Underground Explosion Nuclear Energy

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Abstract

Author offers the new method for obtaining very cheap electric energy, liquid fuel, thermal energy, fresh water and cheap nuclear fuel. He uses deuterium underground thermonuclear explosions.

He shows the installation for getting of energy (creating the underground cavity by nuclear explosive) is on the order of a thousand times cheaper than surface steel boiler designs offered by Russian scientists and more safe because in case of any damage the radiation is in the deep underground cavity. The offered system will also produce a lot of fresh water for arid regions.

Author developed the theory of underground explosions, artificial earthquake, computed projects and investigates the problems of nuclear security.

Key words: Energy, cheap energy, peaceful nuclear explosive, warm energy, fresh water, liquid fuel, cheap nuclear fuel, theory of underground explosion, artificial earthquake.

Introduction

History of the USA Plowshare Project and Russian Nuclear Explosions for the National Economy Project.

Nuclear explosions can be used for big national economics projects. There are design for canals, roads and tunnels in mountainous areas, the creation of artificial lakes and water reservoirs, construction of underground storage facilities for natural gas and oil, the creation of river dams, strengthening oil and gas exploration, seismic surveys, etc.

Russia.

Nuclear Explosions for the National Economy (sometimes referred to as *Program #7*), was a Soviet program to investigate Peaceful Nuclear Explosions (*PNEs*). It was analogous to the US program *Operation Plowshare*.

Once underway the Soviets conducted a much more vigorous program than the Americans' Operation Plowshare, consisting of some 156 (other data 169) nuclear tests, some with multiple devices, between 1965 and 1989. These tests were similar in aims to the American effort, with the exception that six of the shots were considered of an applied nature, that is they were not tests per se, but were used to put out runaway gas well fires and a methane blow out. Four of them were not successful.

One of the better-known tests was *Chagan* of January 15, 1965. Radioactivity from the Chagan test was detected over Japan by both the U.S. and Japan in apparent violation of the 1963 Partial Test Ban Treaty (PTBT). The United States complained to the Soviets, but the matter was dropped.

There were in fact two programs:

- "*Employment of Nuclear Explosive Technologies in the Interests of National Economy*," also referred to as "*Program 6*," involved industrial underground PNEs and testing of new PNE technologies. As part of the program, 124 tests with 135 devices were conducted. Primary objectives of the program were water reservoir development, dam and canal construction, and creation of underground cavities for toxic waste storage.
- "*Peaceful Nuclear Explosions for the National Economy*," also referred to as "Program 7," involved testing of industrial nuclear charges for use in peaceful activities. Nuclear

> detonations were conducted with the stated purpose of searching for useful mineral resources with reflection seismology, breaking up ore bodies, stimulating the production of oil and gas, and forming underground cavities for storing the recovered oil and gas. The "Program" numbers come from the USSR's classification system of nuclear explosions, the first five programs designating various phases of nuclear weapon development.

All together, the *Program 7* conducted 115 nuclear explosions. Among them:

- 39 explosions for the purpose of geological exploration (trying to find new natural gas deposits by studying seismic waves produced by small nuclear explosions)
- 25 explosions for intensification of oil and gas debits
- 22 explosions for creating underground storage for natural gas
- 5 explosions for extinguishing large natural gas fountains
- 4 explosions for creating channels and dams (including the Chagan test in Kazakhstan, and the Taiga test on the potential route of the Pechora-Kama Canal)
- 2 explosions for crushing ore in open-pit mines
- 2 explosions for creating underground storage for toxic wastes
- 1 explosion to facilitate coal mining in an underground mine
- 19 explosions were performed for research purposes (studying possible migration of the radioactivity from the place of the explosions).

There were two large explosions of 140 kilotons and 105 kilotons; all others were relatively small with an average yield of 12.5 kilotons. For example, one 30 kiloton explosion was used to close the Uzbekistan *Urtabulak* gas well in 1966 that had been blowing since 1963, and a few months later a 47 kiloton explosive was used to seal a higher pressure blowout at the nearby *Pamuk* gas field, successful experiments later cited as possible precedents for stopping the Deepwater Horizon oil spill.

The last nuclear explosion by the Program 7, codenamed **Rubin-1** was performed in Arkhangelsk oblast on September 6, 1988. The explosion was a part of a seismic program for geological exploration. The Soviets agreed to stop their PNE program at the end of 1988 as a result of then president Mikhail Gorbachev's disarmament initiative.

There are proponents for continuing the PNE programs in modern Russia. They (e.g. A. Koldobsky) state that the program has already paid for itself and saved the USSR billions of rubles and can save even more if it would continue. They also allege that the PNE is the only feasible way to put out large fountains and fires on natural gas deposits, and it is the safest and most economically viable way to destroy chemical weapons.

Problems.

The experiments ended with the adoption of a unilateral moratorium on nuclear weapons testing at Soviet sites in 1989. Although this primarily was designed to support Mikhail Gorbachev's call for a worldwide ban on nuclear weapons tests, the Russians apparently applied the moratorium to peaceful nuclear explosions as well.

Conclusion.

As noted, the Soviet PNE program was many times larger than the U.S. Plowshare program in terms of both the number of applications explored with field experiments and the extent to which they were introduced into industrial use. Several PNE applications, such as deep seismic sounding and oil stimulation, were explored in depth and appeared to have had a positive cost benefit at minimal public risk. Some, such as closure of runaway gas wells, demonstrated a unique technology that may yet find application as a last resort. Still others were the subject of one or two tests but were not explored further for reasons that have never been explained. Overall, the program represented a significant technical effort to explore what was seen at the time to be a promising new technology, and it generated a large body of data, although only a small fraction of it has been made public.

Subsequently the United States and the Soviet Union halted their programs. Definitions and limits are covered in the Peaceful Nuclear Explosions Treaty of 1976. The Comprehensive Nuclear-Test-Ban Treaty of 1996 prohibits all nuclear explosions, regardless of whether they are for peaceful purposes or not.

United States: Operation Plowshare.

Operation Plowshare was the name of the U.S. program for the development of techniques to use nuclear explosives for peaceful purposes. Twenty-eight nuclear blasts were detonated between 1961 and 1973.

