contained nuclear explosions and industry

The second meeting of a panel of experts to consider practical aspects of the use of contained nuclear explosions for industrial purposes was convened by the IAEA early this year. This article reviews some of the data presented at the meeting.

The work of the first such panel of experts was reviewed in an article in the *Bulletin* in April 1970 (Vol. 12 No. 2). A second article in that issue discussed a paper prepared in the USSR on possible applications of peaceful nuclear explosions (PNE) for specific purposes in the Soviet Union.

The second meeting, at Agency headquarters, was attended by 64 experts, eight of whom formed the panel proper, from 25 member States and three other international organizations — the World Health Organization, Euratom and the United Nations. Six general statements of

Before . . .
The 40-kiloton nuclear device
used in Project Rulison
is lowered into
the emplacement hole.
Photo:
Los Alamos Scientific Laboratory

... and after.
This photograph, taken at ground zero shortly after
the Rulison device was detonated,
shows observers being briefed.
The technician (in the white 'hardhat') is monitoring the sealed-off wellhead
for radiation leakage: there was none.
Photo: Los Alamos Scientific Laboratory

national interest and activity in the use of peaceful nuclear explosions and 20 technical papers were presented; and panellists saw four films — two showing PNE projects for the stimulation of natural gas reservoirs in the USA, Projects Rulison and Gasbuggy, and two from the USSR, showing use of underground nuclear explosions to extinguish an uncontrolled gas fire and to create a water reservoir. Each of these films had also been shown previously to Agency personnel.

The agenda for the panel demonstrates adequately the scope of the work in hand or being considered at this time: Natural gas and oil reservoir stimulation, the creation of storage caverns for natural gas, the use made in the USSR of PNE to extinguish the gas well fire and possible use for extinguishing gas or oil "eruptions" in general, and other applications such as easing access to underground mineral deposits; mechanical and seismic effects of PNE; and the assessment of their radiological effects.

Stimulating gas flow

Papers presented by US participants described in detail the two experiments carried out by the US Government in co-operation with industrial sponsors. One of the two special consultants to the panel, Mr. Milo D. Nordyke, of the Lawrence Radiation Laboratory, Livermore, California, presented data relating to the supply of natural gas in the United States during the next 10 to 20 years, which indicated that a severe shortage would develop unless steps were taken soon to change present conditions. Both Rulison and Gasbuggy had given promising results, but a large number of engineering problems remained to be solved if costs were to be reduced to a level at which it would be economic to use this method of gas flow stimulation. In particular, a number of nuclear explosives may have to be used at one site to achieve the desired result, detonated either simultaneously or sequentially. In the latter case each explosive device would have to be sufficiently rugged to withstand the shock of earlier nearby explosions.

"However," Mr. Nordyke continued, "much work in this general area has been done... and the problem is largely one of applying (the) technology to the explosives currently being developed for gas stimulation. While this will be a significant engineering task, the economic benefits would appear to warrant this effort."

