Underground Nuclear Explosions as a Source of Heat for Electrical Power

A. DIRECT USE OF THE ENERGY OF THE NUCLEAR EXPLOSIVE

A kiloton (kton) of (explosive) energy is defined as 10^{12} ~~ergs~~ calories (4.2×10^{12} joules) so that the detonation of a [redacted] nuclear explosive releases about [redacted] [redacted] days of energy. In a contained underground nuclear explosion most of this energy will be deposited as heat in a region surrounding the explosion point. One of the earliest objectives of the United States Plowshare Programme was to determine the amount of energy remaining in this region as available heat and to study the problems connected with recovering this heat for the generation of (electrical) power.

2. In the initial stages of a contained underground explosion the expansion of the gas bubble consisting of reaction products and vaporised rock gives rise to a roughly spherical cavity. In most cases this cavity is unstable and suffers upward collapse to give a roughly cylindrical rubble filled column (or chimney). The only examples of standing cavities are in massive deposits of rock salt.

3. Measurements made at Rainier, the first American contained underground nuclear explosion (September 1957) showed that an appreciable water content in the geologic medium reduces the final temperature to the boiling point of water. One of the objectives of the Gnome explosion (December 1961) was to overcome this difficulty by working in a salt medium with a very low water content. Hopefully much higher residual temperatures would be obtained and thermal efficiencies might be acceptably high. It was anticipated that a permanent cavity with impermeable walls would be formed. At the bottom would be a slowly solidifying pool of salt. Water could be forced down a re-entry hole, heated, brought to the surface, flashed into steam and run through a turbine to produce electricity. Carbon dioxide, nitrogen and dry air were considered as alternative working fluids. [redacted] paper* to the second UN Conference on the Peaceful Uses of Atomic Energy illustrates the speculations current at the end of the fifties.

4. The results of Gnome were disappointing - at least from the heat source viewpoint. Firstly there were quite large amounts of water about and the maximum temperature 6½ months after the explosion was only 83° C. (There are three main sources of water - artificial introduction, say during drilling; the natural water table; and chemical water found in minerals of the medium). Secondly partial collapse of the cavity occurred due to interbedding of clay etc in the salt medium so that the pool of molten salt was quenched and heat losses by conduction and convection greatly increased.

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5. Following their analysis of the Gnome results the Plowshare Group appear to have lost interest in this application of Peaceful Nuclear Explosions (PNE). A more promising related application is to assist in the exploitation of geothermal heat.

B. EXPLOITATION OF GEOTHERMAL ENERGY

6. There are three types of geothermal energy resources - dry steam, hot water and hot dry rock. Hot dry rock occurs everywhere but the depth to practically useful temperatures (170°C upwards) varies from place to place. The other resources are more localised [see review* by [redacted] Science 177, 978 (15 September 1972)].

7. The use of nuclear explosions to assist in the recovery of this energy was first suggested about 1959 and was the subject of a paper to the Third Plowshar Symposium in 1964 (TID-7695 pps 305-8). Since the advent of growing interest in geothermal energy in general possible schemes have been studied in more detail notably in PNE-1550 (April 1971)**. The main concept of this report is that nuclear explosives should be used to fracture large quantities of hot rock. Heat would be extracted from the fractured region by piping water to it and creating steam for use in a turbine. The system would be closed by recycling the condensed steam from the power plant back to the fractured rock. For reasonable output - say a 200 MW(E) plant operating for 30 years - a large number of explosions would be required. Some tens of high yield explosives - in the [redacted] range - fired in arrays are likely to be required. The main difficulty is to deal with the seismic damage hazard. As far as the power station itself is concerned this means either (i) carrying out all the explosions before power station construction or (ii) building a hardened station or (iii) using a mobile station. The closed cycle concept and the great depth of working is held to ensure that no radio-activity will enter the atmosphere or ground water.

8. Nuclear explosions appear to have advantage in tapping the hot dry rock source of geothermal energy. But hydrofracturing coupled with better drilling techniques could allow a more conventional exploitation of this source (see [redacted] article).

9. Nuclear explosives could be used to stimulate dry steam and hot water geothermal energy sources if low permeability prevents their exploitation by conventional means.

10. Remembering the seismic damage hazard the logical place to use nuclear explosives to exploit geothermal energy is perhaps beneath the seabed using a (mobile) ship-borne power station.

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11. The exploitation of geothermal energy resources was the subject of a meeting of the American Nuclear Society's Civil Explosion Application Division in June 1972 (Trans.Am.Nuc.Soc. 15, 13)*.

C. OTHER APPLICATIONS OF NUCLEAR EXPLOSIVES IN THE ENERGY INDUSTRIES

12. Other proposed applications of nuclear explosives impinging on the energy industries include

(a) Gas stimulation
(b) Oil stimulation
(c) Gas storage
(d) Oil storage
(e) Recovery of oil from shale
(f) Recovery of oil from tar sands
(g) Extinction of gas and oil well fires
(h) Energy "storage" using nuclear cavities to contain compressed air or water.
(i) In-situ gasification of coal

Of these (a) (b) (c) and (g) have been the subject of American and/or Russian actual development shots or real projects.

13. In all uses of nuclear explosive to produce fuels or energy it is important to consider the relative advantage of using the fissile material involved in the PNE application as against a thermal and/or fast power reactor cycle. To my knowledge this has only been done for the American gas stimulation programme; the outcome does favour the PNE application of the fissile material.

[redacted]
27 November 1973

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