One of the first U.S. proposals for peaceful nuclear explosions that came close to being carried out was Project Chariot, which would have used several hydrogen bombs to create an artificial harbor at Cape Thompson, Alaska. It was never carried out due to concerns for the native populations and the fact that there was little potential use for the harbor to justify its risk and expense. There was also talk of using nuclear explosions to excavate a second Panama Canal.

The USA shallow and deep underground explosions.

On 26 July 1957, *Plumbbob Pascal-A* was detonated at the bottom of a 485-foot shaft. According to one description, it "ushered in the era of underground testing with a magnificent pyrotechnic Roman candle!" As compared with an above-ground test, the radioactive debris released to the atmosphere was reduced by a factor of ten. Theoretical work began on possible containment schemes.

Plumbbob Rainier was detonated at 899 ft (274) underground on 19 September 1957.[1] The 1.7 kt explosion was the first to be entirely contained underground, producing no fallout. The test took place in a 1,600 – 2,000 ft (488 ÷ 610 m) horizontal tunnel in the shape of a hook. The hook "was designed so explosive force will seal off the non-curved portion of tunnel nearest the detonation before gases and fission fragments can be vented around the curve of the tunnel's hook." This test would become the prototype for larger, more powerful tests. Rainier was announced in advance, so that seismic stations could attempt to record a signal. Analysis of samples collected after the test enabled scientists to develop an understanding of underground explosions that "persists essentially unaltered today."[23] The information would later provide a basis for subsequent decisions to agree to the Limited Test Ban Treaty.

Cannikin, the last test at the Amchitka facility was detonated on 6 November 1971. At approximately 5 megatons, it was the largest underground test in US history.

Effects in case of small depth.

The effects of an underground nuclear test may vary according to factors including the depth and yield of the explosion, as well as the nature of the surrounding rock. If the test is conducted at sufficient depth, the test is said to be *contained*, with no venting of gases or other contaminants to the environment. In contrast, if the device is buried at insufficient depth ("underburied"), then rock may be expelled by the explosion, forming a crater surrounded by ejecta, and releasing high-pressure gases to the atmosphere (the resulting crater is usually conical in profile, circular, and may range between tens to hundreds of metres in diameter and depth). One figure used in determining how deeply the device should be buried is the *scaled depth of burial*, or *-burst*. This figure is calculated as the burial depth in meters divided by the cube root of the yield in kilotons. It is estimated that, in order to ensure containment, this figure should be greater than 100.

Table 1. Radius of deformation in rock.

Name	Radius

Melt cavity	4 – 12 m/kt$^{1/3}$
Crushed zone	30 – 40 m/kt$^{1/3}$
Cracked zone	80 – 120 m/kt$^{1/3}$
Zone of irreversible strain	800 – 1100 m/kt$^{1/3}$

The energy of the nuclear explosion is released in one microsecond. In the following few microseconds, the test hardware and surrounding rock are vaporized, with temperatures of several million degrees and pressures of several million atmospheres. Within milliseconds, a bubble of high-pressure gas and steam is formed. The heat and expanding shock wave cause the surrounding rock to vaporize, or be melted further away, creating a *melt cavity*. The shock-induced motion and high internal pressure cause this cavity to expand outwards, which continues over several tenths of a second until the pressure has fallen sufficiently, to a level roughly comparable with the weight of the rock above, and can no longer grow. Although not observed in every explosion, four distinct zones (including the melt cavity) have been described in the surrounding rock. The *crushed zone*, about two times the radius of the cavity, consists of rock that has lost all of its former integrity. The *cracked zone*, about three times the cavity radius, consists of rock with radial and concentric fissures. Finally, the *zone of irreversible strain* consists of rock deformed by the pressure. The following layer undergoes only an elastic deformation; the strain and subsequent release then forms a seismic wave. A few seconds later the molten rock starts collecting on the bottom of the cavity and the cavity content begins cooling. The rebound after the shock wave causes compressive forces to build up around the cavity, called a **stress containment cage**, sealing the cracks.

Several minutes to days later, once the heat dissipates enough, the steam condenses, and the pressure in the cavity falls below the level needed to support the overburden, the rock above the void falls into the cavity, creating a *rubble chimney*. Depending on various factors, including the yield and characteristics of the burial, this collapse may extend to the surface. If it does, a subsidence crater is created. Such a crater is usually bowl-shaped, and ranges in size from a few tens of metres to over a kilometre in diameter. At the Nevada Test Site, 95 percent of tests conducted at a scaled depth of burial (SDOB) of less than 150 caused surface collapse, compared with about half of tests conducted at a SDOB of less than 180. The radius r (in feet) of the cavity is proportional to the cube root of the yield P (in kilotons), $r = 55 \times P^{1/3}$; a 8 kiloton explosion will create a cavity with radius of 110 feet (33 m) .

Other surface features may include disturbed ground, pressure ridges, faults, water movement (including changes to the water table level), rockfalls, and ground slump. Most of the gas in the cavity is composed of steam; its volume decreases dramatically as the temperature falls and the steam condenses. There are however other gases, mostly carbon dioxide and hydrogen, which do not condense and remain gaseous. The carbon dioxide is produced by thermal decomposition of carbonates, hydrogen is created by reaction of iron and other metals from the nuclear device and surrounding equipment. The amount of carbonates and water in the soil and the available iron have to be considered in evaluating the test site containment; water-saturated clay soils may cause structural collapse and venting. Hard basement rock may reflect shock waves of the explosion, also possibly causing structural weakening and venting. The noncondensible gases may stay absorbed in the pores in the soil. Large amount of such gases can however maintain enough pressure to drive the fission products to the ground.

Although there were early concerns about earthquakes arising as a result of underground tests, there is no evidence that this has occurred.

Below is a huge cavern, a result of a small nuclear test. (Fig. 1) Project GNOME detonated a 3.1 kiloton device 1200 feet down in December 1961. This is a profile of the GNOME cave. In the late spring of 1962 the AEC excavated to the cavity atop the rubble chimney. The worker is standing under the roof of the cave, but atop the heap of the rubble chimney of fractured rock.

