# ideas for peaceful nuclear explosions in ussr

Three papers prepared in USSR have been made available to the Agency for circulation among Member States. One examines radioactive contamination and methods for predicting it, of natural environments during underground explosions. Another deals with the mechanical effect of underground explosions. The third, which forms the basis of this article, reviews possible applications of peaceful nuclear explosions in the Soviet economy.

## Nature of the problem

In the Soviet Union, where the volume of construction work is very great and where there are vast, thinly populated regions with harsh climatic conditions and large mineral deposits, there is considerable scope for the industrial application of underground nuclear explosions.

Scientific research figures prominently in plans for the future industrial application of nuclear explosions.

Contained blasts and excavation blasts (for bulking, cratering, etc.) have been investigated.

There has been considerable study of the industrial application of contained blasts, which are less hazardous than excavation blasts. The preference shown for contained blasts in experiments and research is due to the fact that the Soviet Union adheres strictly to the Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and Under Water.

Calculations and investigations have shown that the shattering and excavation of large masses of rock and earth can be achieved more economically by excavation blasts than by modern mining methods. It is estimated that in some projects tens and even hundreds of millions of roubles could be saved by using excavation blasts.

Investigations have yielded valuable scientific and technical information about the mechanical, seismic and radiation effects of nuclear explosions. The engineering properties of shattered and fissured rock and of ejecta have also been investigated.

Together with the study of nuclear explosions as such, a great deal of work has been done to define fields of application and actual projects in which such explosions could be used for industrial purposes.

Taking account of the effects of underground nuclear explosions on the geological environment, studies are being carried out and projects prepared in respect of the following possible industrial applications in different sectors of the Soviet economy:

*Excavation blasts*

Uncovering of mineral deposits;
Canal construction;
Construction of earth- and rock-fill dams;
Reservoir construction;
Creation of cuts and embankments for railways and roads;
Harbour construction;
Creation of craters for the disposal of mining and processing wastes.

*Contained blasts*

Intensified exploitation of oil and natural gas deposits;
Creation of underground cavities for the storage of natural gas, gas condensates and oil products;
Creation of underground cavities for the burial of biologically dangerous industrial wastes;
Underground working of ore deposits;
Control of overburden pressure (e.g. for prevention of oil and gas blow-outs).

Plans have been drawn up for a number of projects involving the use of underground nuclear explosions in civil engineering and in the preparation and exploitation of large mineral deposits. The authors of these plans have drawn extensively on the results of theoretical and experimental investigations of the mechanical effects which such explosions produce in the geological environment and of their effectiveness in particular applications. They have also made use of theories and practical experience relating to the use of conventional high explosives in the Soviet Union and abroad for the construction of reservoirs, dams and canals, for quarrying, for driving underground galleries, etc.

The engineering and scientific problems have been studied with the help of:

Simulated explosions under laboratory conditions;

Test shots with chemical explosives in the field;

Experimental and pilot-scale nuclear explosions both on test ranges and at the sites of potential projects.

Through successive increases in the size of the explosions it has been possible to extend considerably the scope of the investigations, which have included:

Qualitative and quantitative investigation of the mechanical (shattering and redisposition of earth materials), seismic, radiation and thermal effects of nuclear explosions;

Formulation of optimum technical procedures for industrial nuclear explosions;