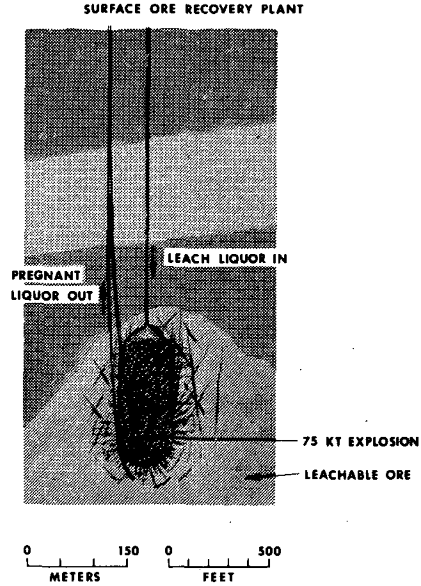
Easing access to minerals

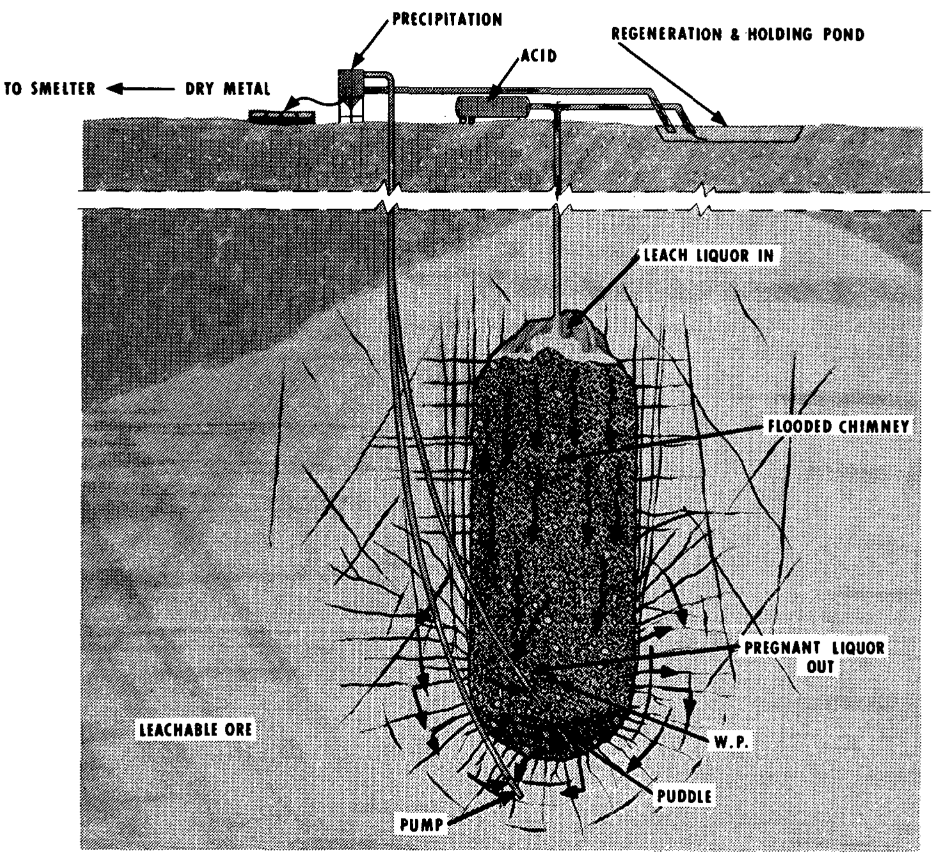
A great deal of the work done in gas stimulation has been described in detail elsewhere. Mr. Nordyke in his paper turned next to other possible applications of PNE, such as the recovery of mineral deposits.

"Throughout the world a large number of low-grade copper ore deposits exist that contain large quantities of copper so diffusely distributed that it is not economical to remove the copper, either by conventional block cave mining or by overburden removal and open pit mining," he said. "For copper oxide deposits which are sufficiently deep the application (of PNE) would involve creating a chimney in the ore

IN-SITU ORE LEACHING

the concept discussed by Mr. Nordyke.





deposit followed by introduction of an acid solution at the top of the chimney. As the solution percolated downward through the broken ore, copper would be leached from the new surfaces as well as from those fractures accessible to the leaching solution within the rock.

"The pregnant liquor would be recovered at the bottom of the chimney and pumped to the surface where conventional separation facilities would remove the copper and return the acid to the top of the chimney for another cycle. Two methods of recovery are available. One is illustrated in the figure, in which drill holes from the surface have been whipstocked into the lower chimney region. Downhole pumps would be installed and used to pump solution to the surface. Alternatively, a shaft and tunnel below the chimney with collection galleries radiating from the tunnel could be used."

This technique, he pointed out, would be applicable primarily to oxidized or secondary ore deposits; but the vast majority of copper deposits in the US occurred as primary or chalcopyrite ore. Mining of such deposits containing sulphide minerals, or other minerals such as molybdenite, might be possible if they occurred well below the water table in conditions which allowed sulphide oxidation.

The principle hazard associated with the use of nuclear explosives for *in situ* leaching was that which would arise from the presence of radioactivity in the leach solution, Mr. Nordyke argued. This would be confined, however, to the separation or processing plant and could be handled in a manner similar to that in which many other industrial hazards were dealt with.

"Not only does this application appear to be very attractive from an economic point of view, the environmental advantages are very great", said Mr. Nordyke. "Conventional recovery techniques of such ores require mining the ore to bring it to the surface or digging a huge open pit mine, processing the ore in a large surface plant, and disposal of the processed rock in tremendous dumps. The nuclear technique offers the opportunity to eliminate the hazardous mining operation, the unsightly open pit mines and mine dumps, and the air pollution resulting from roasting sulphide ores to drive sulphur dioxide out of the ore and into the air."

Tapping the heat of the earth's core

In some parts of the world use is already being made on a limited scale of geothermal energy, tapped in the form of steam from bores or by bringing natural geysers under control. One such area is at Wairakei, in the North Island of New Zealand. But, as Mr. Nordyke pointed out in his paper, commercial exploitation of such sources of energy "is presently limited to those areas where a natural system of fractures acts to collect heat from a large volume of rock and sufficient naturally occuring water is available to act as a heat transfer agent".

One application of PNE could be to create a chimney and associated fracture system, using a nuclear explosion to increase the permeability of hot rock underground and thus enable recovery of geothermal energy. Conventional techniques for such recovery involved the drilling of many holes, attempting to intersect fractures containing hot water or steam;

they were limited to very special geological situations and were very inefficient with respect to the proportion of the available energy that they recovered. Potentially, use of an underground nuclear explosion could enable recovery of geothermal heat from dry geothermal reservoirs as well as improving the efficiency of recovery from fractured reservoirs in which a source of natural underground water was available.