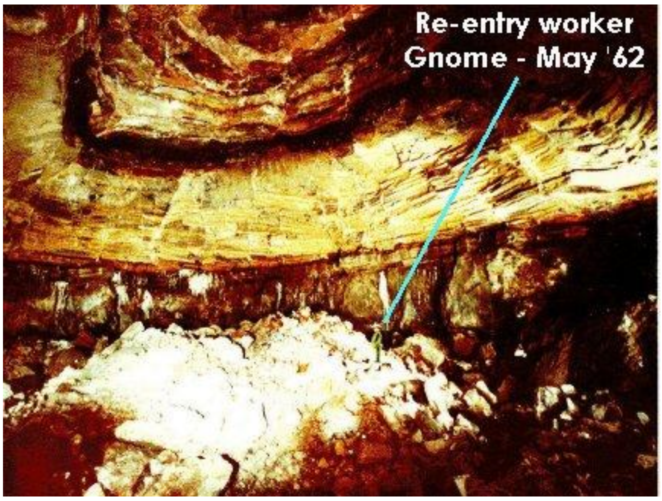

Fig. 1. Project GNOME Rubble Chimney. Look your attention to man into the nuclear underground cavity.

International treaties concerning nuclear explosions.

Signed in Moscow on August 5, 1963 by representatives of the United States, the Soviet Union, and the United Kingdom, the Limited Test Ban Treaty agreed to ban nuclear testing in the atmosphere, in space, and underwater. 108 countries would eventually sign the treaty, with the significant exceptions of France and China.

In 1974, the United States and the Soviet Union signed the Threshold Test Ban Treaty, which banned underground tests with yields greater than 150 kilotons. By the 1990s, technologies to monitor and detect underground tests had matured to the point that tests of one kiloton or over could be detected with high probability, and in 1996 negotiations began under the auspices of the United Nations to develop a comprehensive test ban. The resulting Comprehensive Nuclear-Test-Ban Treaty was signed in 1996 by the United States, Russia, United Kingdom, France, and China. However, following the United States Senate decision not to ratify the treaty in 1999, it is still yet to be ratified by 8 of the required 44 'Annex 2' states and so has not entered into force as United Nations law.

The nuclear bomb of energy 30 kt (in quantity) can cost about $1M (in the USA). Increasing of the bomb power only slightly increases their cost because deuterium is cheap. The underground nuclear test costs in the USA: In vertical mine about $20-30M, in horizontal mine about $40-60M. The major part of the cost is the tunnel building.

Russian Project “Nuclear Explosive Boiler” (NEB), (KBC in Russian).

On 1994 – 2004 in Russia the team from the State Institute of District Heating (РФЯЦ – ВНИИТФ, г. Снежинск [1]) theoretically developed and offered a nuclear power station used the nuclear charges/bombs as the energy source. That is gigantic and very expensive installation having the big strong steel boiler for permanently explosion of the nuclear bombs. The boiler has a size (fig.2): internal diameter 160 m, height 260 m, thickness of wall more 35 m. One requests 4 millions tons of a quality steel, 20 millions tons of a concrete and 300 thousands tons of a sodium/natrium as transfer of energy/cooler. The boiler is located inside the artificial mountain having a height more 300 m.

Installation works the next way. The nuclear explosion heats the liquid sodium (metal natrium) up 500 - 600 °C.

The sodium is transferred to a heat exchanger, heats a water; steam rotates the electric turbo generator.

The sodium goes to a separator. One separates the useful nuclear fuel and radioactive fission fragments and sends the sodium back into system. The power of installation is about 50 GW and the produces an energy equivalent about 150 millions of tons of oil per year.

The Russian project is very expensive (cost is many tens of billions, see “Economic Section”) and **no** guarantee can be made that the nuclear bomb will not destroy the boiler, create radioactive contamination of a large region. In heat exchanger the liquid natrium (sodium) transfers energy to water. But natrium ignites when one has contact with water. If exchanger will have even slight damage, the 150 -300 thousand tons of natrium can create a gigantic explosion. In accident a big amount of natrium/sodium in a rain can create a gigantic fire (sodium is flammable explosive and poisonous in contact with water).

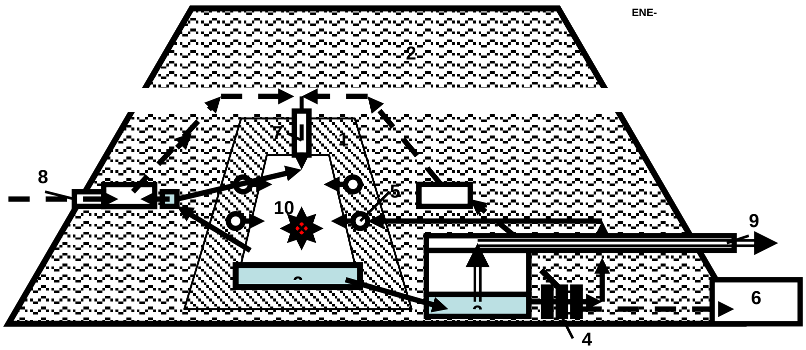

Fig.2. Russian installation “Nuclear Explosive boiler”. *Notations*: 1- Steel-concrete boiler (160x260 m); 2 – artificial mountain (height about 300 m); 3 – heat transfer agent (sodium coolant 120 thousand tons); 4 – separator; 5 – sodium injector; 6 – fission fragments; 7 – injector of the nuclear charges; 8 – nuclear fuel; 9 – heat energy; 10 – nuclear explosion.

