. While discussing this with the radiochemists at LRL, I was told, "You won't even let us propose such extensive work, let alone actually get them funded and carried out."

Now we have three of the five nuclear countries presenting data relevant to the question of peaceful uses of nuclear explosives. I think this is a most significant result of this particular technical meeting.

PART II: BROADER RESEARCH PAPERS

There were quite a few broader research papers on the question of a theoretical understanding of the outgoing shock wave, cavity growth, and fracturing. We heard papers on the finite difference method of making calculations and were pleased that the United Kingdom has mounted an effort. One of the symposium papers will have the listing of the LRL one-dimensional program. Let me caution you that it takes a great deal of effort, both in the field and in the laboratory, to measure the rock properties to obtain a proper description of the material to make these calculations useful. When Plowshare moves into new situations, such theoretical calculations with their accompanying equation-of-state and logging data can help us avoid multi-million dollar mistakes. Therefore, the effort is clearly going to pay for itself many times over in a very practical sense. Now, that's not to say that there isn't room for the analytical approach. That is the simpler approach of interpreting data and scaling. That's the first approach of project design, and if we are operating within the realm of past experience, that's the way it should be done. It is gratifying to see a number of papers to improve those techniques and make them more generally available, more useful, and more accurate.

In the chemistry area, the French data on the analysis of the residual gases that they have observed (hydrogen, methane, etc.), and the fact that perhaps 50 percent of the tritium is trapped in the melt is new information and a significant contribution. To interpret this data, more work will be needed on the silicon hydroxides that are thought to play a dominant role in the cooling of the cavity gas.

Turning now to the seismic area, one of the biggest technical setbacks that the Plowshare Program has ever had was the firing of the Salmon Event, with the totally unexpected number of plaster crackings and other architectural-type complaints. It was "back to the drawing boards, the high explosive criteria for quarry blasting won't work." Over the years, through the contributions of many organizations, we have developed an understanding of the problem and now have methods to predict the damage and to assess the cost. The work that was done on Rulison in ground motion, building surveys, and analysis of damage has demonstrated these methods. On future projects, I think there will be less expense; the technical methods appear quite adequate. Both Gasbuggy and Rulison have taught us that with these high overburdens, at least in those kinds of rock, there is more energy, proportionately, in the higher frequency band. So those shots have taught us that, because of attenuation there are higher amplitudes close in and lower amplitudes farther out than were previously anticipated.

A session was devoted to engineering developments for the first time. Curves relating cost of explosives and cost of drilling were presented. Projections of costs as a function of diameter and depth are beginning to appear. Unfortunately, the costs are relative, but some day soon we hope that actual cost data can be presented. We have had some descriptions of radio fire links that can cut costs, as well as methods for emplacement, stemming, reentry, and shock mounting of equipment. All these areas are unclassified, and we hope that industry can make major contributions to them in the future. We would certainly encourage you to do so, to reduce costs and make these field operations more efficient.

PART III: APPLICATIONS

Many applications were discussed in the meeting. I have just sorted out in my own mind some of those that I would like to comment on, and by no means do I feel the list is complete. The granddaddy of all of the applications that have been studied, of course, is the interoceanic canal. Field data have come from Panama and Colombia. There were surprises -- the clay shales on Route 17 were unexpected, and the solution seems to be to excavate through the clay shale portion conventionally, at a higher cost. When the plans were laid to consider the feasibility of an interoceanic canal, it was presumed that as the field data came in, the nuclear technology data, including high yield explosions and rows of high yield explosions, would be available. Well, it didn't work out that way. What can be said at this point is that if our projections are correct about nuclear excavation, if the megaton craters are as calculated and presented at this symposium, if the enhancement is as hypothesized based on Buggy and Dugout experiments and on the various HE experiments, then it is indeed feasible to build the canal. However, there needs to be experimental verification of these concepts. The potential saving of over one billion dollars is still there, and I, for one, hope that we'll be able to prove those concepts before the final canal decision is made.

In the gas stimulation field, there is a great deal of momentum that you are all aware of. I'll not stand here and discuss the plans of various companies; it would be inappropriate. But, I think the progress that has been made in analyzing the Gasbuggy gas, its chemistry, and its radiochemistry, and the work on how that gas would be diluted in pipelines and distribution systems (not that this has been done or is planned) is a most interesting and significant development in the gas stimulation field.

An oil stimulation project was proposed in the soviet paper. We also heard a French paper on the subject. The U.S. papers on the subject -- well the silence is deafening. I suppose there are good economic reasons for that.

Regarding storage concepts, we evidently have reached the era of careful design and cost analysis and it indeed looks favorable. Again we find soviet projects proposed. We find extensive discussion in the United Kingdom paper, and I would hope that we will be moving forward very quickly in the storage area.

Progress in oil shale is, frankly, disappointing. Although we are, of course, pleased that the Bureau of Mines, 150-ton retort is on stream and giving data, we'll be looking forward to a complete report.

In the mining session, a number of very fine review papers were presented. The interesting new development is the leaching of deep sulfide copper ores. Leach rates of sulfide ores at normal pressure are very slow, but the concept put forward was to use a high pressure system where the oxygen is put into solution. It is projected that the leaching rate can be speeded up by a factor of 300. If this technique can be proven out economically, we may indeed have a new, unique approach to the recovery of copper ores.

In the area of waste disposal we have one interesting paper, but I was frankly a little surprised that we didn't have more. Of course, we at LRL have been looking at waste disposal over the years and had become a bit discouraged because no one, until recently, wanted to pay to clean up the environment. Times are changing, and I would hope some industrial company would perform a very thorough and very careful analysis of the waste disposal problem using a nuclear solution.

Lastly, I wish to mention geothermal heat. Plowshare could be opening up a new industry. It could be a very important industry in the control of smog and air pollutants, because geothermal heat requires no release of burned hydrocarbons to the atmosphere.

Now, a few concluding statements. Commissioner Thompson described the National Environment Policy Act, which became the law of the land January 1. This country is dedicated to a positive program for improving the quality of our air and water. These are right and proper goals and should be carefully analyzed and systematically approached, but I think we need a yardstick, a measure of pollution. Why not use the ratio of the pollutant to natural background? The pre-man level? By that yardstick, the nuclear energy industry has a very proud record indeed. Improving the quality of our air and water will be very costly, as Commissioner Thompson has said, but the way for that improvement is through technology. If we have the foresight to set aside emotional irrationalities, we can move forward using nuclear energy and nuclear explosions to improve our environment. The papers presented at this symposium have recognized the importance of the environment. If smog can be reduced, if mining dumps can be avoided, if waste can be disposed, and if nonfossil fuel energy can be tapped, indeed, Plowshare will have made a most important positive contribution to cleaning up the environment.

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