If a geothermal reservoir were dry, it was envisaged that water would be introduced into the chimney/fracture system through injection wells or through adjacent chimneys, and that superheated steam would then be removed to generate electric power. For a geothermal reservoir that was fractured and had a source of water, the chimney and fracture zone would play the role of a greatly enlarged well-bore, in a manner analogous to the stimulation of a low permeability oil or gas reservoir with a nuclear explosive.

Mr. Nordyke considered that the principal hazard associated with this suggested application would be ground shock, since all radioactivity produced by the nuclear explosions used would remain underground or within the closed circulation system. Because of the size of explosions required and the nature of large capacity generating plants it might be necessary to develop a supply of steam sufficient for 30 to 50 years before the generating plants were built.

Radioactive waste disposal

"As the number and size of nuclear power reactors grow over the next 20 to 30 years, the quantities of radioactive waste material resulting from reprocessing the reactor fuel elements will attain major proportions," said Mr. Nordyke. "Radioactive waste disposal is expensive. Because of the heat generating capacity and chemical nature of the waste, it can become very hazardous unless properly handled...

"Under certain conditions, disposal of liquid high-level waste in chimneys or cavities produced by nuclear explosions in impermeable formations offers a number of potential advantages. In an impermeable rock, such as an igneous or metamorphic rock, shale, or an impermeable sandstone, migration of the radioactive waste could be greatly reduced or even possibly eliminated. Such sites are much more common than the permeable ones required for injection. In addition, pressurization tests could be used to test the integrity of the chimney or cavity before introduction of the waste.

"The concept currently under study envisages introducing high-level liquid wastes directly into a nuclear chimney and permitting the water to boil off until it becomes a solid. The water and rare gases would be processed and filtered at the surface and vented. Upon completion of the evaporation process, the holes would be sealed. The energy content of most reactor waste is sufficiently high that it will continue to increase in temperature, melting the rock in the chimney or immediately outside the cavity. Ultimately, the dilution by melted rock and heat conduction will lead to solidification of the molten rock and permanent entrapment of the radioactive waste."

Such a technique, if successful, would be "significantly faster, cheaper and inherently safer method of disposal than others that have been studied", said Mr. Nordyke. "It should be pointed out that such a technique could not be used everywhere and would not be suitable for disposing of all types of radioactive waste. In addition, much more study is needed before all aspects of this technique have been analyzed.

"However, the tremendous advantages of this method for high-level wastes in some situations, and the fact that it would lead to truly 'permanent' disposal, makes further study of this application desirable."

In almost all the applications being studied, said Mr. Nordyke, "the potential exists for making a significant contribution to industrial technology and, in the process, reducing industry's impact on the environment".

In the view of the panel, it should be stressed however that studies of applications of this kind are still only of a preliminary nature.

Work in the USSR

Three papers relating to the study of PNE in the USSR were circulated to member States of the Agency last year: one examined radioactive contamination of the environment as a result of the use of PNE, and methods for predicting it, a second mechanical effects of PNE, and a third reviewed possible applications of PNE in the Soviet economy. This third paper was reviewed in some detail in the Bulletin, Volume 12 No. 2, in April 1970, soon after the first meeting of the panel on PNE.

At this second meeting Professor O. L. Kedrovski, of the State Committee on the Utilization of Atomic Energy of the USSR and also a special consultant to the Agency on PNE, described a method using an underground nuclear explosion to extinguish an uncontrolled natural gas well flare. This application was also the subject of one of the films shown to panel members. Normal methods of extinguishing two such fires were tried but were not successful, and in each case it was decided to detonate a nuclear device underground near to the bore which had got out of control. The principle of this method is that pressure in the bedrock resulting from the nuclear detonation may be sufficient to squeeze closed the casing of the well bore, and at the same time crush and displace nearby rock so that the bore can no longer function. The well bore or shaft is effectively sealed in such a way that gas or oil deposits are no longer accessible to the surface through it.

Professor Kedrovski pointed out that great care must be taken in selecting the geological "horizon" at which the explosion is to take place for such an application, the explosion well must be completely isolated, surrounding wells must be sealed hermetically, the amount of radioactivity in the wells and in water-bearing horizons must be monitored, and so on.

The panel felt that the analyses used in the design of the two projects Prof. Kedrovski described, and the apparent conformance of results to predictions, lead to the conclusion that this application could be regarded as a viable industrial tool for dealing with similar catastrophes in future. The panel pointed out that "as with gas stimulation, a careful economic balance should be struck. The economic loss, the environmental insult, and the potential hazards posed by the uncontrolled well must be balanced against the costs and potential hazards of the nuclear application".

Groundwork for the future

It should be stressed again that, with exceptions noted in this article, the practical use of contained nuclear explosions for peaceful purposes is still technically in its infancy. Many technical, economic and legal and administrative questions remain to be answered. Nevertheless, this panel meeting like the first indicated the potential value of PNE for the future.

Papers presented at the panel meeting, and the panel's conclusions, are expected to be published by the Agency in a few months.