Innovations and advantages

The author offers an alternative design of the nuclear station, which do not have the noted (Russian) defects. We drill a main well 3 (fig.3a) having a deep about 800 – 1200 m., let down into well a nuclear charge 4 (fig.3a), blow it and create a cavity (fig 2a). After it we fill into the cavity some amount a liquid cement 7 (fig.3b), put into liquid cement 7 a conventional explosive 6 and blow it (fig.3b). As result the liquid cement closes the gaps, cracks in the walls 13 (fig.3c) of the cavity and strengthens their. In the third step we drill two-three additional wells. One 10 is used for filling a water into artificial underground cavity and the other 11 is used for getting steam for turbines (electric generators) and heat (water) for industry and population (fig.3c). That well 11 is also used for deleting the radioactive fission fragments

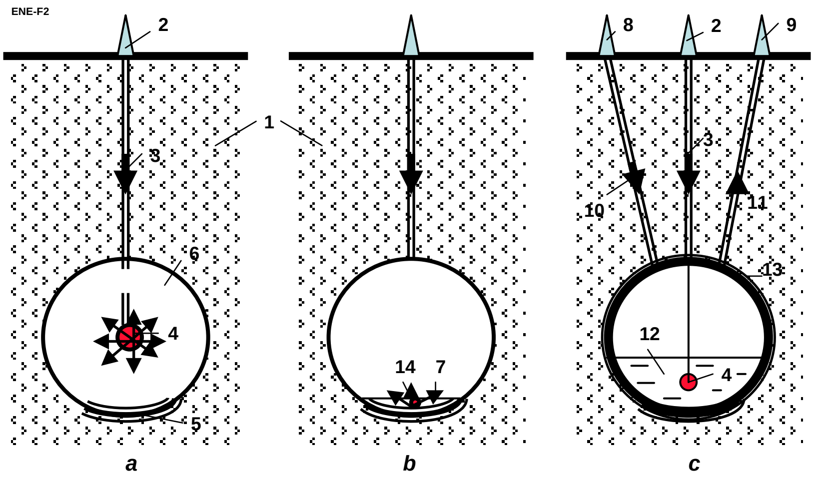

Fig.3. Creating the underground nuclear cavity for the nuclear electric station. ***a***– drilling of the main borehole (well) and creating the cavity by the nuclear explosion, ***b*** – making the concrete shall by conventional charge, ***c*** – drilling the two additional borehole for pumping the water into cavity and getting the steam after the nuclear explosion. *Notations*: 1 – soil/rocks, 2 – drilling rig, 3 – borehole for nuclear charge, 4 - nuclear charge, 5 – molten rock, 6 - cavity, 7 – liquid cement, 8 – drilling rig for pumping of

water, 9 – drilling rig for getting the steam, 10 - borehole for pumping of water, 11 – borehole for getting the steam, 12 – water, 13 – concrete shell. 14 – Conventional charge.

The detail installation is shown in fig. 4. That contains steam turbines and electric generator 8, separator 9 (one separates the useful nuclear fuel and radioactive fission fragments), storage 10 for the radioactive fission fragments, heat exchanger 11 for getting a hot water for industry and population, water storage12, retractable hose for pumping a waste 13 in flushing, valves 14.

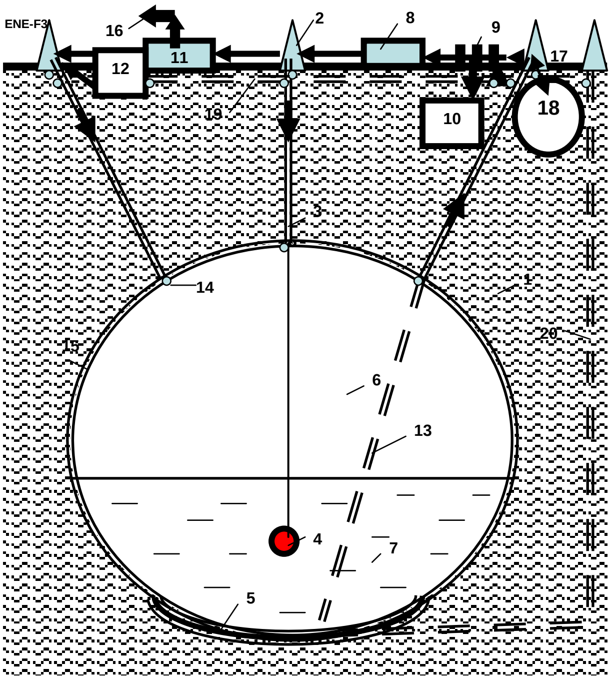

Fig. 4. Principal Installation for producing electricity, warm, fresh water, and nuclear fuel (out of scale). *Notations*: 1 – soil/rocks, 2 – drilling rig, 3 – borehole for nuclear charge, 4 - nuclear charge, 5 – molten rock, 6 – cavity, 7 – water, 8 - steam turbines and electric generators, 9 – separator (one separates the useful nuclear fuel and radioactive fission fragments), 10 – storage for the radioactive fission fragments, 11 – heat exchanger, 12 –water storage, 13 – retractable hose for pumping a waste, 14 –valves, 15 – concrete shall, 16 – industrial and household heat, 17 – exit of borehole, 18 – storage for heat (compressed hot steam), 19 – connection of all 3 (4) boreholes, 20 – additional (optional) boreholes for cleaning of cavity.

Installation works the following way (fig.4). Through the well 10 into cavity (chamber) operator pours water (that may be sea water). Through the main well 2, operator (or computer) omits the nuclear charge 4, closes all valves 14 and blows it. The water is converted to hot steam under large pressure. The steam goes to turbines 8 and storage 16, produces the electricity. After this steam goes to the separator 9. Here the steam is cleaned from radioactive fission fragments and a nuclear fuel is separated. The radioactive fission fragment is sent to a special storage 10, the nuclear fuel is sent to 2 for producing the new nuclear charges. Further the hot steam is sent to the heat exchanger 11, where one heating the other water which is used for industry and population. The clean steam after devaporation (condensation) is fresh water and it may be used for agriculture.

Sometimes the cavity/chamber is rinsed (washed) by water for complete removal of all solid radioactive fission fragments and sea salt if you use sea water. For this is used the retractable hose 13.

Advantages of offered method over Russian project.

1. Offered method is cheaper by a factor of one thousand times (see computation in Economics section).
2. Offered method is very safe. In any accident the all waste will be located deep under Earth's surface.
3. Save millions tons of quantity steel and cements and hundred thousands of tons of metallic natrium (sodium).

4. The time of construction is less by 3 – 5 times.

Advantages of offered method over the current nuclear and conventional stations.