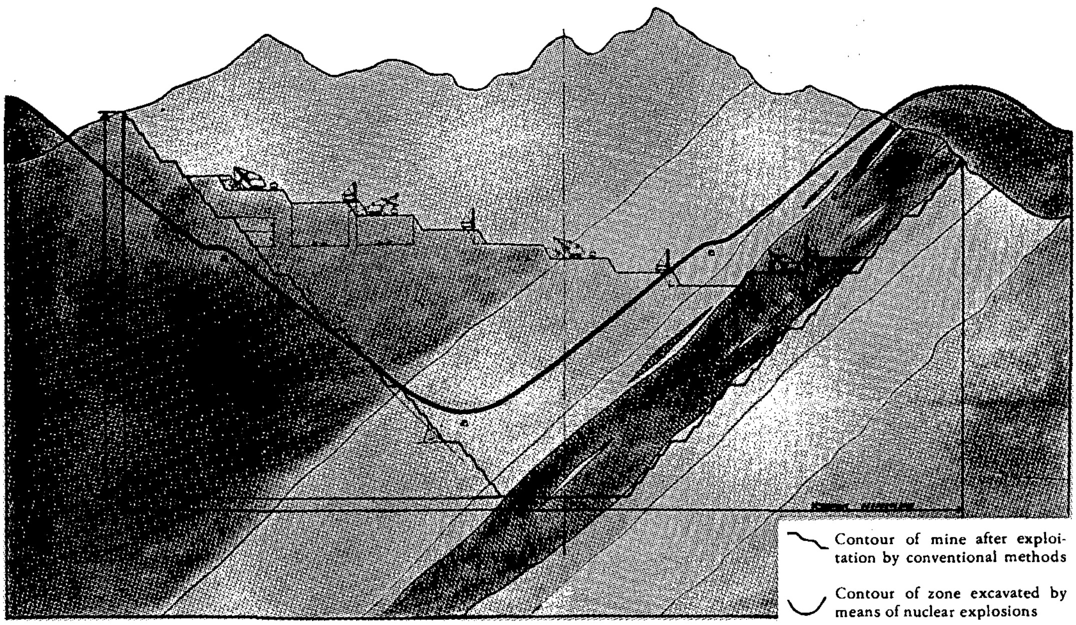
Accumulation of data on the stability of engineering structures created with the help of nuclear explosions;

Study of the effects of seismic waves from conventional and nuclear explosions on the stability of surface and underground installations etc.

The positive results of the theoretical studies and of the experimental and pilot-scale explosions justify proposing a number of major projects involving the industrial application of nuclear explosions.

The following report contains a brief account of explosions which have already taken place and of research already carried out, and presents the basic features of a number of projects.

Possible excavations to uncover mineral deposits.



## I. Reservoir construction

The desert and arid regions of the Central Asian republics of the Soviet Union have always suffered from an acute shortage of water, which has now become an economic problem due to the development of cattle raising, the expansion of agriculture based on irrigation and the opening up and settlement of virgin land.

A characteristic feature of these regions is that most of the surface waters are discharged through streams in spring, so that direct use can be made of run-off only during this season. The water supply problem of these developing regions can be solved by establishing an extensive network of artificial reservoirs for regulating the spring run-off and making rational use of the available water throughout the growing period.

The use of nuclear explosions, on the basis of experience gained in the Soviet Union and the United States with experimental cratering, will help to solve this economic problem much more rapidly.

An example of such an application of nuclear explosions is the proposed construction of a reservoir for experimental and irrigation purposes. The reservoir complex will include: two barrier dams, a spillway, a training dam, an earth dam of normal profile with bottom-discharge conduit, an inlet canal and a min irrigation canal.

The total capacity of the proposed reservoir will be 30 million cubic metres and the useful capacity 27 million cubic metres. After an initial period of operation lasting several years, the guaranteed annual discharge will be 10.8 million cubic metres (20 million cubic metres during low-water periods); this represents 75% of the water requirements of the region.

The first stage will be the creation of the two barrier dams using two 150-kiloton (kt) nuclear charges. The charges will be detonated in porphyrite at a depth of 185 m; this depth has been chosen so as to produce crater lips of maximum height, thereby obviating the need for subsequent work on building them up to the required level.

The calculated crater parameters are:

| | |
|---|---|
| Diameter | 180 m |
| Depth | 105 m |
| Maximum height of lip | 31.5 m |
| Radius of surrounding fracture zone | 650 m |
| Volume of ejecta | 5.7 million cu.m. |

The region where the explosions are to take place is very sparsely populated, so that extensive seismic and radiation safety precautions will not be necessary.

Calculations of the extent of areas restricted for radiation safety reasons are based on values given by Johnson and Higgins for the amount of radioactive products released in such explosions ("Engineering applications of nuclear explosives - project Plowshare", paper P/291 presented at the Third United Nations International Conference on the Peaceful Uses of Atomic Energy, Geneva, 1964).