1. Offered project is cheaper than any current nuclear station of same power by tens of times.
2. Time of construction is 1.5 - 2 years (not 4 – 6 years as current nuclear and conventional stations).
3. The power of station is in 10 – 20 times more than power of any current nuclear and conventional stations.
4. Return of investment in 3 – 5 months after working of station in full power. Conventional and nuclear stations have return investment time in 3 – 6 years).
5. The offered station uses the fusion (not fission) thermonuclear reaction.
6. The offered installation uses cheap deuterium as thermonuclear fuel. Resources of deuterium are essentially unlimited in Earth's oceans. (Suitable uranium is limited in the Earth).
7. Installation produces the nuclear fuel (enriched uranium) for self and other conventional station.
8. Installation produces a lot of heat for industry and population.
9. Using the generated heat and and imported coal this Installation can produce artificial liquid fuel for car and transport.
10. Installation can produce a lot of fresh water for agriculture.
11. Cost price is extremely small – less 0.01 cents per kW-hour.

Theory of the offered Explosive Nuclear Installation

Theory of Underground Explosions and Artificial Earthquakes

Conventional Underground Explosive in soil

The underground explosions were widely used for production underground gas storages, creating storages for toxic wastes, activity the oil and gas extraction and increasing the mining, milling of minerals, the permeability of the soil, for creating of seismic wave (geological exploration), creating canals and dams, open-pit manes and so on. In period from 1957 – 1988 the USSR made 169 and USA made 28 underground explosions.

The radius of cavity after explosion may be computed by equation:

$$r_0 = \sqrt[3]{\frac{4}{\pi}\frac{E}{p}} \,, \qquad (1)$$

Where r_0 is radius after explosion, m; E is energy of explosive, J; p is collapsing pressure of the soil/rock, Pa. The energy of TNT is $E = 4.184 \cdot 10^9$ J/ton.

The critical collapsing pressures p for different materials is presented in Table 2.

Table 2. Critical collapsing pressures *p* for different materials [2].

Material	Density, kg/m^3	p, MPa= 10 atm	Material	Density kg/m^3	p, MPa= 10 atm
Reinforced concrete	2000÷2200	4.9 ÷34	Sand	1200÷1600	0.1 ÷ 1
Brick	1600÷1700	7 ÷29	Sandstone	1500 ÷ 1800	1 ÷ 5
Granite	2010 ÷2250	147÷255	Soil, gravel	1500÷2000	1 ÷ 4

Example: for 100 kg of TNT in sandstone having p = 2 MPa the radius cavity equals 6.44 m.

The shift of soil and the radius of milling may be estimated the equations:

$$A = \frac{r_0^4}{r^3}\,, \quad r = r_0 \sqrt[3]{\frac{r_0}{A}} \qquad (2)$$

where A is the shift of soil, m; r is radius (distance from center of explosion) of soil, m. Radius strongly depends on the fragility and viscosity of the soil/rocks.

Example: If TNT is 1 ton ($E = 4.184 \cdot 10^9$ J), p = 2 MPa, A = 1 mm = 0.001 m, that the r_0 = 14 m, $r \approx$ 338 m for the fragile soil.

The computations of the cavity and the radius of permeability for conventional explosive are presented in Figs. 5 – 6.

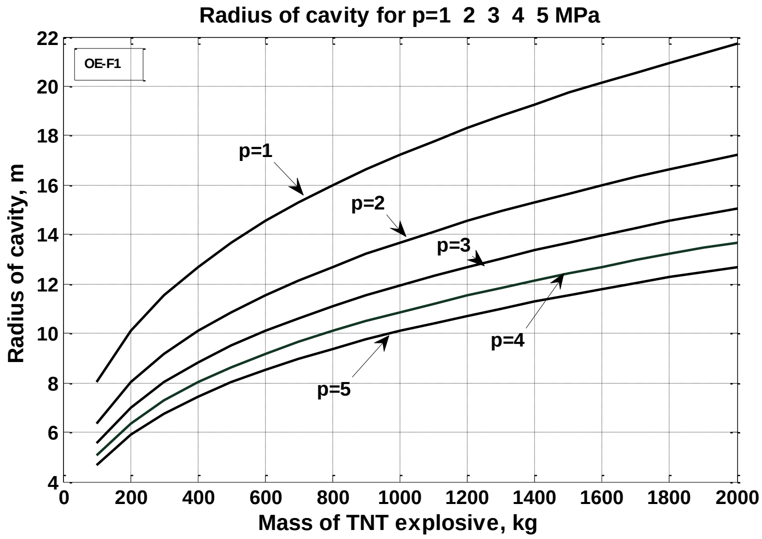

Fig.5. Radius of the underground cavity via mass of TNT explosive for the different ground strength.

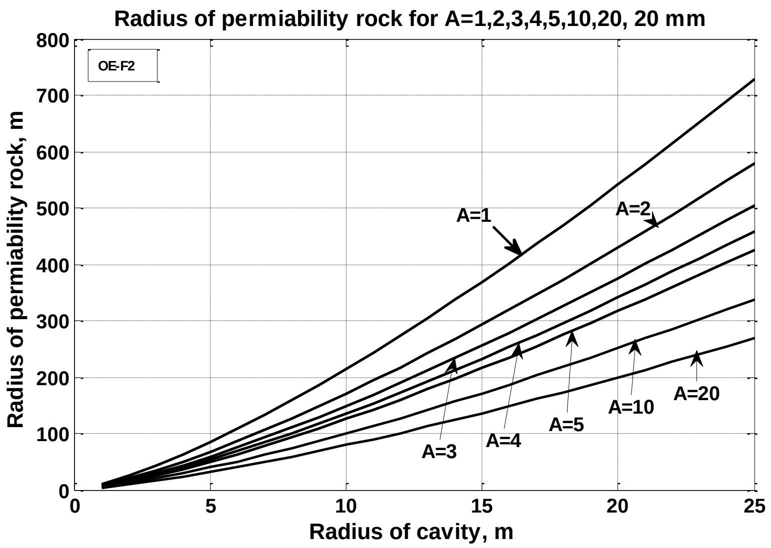

Fig.6. Radius of ground permeability vs. radius of the underground cavity for the different shift of ground.