The timing of the explosions will depend on the meteorological conditions, which should be such as to allow the specially designed safety measures to be taken.

Normal construction work will begin two months after the explosions and will be completed in the course of the subsequent five months. The radiation dose received by those engaged in this work will not exceed the permitted levels (5 R/year). Calculations indicate that the strontium-90 concentration in the water of the reservoir will be much lower than the maximum permissible concentration.

The use of nuclear explosions for building these two barrier dams will reduce the capital costs by a factor of 1.5 as compared with normal civil engineering methods.

## II. *Canal construction*

Project for the diversion of northern rivers into the Volga

Over the past 35 years the level of the Caspian Sea has fallen by 2.5 m due to abnormal climatic conditions, increased water consumption and the construction of reservoirs on the Volga, the Kama and other rivers of the Caspian basin. This has resulted in considerable harm to fishing, sea transport and other branches of industry in the littoral zone.

Calculations have shown that, even under favourable climatic conditions proposed future projects involving various forms of water utilization will cause a further drop in the level of the Caspian Sea of 0.6 m by 1980 and 1.7 m by the year 2000.

The growing need for water in the central and southern regions of the European part of the Soviet Union can be met and the level of the Caspian Sea stabilized by diverting northern rivers (in particular the Pechora), the waters of which are in excess of the requirements of the northern regions.

In addition to a complex of hydraulic engineering structures, the project will entail the construction of a deep, 112.5-km canal across the Pechora-Kolva watershed.

The calculations for this project justify the use of spaced nuclear charges to excavate a 65-km section of the canal through rocky country with the highest elevations, the remaining sections to be constructed by the conventional methods of hydraulic engineering through country with softer formations and with elevations not exceeding 130-149 m.

The principal geological formations in the area where nuclear explosions are to be used are sandstone, aleurites and rock salt.

The region in question is sparsely populated (less than one inhabitant/km$^2$ system).

The plan is to excavate a canal with a useful cross-section of 5 000 square metres by the simultaneous detonation of linearly spaced charges Altogether about 250 charges will be required. In order to place these at the appropriate depths (150-285 m) a total of some 65 000 m of borehole will require to be drilled.

Calculations have schown that the simultaneous detonation of 20 charges totalling 2 megatons TNT equivalent produces along the canal an elliptical danger zone with a major axis of 20 km.

The use of nuclear explosions for excavation purposes will reduce the cost of constructing the canal by a factor of 3-3.5 as compared with conventional methods.

### III. Uncovering mineral deposits

Nuclear explosions can be used in opencast mining to remove barren overburden, to blast access cuts and to crush ore and surrounding rock.

It is planned to use groups of nuclear charges for removing the overburden from a large deposit of non-ferrous metals. The climatic, geographic and economic conditions of the region are those of extreme northern territories, including permafrost to a depth of 650 m. The region is also characterized by frequent earthquakes and landslides. The population density is very low (1 inhabitant/20 km$^2$) and the deposit is remote from existing railways and roads.

The mineralization is confined to a sandstone formation, the extent of that part containing minerals in commercially interesting amounts being 11-12 km.

About 70% of the ore is to be mined by opencast methods involving the removal of 2300 million cubic metres of overburden. Excavation work on this scale by conventional methods would require a great deal of heavy mining and earth-moving equipment. However, because of the severe climatic conditions and inhospitable nature of the region and its remoteness from principal transport routes and sources of electric power, it is possible and even advantageous to carry out such work with the help of nuclear explosions.

By means of multiple explosions, 900 million cubic metres out of a total of 2300 million cubic metres of overburden will be displaced from the areas scheduled for mining, with an anticipated saving in costs of 1000 million roubles.

In order to determine precisely the basic parameters of explosions in such formation a test blast with a special programme of experimentation is planned.