Nuclear underground explosion

Computations of underground nuclear peaceful explosives for the economic development. The results of computation are presented in fig. 7 and 8. You can find the radius of cavity and ground permeability.

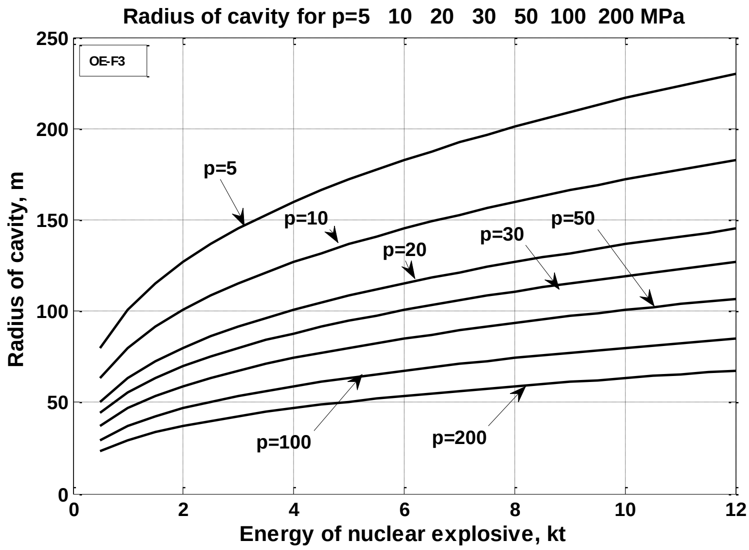

Fig.7. Radius of the underground cavity via energy of nuclear explosive for different ground strengths.

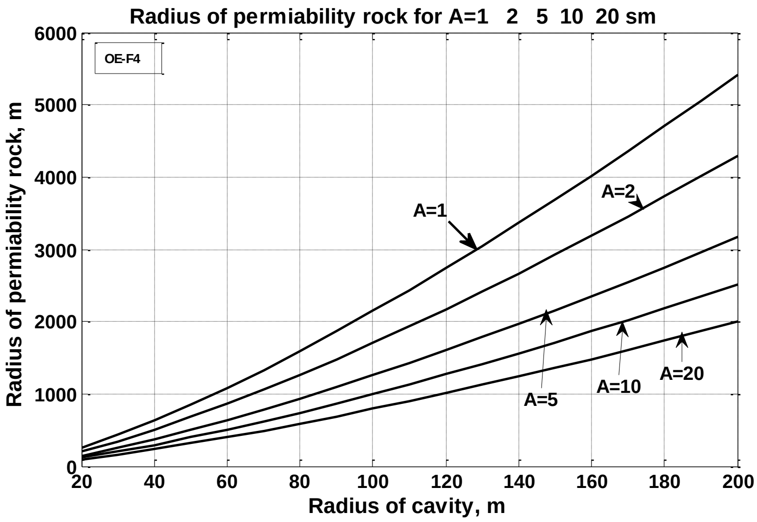

Fig.8. Radius of ground permeability via radius of the underground nuclear cavity for the different shift of ground.

Artificial Earthquake from underground explosion

There are several methods for estimation of the earthquake. In Europe, magnitude of earthquake is measured on the Richler scale (EMS).

The magnitude of the artificial earthquake from underground explosion may be estimated by equation

$$M = \frac{2}{3}(\lg E - 4.8) \ , \qquad (3)$$

where M is magnitude; E is energy of the explosion, J; 1 kt = 4.184×10^9 J.
Energy of nuclear bomb in 1 Mt of TNT equals 4.184×10^15 J and produced the earthquake in 7 magnitudes.

The magnitude of Richler scale is computed by equation:

$$M_R = \lg A + f \ , \qquad (4)$$

Where A is the shift of ground in micron (μm = 10^{-6} m, see over); f is correction on distance from epicenter of an explosion (it is in special table). Top of the Richter scale is 9.5 .

In reality the power of earthquake is estimated in points (visible damages).
1. point (imperceptible) - tremors, celebrated the device;

2. points (very weak) - Earthquake felt in some cases, people who are at rest;
3. points (weak) - fluctuation observed a few people;
4. points (moderate) - Earthquake noted by many people, perhaps swing windows and doors;
5. points (quite strong) - Hanging objects swing, creaking floors, rattling windows, crumbling whitewash;
6. points (severe) - slight damage to buildings: Fine cracks in plaster, cracks in the furnaces and the like;
7. points (very strong) - significant damage to buildings, cracks in plaster and breaking off individual pieces, thin cracks in the walls, damaged chimneys, cracks in damp soils;
8. points (destructive) - destruction of buildings: large cracks in the walls, drop cornices, chimneys. Landslides and cracks up to a few centimeters in the hills;
9. points (devastating) - falls in some buildings, the collapse of walls, partitions, roofing. Landslides, debris and landslides in the mountains. The rate of progress of cracks can be up to 2 km / s;
10. points (kills) - falls in many buildings, in others - serious damage. Cracks in the ground up to 1 m wide, cave-ins, landslides. Through the rubble of the river valleys there are lakes;
11. points (catastrophe) - the numerous cracks in the surface of the Earth, large avalanches in the mountains. The total destruction of buildings;
12. points (severe accident) - change in relief on a large scale. Huge rock falls and landslides. The total destruction of buildings and structures.

In reality only the large underground nuclear explosion can produce the strong earthquake.

Nuclear Reactions in Energy Charge

Energy charge contains the nuclear detonator, the deuterium as explosive and cheap Uranium-238 for production the nuclear fuel for next nuclear detonator and fuel for the nuclear electric stations and nuclear weapon[1].