Contained blasts

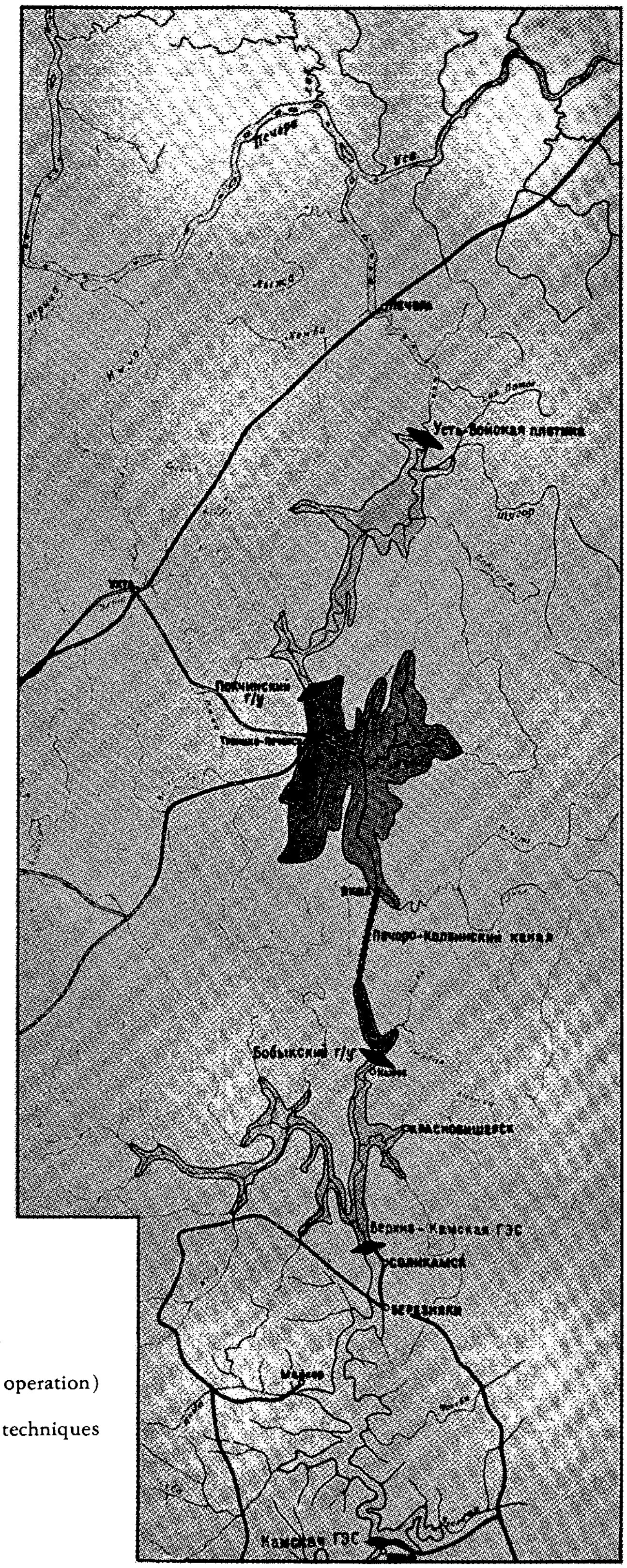
### IV. Intensified exploitation of oil and gas deposits

Experience of exploiting oil and gas deposits has shown that, due to a number of natural factors, in the vast majority of cases the total production is very low - rarely exceeding 0.3-0.5 of the potential yield. Moreover, the process of exploiting an oil or gas deposit is a lengthy one, lasting many years and involving significant capital and operating costs.

Theoretical studies and test blasts have shown that the day-to-day output from an oil or gas deposit can be substantially increased and the exploitation period reduced by using underground nuclear explosions.

Plans have been prepared for investigating two exploitation methods involving explosions.

Scheme for diversion of the Pechora into the Volga.




Proposed hydroelectric power station

Kama hydroelectric power station (in operation)

Canal to be constructed by special techniques (Pechora-Kolva canal)

Primary reservoir

Secondary reservoir

1. With the first method the nuclear charge is detonated in the oil or gas reservoir in such a way as to preserve the natural separation between the productive zone and the water-bearing zone, so that exploitation proceeds with the help of the reservoir energy alone.