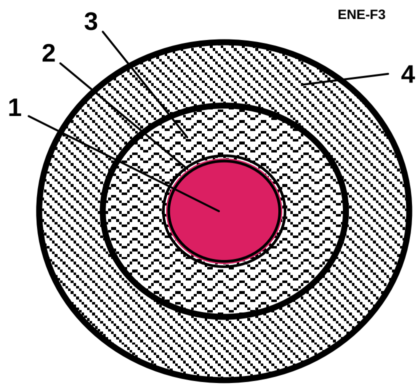

Fig.9. Energy charge[1]. Notations: 1 – Nuclear charge/initiator (Uranium-233 or Plutonium-239); 2 – neutron reflector; 3 – deuterium; 4 – Uranium-238 or Thorium-232. Diameter is about 1 m, mass is about 1 ton.

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[1] Author does not give design of Energy Charge because design may be used by terrorists for production of thermonuclear bombs.

The main fuel is deuterium which is contained in sea water. The Earth has gigantic reservoir of deuterium about 0.015% from all hydrogen on Earth. Its price is about $700/kg (2012).
The fuel charge may also contain the cheap lithium and beryllium because they help to produce the energy and tritium – important and expensive fuel for thermonuclear reactors.
Nuclear Reactors can use the isotopes Uranium- 233, 235, 238; isotopes Plutonium-239-242; isotopes Thorium: Th-232.
The nuclear detonator 1 (fig.8) may be used the Uranium-233 or Plutonium-239.

For Uranium-233 reaction is

$$^{233}U + n \rightarrow X_1 + X_2 + \bar{\nu}_1 n + 200\,\text{MeV}, \qquad (5)$$

where U-233 is uranium, n is neutron, X_1, X_2 are fission fragments, $\bar{\nu}_1$ is multiplication factor (one is ≈ 2.7 - 3 for U-233), MeV is unit of energy (1 MeV = $1.6\cdot10^{-13}$ J).

For Plutonium-239 the reaction is

$$^{239}Pu + n \rightarrow X_3 + X_4 + \bar{\nu}_2 n + 200\,\text{MeV}, \qquad (6)$$

Where Pu-239 is plutonium; n is neutron, X_3, X_4 are fission fragments; $\bar{\nu}_2$ is multiplication factor (one is ≈ 3.5).

The high temperature produces the chain reactions in deuterium (layer 2 of fig.8.). We can shortly write the thermonuclear reaction in deuterium as:

$$7D \rightarrow 2\,{}^4_2He + 3p + 3n \quad + 41MeV, \qquad (7)$$

where D is deuterium; p is proton; He-4 is helium-4 (stable isotope) .

The neutrons from (3) go to the layer 4 (fig.8). The layer 4 contains the cheap Uran-238 or cheap Thorium-232. Neutrons convert them into very expensive Plutonium-239 or Uranium-233. Short (simplified) final reactions are:

$$^{238}U + n \rightarrow {}^{239}Pu\,, \quad {}^{232}Th + n \rightarrow {}^{233}U\,. \qquad (8)$$

As you see the cycle is closed-loop. Both products (Plutonium-239 and Uranium-233) may be used as nuclear fuel in production very cheap energy for the new energy-charges (see equation (1)-(2)) or for thermonuclear devices. We get some times more nuclear fuel in every cycle than spent in the energy-charge. The cost of U-238 and Th-232 is about 700$/kg (2012), deuterium about 3500$/kg. The cost of Pu-239 and U-233 is about 60 Million $/kg in black market. The Russia offers the USA the price of 16 Millions $/kg.

For simplify we wrote only initial and final products in chain of reaction (without intermediate reactions). For example, in reality the reaction (3) is:

Initial fuel		Intermediate fuel		Combustion product	Energy, MeV	
$D + D$	$\rightarrow$	T	+	H	+ 4.03	
D	+	T	$\rightarrow$	He-4 + n	+17.6	(9)
$D + D$	$\rightarrow$	He-3	+	n	+ 3.27	
D	+	He-3	$\rightarrow$	He-4 + H	+18.3	

Summary this chain of reactions may be presented as:

$$6\,{}^2_1D \rightarrow 2\,{}^4_2He + 2\,{}^4_2He + 2n \quad + 43.6MeV\,. \qquad (10)$$

If we add the reaction $D + n \rightarrow p + 2n$ -2.2MeV, we receive the final reaction (3).

Neutrons are very useful for getting of the nuclear fuel. For increasing the production of nuclear fuel we can add into the energy-charge the Beryllium-9:

$$^9Be + n \rightarrow {}^8Be + 2n \rightarrow 2\,{}^4He + 2n\,. \qquad (11)$$

But for this reaction the energy of n must be more >1.85 MeV. For this the lithium also may be used.

The list of possible reactions is below in table 3.

Table 3. Thermonuclear fusion reactions in deuterium area

(1)	D	+	T		^{4}He	(3.5 MeV)	+		n	(14.1 MeV)					
(2i)	D	+	D		T	(1.01 MeV)	+		p	(3.02 MeV)					*50%*
(2ii)					^{3}He	(0.82 MeV)	+		n	(2.45 MeV)					*50%*
(3)	D	+	^{3}He		^{4}He	(3.6 MeV)	+		p	(14.7 MeV)					
(4)	T	+	T		^{4}He		+	2	n	+ 11.3 MeV					
(5)	^{3}He	+	^{3}He		^{4}He		+	2	p	+ 12.9 MeV					
(6i)	^{3}He	+	T		^{4}He		+		p		+	n	+ 12.1 MeV		*51%*
(6ii)					^{4}He	(4.8 MeV)	+		D	(9.5 MeV)					*43%*
(6iii)					^{4}He	(0.5 MeV)	+		n	(1.9 MeV)	+	p	(11.9 MeV)		*6%*
(7)	D	+	^{6}Li	2	^{4}He	+ 22.4 MeV									
(8)	p	+	^{6}Li		^{4}He	(1.7 MeV)	+		^{3}He	(2.3 MeV)					
(9)	^{3}He	+	^{6}Li	2	^{4}He		+		p	+ 16.9 MeV					
(10)	p	+	^{11}B	3	^{4}He	+ 8.7 MeV									

p (protium), D (deuterium), and T (tritium) are shorthand notation for the main three isotopes of hydrogen.