This method is the basis of a project to exploit a particular gas deposit which is typical of many found in oil-producing regions of the Soviet Union.

This gas deposit lies in a sedimentary ridge; the overlying material, which is 1000 m thick in places, consists of anhydrites and rock salt. The gas is separated from the bottom water by an 85-m zone of oxidized oil. By detonating charges in the carbonate reservoir rock it is intended to create a large system of fissures, thereby substantially increasing the permeability of the formation and releasing isolated pockets of gas.

It is planned to detonate three charges of 40 kilotons each at a depth of 1600 m so as to form three highly fractured zones each 270 m in radius. The charges will be placed in the productive part of the northern dome, in which 60% of the gas and gas-condensate reserves are concentrated.

If possible, the holes drilled for the emplacement of the charges will subsequently be used for production purposes; if not, three new holes will be drilled.

According to the hydrodynamic calculations which have been made, the output from the wells as a result of the explosions will be 2 million cubic metres/day - as opposed to 0.25 million cubic metres/day. Thus the anticipated result is an increase by more than a factor of ten in the mean annual production of gas and gas condensates and an elevenfold reduction in the total exploitation period, with an annual saving of some 5-6 million roubles.

2. With the second method the detonation of nuclear devices in oil-bearing formations is designed to shatter both the oil-water contact zone and the dense obtruding rock strata in the oil-bearing and water-bearing zones, thereby allowing the water - which is under very high pressure - to penetrate the oil-bearing zone, raise the pressure there and force the oil towards the wells.

It is considered that the best approach would be to detonate three 20-30 kt devices below the centre of the oil-bearing zone, beneath the oil-water contact. Both the oil-saturated and the water-bearing zone would experience the mechanical effects of the explosions.

It is expected that the use of explosions and of the pressure of the bottom waters to force oil from the reservoir would result in a significantly higher and more stable rate of current production over a long period.

## V. Experimental contained explosions in salt formations

A. 1.1-kt device has been detonated in the large, dome-shaped elevation of a salt formation.

The aims of the experiment were:

To study the feasibility of using a nuclear explosion to produce a large underground storage cavity in a salt formation;

To determine the configuration and dimensions of the cavity and of the deformation zones;
To investigate the seismic effects on surface buildings, installations and boreholes;
To investigate the distribution of radioactive products in the salt and at the surface.

All these aims were accomplished: the explosion was contained completely.

Investigations of the seismic waves in the vicinity of the explosion (up to 2.3 km) and at intermediate (7.5-45 km) and greater (up to 170 km) distances indicate that the effects on structures in the vicinity were comparable with those of an earthquake of force 6-7.

No release of radioactive products into the atmosphere was observed at the time of detonation. At 12 minutes, 24 hours and 35 hours after detonation, radioactive noble gases were detected escaping from the observation boreholes. The quantity involved did not exceed 1% of that formed in the explosion.

Radioactive products penetrated along cracks into the salt formation. Strontium-89 and caesium-137 spread furthest from the cavity, strontium-90 and yttrium-91 somewhat less and antimony less still. Zirconium-95, cerium-144 and ruthenium-106 concentrated in the zone immediately surrounding the cavity.

The experiment confirmed the suitability of nuclear explosions for creating underground storage cavities in large rock salt formation and provided a considerable amount of new information about the effects of explosions in such media.

## VI. Creation of underground cavities for storing natural gas, gas condensates and oil products

The rate of development in the oil and gas industry is closely bound up with the construction of storage facilities.

The conventional methods of forming underground storage facilities are either very laborious (e.g. excavation by means of normal mining techniques) or unsuitable for general use (e.g. flushing out cavities in salt formations). The latter technique requires thick salt formations, a plentiful supply of fresh water and natural facilities for the disposal of brine.

It has therefore become necessary to seek new, improved ways of making underground storage cavities. Theoretical studies, trials with models and analyses of the mechanical effects of contained nuclear explosions can be used for this purpose.

Preliminary technical and economic estimates indicate that by using nuclear explosions it is possible to reduce the costs of gas storage by a factor of six compared with storage above ground after liquefaction and by a factor of three compared with storage in cavities created by flushing; under certain conditions the costs are about the same as for gas storage in natural water-filled reservoirs.

The investigations which have been carried out point to three ways in which nuclear explosions can be applied to produce underground storage facilities.

They can be used to:
Create cavities in rock salt and dry clay deposits;
Create cavities in hard rock formations by causing rock collapses and producing zones of shattered and fractured rock;
Improve the filtration properties of natural reservoir rock.

The two examples given below give an idea of the technological stage reached in the creation of underground storage facilities.

In the first case a reservoir for 300 000 cubic metres of gas condensate is to be made in a thick rock salt formation underlying sandstone.

In order to exclude seismic effects on surface buildings and installations the power of a single blast will have to be limited to 35 kt. This will produce a cavity of 152 000 cubic metres. Two further blasts will be necessary in order to obtain a reservoir of the required capacity. The charges will be placed at a depth of 810 m. The smallest distance between charges at which the cavities will remain intact under the influence of the compression wave is 528 m. Boreholes for subsequent utilization of the cavities will be drilled one month after the explosions.

In the second case a reservoir for 70 million cubic metres of natural gas is to be created under a 190-m permafrost zone. In this region the maximum permissible power of a single blast at a depth of 710 m is 40 kt. The volume of the cavity produced by an explosion of this power will be 360 000 cubic metres. It will be possible to store gas at a pressure of 70 atm, so that a reservoir volume of 1 million cubic metres will be necessary for the storage of 70 million cubic metres of gas. Three 40-kt charges 100 m apart will be needed to form a reservoir of this volume.

It is not yet clear what subsequent operating procedures would be best from the point of view of minimizing the radioactive contamination of products stored in cavities created by nuclear explosions. It has been found in experiments that gas introduced into a cavity immediately after an explosion shows no signs of radioactivity when extracted 120 days later. The possibility of considerably reducing this "cooling" period is to be studied carefully after the next test explosion.

As a rule, fresh boreholes have to be drilled in order to gain access to cavities created by explosions. However, methods are at present being developed with a view to using the boreholes drilled for emplacement of the charges.

## VII. Underground working of ore deposits

Experiments with contained explosions in granite formations have shown that:

Approximately 400 000 t of granite is shattered by a completely contained blast of 1 kt;
Underground mine workings collapse completely at distances up to 30-80 m from the explosion and rocks are dislodged at distances up to 60-150 m depending on the nature of the formation;
Size of resulting zones can be calculated with reference to the power of the blast.

These results suggest that contained nuclear explosions are an effective means of shattering rock in mining operations with large-scale caving.

The use of widely spaced nuclear charges offers the possibility of shattering large rock masses, thereby changing radically the technology of underground mining for ores. With the help of such nuclear blasts it will be possible to:

Reduce by a high factor the amount of excavating and drilling;

Concentrate mining operations by combining the shattering and caving of large amounts of ore;

Simplify considerably procedures involving large-scale caving;

Increase significantly the efficiency of mining operations.

For example, the simultaneous detonation of two or three 1-1.5 kt charges can cause the collapse of 1.5-2.0 million tons of ore, and would require tunnelling for a total distance of only 0.3-0.4 km. According to rough estimates, the cost of mining one ton of ore could be reduced by a factor of 1.5-2.0 by using powerful explosions, thereby opening up the possibility of exploiting deposits or sections of deposits which have so far been considered uneconomical.

There are many deposits in the Soviet Union where shattering of the ore could be achieved by nuclear blasts.

In order to work out the details of a system of mining with large-scale caving by means of nuclear explosions (undoubtedly a new concept in mining), a project has been prepared involving an experimental blast at a mine already in operation.

The objectives of the experiment are to:

Determine the size of the resulting zones;

Assess the extent to which the degree of shattering is affected and the seismic effects on the mine complex are reduced by clearing material from the faces of the ore block before the explosion;

Determine the typical size of pieces of shattered ore at different distances from the centre of the blast;

Develop a method for extracting the ore.