Critical mass of uranium depends from his density. That may be computed the equation:

$$M_c = \frac{4\cdot 10^6}{\rho^2} \quad g^3cm^{-6}, \qquad (12)$$

For ρ = 20 g/cm^3 critical mass $M_c = 10\,kg$; for ρ = 40 g/cm^3 critical mass $M_c = 2.5\,kg$; for ρ = 80 g/cm^3 critical mass $M_c = 625\,g$. Using the neutron deflector significantly decreases the critical mass.

If it is used the water neutron reflector, the critical mass of U-235 is 0.8 kg, of Pu-239 is 0.5 kg. In theory the Cf-251 has the minimal critical mass 10 grams.

Thermal conductivity of the soil. Thermal conductivity of undergrowth soil may be estimated by equation [3] p.367.

$$Q = 4\pi\lambda\Delta t/(1/r_1 - 1/r_2)\,, \qquad (13)$$

Where λ is coefficient of heat transfer, W/m.degree; Δt is difference of temperature, K; r is radius of internal and outer spheres, m. λ = 0,326 for dry sand, λ = 0,36 for gravel, λ = 3,14 for granite, λ = 1.28 for concrete.

Estimation shows the loss of heat is small (270 kW). The Earth has high temperature inside (≈ 6000 K), but we do not have trouble from it.

5. Project

For comparison with project [1] (Fig.2 – project on Earth surface under the artificial mountains), we consider version the average powers 50 GW. Our projects are different from projects [1]. Our installations locate a deep under Earth surface (up 1 km in nuclear cavity) and use the water as cooler.

Results of computation are following:
Diameter underground cavity is: ≈ 150 m .
Deep of cavity under surface is: 1000 m.
Energy of single explosion is: 10^{14} J or 25 kt of TNT.
Number explosion is: about one every hour or about 20 per day or 6600 per year.
Full average power of installation is about: 50 GW.
Fuel consumption in year for uranium cycle is:
Uraniun-238: ≈ 1 ton in year; Deuterium: ≈ 4 tons in year.
If it is used thorium cycle, the annual fuel consumption is:
Thorium 2 tons/year, deuterium 10 tons/year.
Bookmark of nuclear fuel is:
Uranium- 238: ≈ 5 tons; Plutonium: ≈ 1 ton.

If it is used thorium cycle, bookmark of nuclear fuel is:
Uranium – 10 tons/year, thorium – 10 tons/year.

Regeneration are:
Uranium: 250 tons;
Plutonium: 50 tons.

The temperature of water may reach up 400^oC, pressure up 450 atm. Average pressure is about 160 atm, temperature 330^oC. (Note: the soil pressure at deep 1000m is about 350 atm).

Production of the fusion fragments is: 1 ton/year;

The water is not radioactive. Only admixtures in water may be radioactive and corrosion of construction metals: iron, nickel, cobalt, chromium. But metal corrosion is easy separated by ion exchanger.

The first 10^5 seconds (about 1 day) the radioactive of fragments is less than natural radioactivity of Earth. That time is enough for their separation and passing into special underground storage.

Radiation of long time radioisotopes is about 20 kCu/GW.year.

Economics section.

Let us compare the Russian and offered projects.

The Russian project of 50 GW requests [1]:

1. Quality steel 4 million tons. In 2012 the cost of conventional carbon steel was 750 ÷ 800 $/ton, stainless steel was 3000 ÷ 3100 $/ton. If we take average cost 2500 $/t, the cost only quality steel is 10 billion of US dollars.
2. Concrete 20 millions tons. In 2012 the cost of concrete (cement) was $300/ton. It is 6 billion dollars.
3. Natrium (sodium) 300 thousand tons. In 2012 the cost of sodium was 500$/ton. It is 150 millions.
4. Artificial mountain. One has volume about 25 millions m^3. The cost of transportation soil is $15\$/m^3$; the total cost of earthwork will cost about 380 millions dollars.

Total cost only material (steel + concrete + sodium + artificial mountain) in Russian project is 16.53 billions.

Suggested project has estimated expenses as follows:

1. Drilling 4 well. Cost of 4 wells deep 1 km is 6 millions (one long 1 km well cost 1.5M).
2. The nuclear bomb cost about 1 million dollars (cost is practically independent from power). That uses for creating of cavity.

The total cost given section is 7 - 8 millions. That is two thousands less than same part of Russian project.

That also has more safety in a lot of times.

Let us now compare efficiency of the Russian vs. the offered project.

1. Production Electricity and heat is same. But cost of energy in our case in ten times less (about $0.001/kWh) because the cost of installation in tens time is less. Payback time in five times is less.
2. Production of nuclear fuel is same. But cost of the nuclear fuel in our case in ten times less because cost of installation in tens time is less. Payback time in about five times is less.
3. Our system will produce 165 millions m^3 fresh water about zero cost. That is very important for arid regions. Average price of fresh water is $1\$/m^3$ now (2012).

Discussing (cost, economics, security)

Humanity needs large energy sources. Fossil fuel reserves are limited (oil, coal, etc.). They became more and more expensive. The wind and solar energy have low density and are inconstant. In present time the installations for them are more expensive than installations for fossil fuel energy.

This problem may be solved by using underground explosive nuclear stations. The nuclear countries have big amount the nuclear bombs and discus about decreasing the nuclear weapons. Part of these bombs may be used for creating the initial underground cavities and nuclear stations which will produce the nuclear fuel for these and next (or conventional) nuclear stations, huge amount of electricity, district heating and the artificial fuel (example, liquid fuel from coal) for moving transport.

The offer version of producing the explosive nuclear energy is cheaper in hundreds times than old surface version. That is more safety. That additionally produces large amount of fresh water (from sea water) very useful for arid regions.

The former USSR produced about 169 underground nuclear explosions. The 22 of them were nuclear explosions for creating the underground gas storages.

One ton of uranium can save 1 million tons of oil or 2 - 2.5 million tons of coal.

Brief Summary

The author offers new underground explosive nuclear station used a cheap deuterium as nuclear fuel and sea water as cooling agent. He shows this station will be cheaper in hundred times than Russian project of surface explosive nuclear station, more safety and produce not only the electricity (as Russian version) but a lot of fresh water for arid regions.

The works closed to this topic are in [1]-[10].

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