The Oil Drum
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

Oil Shale - the Nuclear Option

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Well, as Gazprom consolidates its grip on Russian gas it could be that we may need access to all that oil locked up in the oil shale somewhat sooner than the four years that Shell have said it needs before it can even decide if their process is viable (and I'll cover that in a later post). Now before I get into the piece that follows I should explain that I don't hold any particular animus towards the states of Colorado, Utah, Wyoming or Idaho and so when I start talking about disposing of nuclear weapons in those states by making use of them it should be taken as merely a technical discussion (grin).

The need for a relatively rapidly available resource to allow us to continue being able to supply the worlds needs for oil, even as it increases into the future, will require some fairly rapid and agile production of resources, and as I noted in the first post of this series, with some 2 trillion extractable barrels of oil locked up in the oil shales of the above four states, there lies a potential answer to the problem. But conventional means for extraction, particularly the levels of capital required, and other issues that I will discuss later, make it unlikely that these normal means will produce any significant impact on the gap in economic supply that will develop in the near future. The use of nuclear explosives has the potential to solve that problem. And to explain, rather simply how this might be done (as with the other techie talks), I will explain how, conceptually, this might be achieved.

The papers that I am going to take the concepts from were given at the second and third oil shale symposia and are listed at the end of the post. They describe the application of results from over 150 underground nuclear detonations which were carried out as the United States sought to find peaceful uses for nuclear explosives as part of the Plowshare Program. I will also be using 1960's costs since these were used in the papers.

To set the stage, as I have described earlier, the Western oil shales occur in rock with almost no permeability, and the kerogen that is in the rock will, under normal conditions stay there, rather than flowing even when it has the chance. So if the oil (kerogen) is to be recovered two things will be needed. The first is a way of massively fracturing the rock, and the second is the maintenance of some level of heating to liquefy the oil, and then to keep it flowing. Large scale fracture of the rock will, in turn, require the application of massive levels of energy, and here nuclear explosives are in a class of their own. Explosive yields are usually given in kilotons, where a kiloton has the effective energy in a thousand tons of TNT. (A ton of TNT has an energy content of 4,184 Megajoules). At the same time the devices themselves are relatively small. A 250 KT device would be around 20 inches in diameter and about two to four times that long. The cost to place it, and the device itself, was estimated to be around $500,000 in 1965.

The oil shale layers are about 2,000 ft thick, and under an additional cover of 1,000 ft of overlying rock (overburden to mining engineers). If a 250 KT device was placed at the bottom of the shale layer, therefore, and detonated, it could be expected to create a cavity that would be around 400 ft in diameter. Much of the radioactive material generated (anticipated to be tritium) would be fused into the wall of the cavity, or caught in the gas that could be drawn off and collected through the boreholes subsequently used to take advantage of the blast.

The shockwave from the event is anticipated to create damaging surface motion to a distance of 2 miles or so, and be substantially disturbing to 6 miles, however, for our purpose, in the immediate vicinity of the blast it will induce significant fractures in the surrounding, and overlying rock. This will cause the rock immediately over the blasted cavity to collapse, and to fall in until a chimney of broken rock has been formed. This chimney will grow upwards until the bulking of the rock as it breaks (that gain of 60% I mentioned last post) fills the space available. For the 250 KT shot this chimney is estimated to be around 1,000 ft high. Experience suggests that the blocks will break into pieces up to 3-ft in size, though the collapse and internal fracturing may increase their ignition potential. The rock surrounding the cavity will, for a distance of around 3-cavity diameters be fractured with a permeability of up to 1 darcy. (The Ghawar field in Saudi Arabia has an average permeability of 617 millidarcies). Beyond that range, and out to about 6 to 8 radii the rock will continue to be fractured, but with fractures more widely spaced and less useful.

Thus, if the entire area is to be treated, then shots would need to be fired around 3 - 4 cavity radii apart in order to maximize the break-up of the rock. (Say for our hypothetical model this would be around 750 ft). By drilling sets of 5 shot holes to create individual retorts, and grouping these in sets of four, to create a "plant," we could create a production operation for the recovery of the oil. Depending on whether the intent is to optimize the fragmentation of the rock, or the fracturing of the surrounding rock with the patterns, some 240,000,000 to 1,000,000,000 cubic feet of rock will be broken per shot, at a cost of $0.015 to $0.05 per ton.

Which brings up the second advantage of nuclear explosives. About 2.5 months after the shot the temperature at the wall of the cavity will still be around 1,000 degrees F, and some 11 months after the shot it will be around 180 degrees. Since the only place for this heat to go is into the surrounding rock, it will cook the kerogen in the vicinity into oil, with, at the sustaining temperature, a low enough viscosity that it will flow into any adjacent collection point.

And it is here that the advances of the past 40-years come into play, since oil drilling is now capable of drilling a "bottle brush" collection pattern under the cavity in order to access and collect the oil (and some water) as it drains down through the fractures. However drilling will also be required to feed air into the chimney and to turn it into a large-scale retort to complete the transition of the kerogen in the vicinity to oil, and to mobilize it. Based on USBM experiments, some 75-90% of the oil in the shale can be recovered from such an in-situ retort. Where necessary some of the gas produced may also be used, in the later stages of the upward progression of the fire front, to enhance the strength of the fire front and to ensure that it continues to move up through the shale, not only in the chimney, but then also into the overlying and surrounding rock. (The fire can be controlled to either burn up or down what now becomes an extremely large retort).

Using this technique and applying it to each of the plants, that I have just described, it is anticipated that each plant, which would cover an area about a mile in diameter, would produce some 450 million barrels of oil over twelve years, at a production rate per day of 100,000 barrels, assuming a 75% recovery of the oil over the 2,000 ft interval. It is anticipated that with a feed of around 3,000 cfm/ton of air at 50 psi, that the flame front could progress at a speed of between 1 and 2 ft per day. In 1965 dollars, it was anticipated that the operation could make a profit if the oil were then sold to a refinery at a cost of $1.50 a barrel. Oil recovery would, however, be controlled by the quantity of oil in each "retort" layer, and, by the nature of the operation, all the oil would be anticipated to be recovered but at the rate controlled by the layers as they produced. However the process is considered economic for oil shale at grades above 15 gallons/ton with thicknesses of greater than 400 ft.

So just think, when we talk about "the nuclear option" in future, we may have an entirely different concept in mind (/grin).

(Note that, for consistency I changed some of the numbers to reflect use in the 2,000 ft shale column, rather than the 1,000 ft used in some of the example calculations in the papers).

Reference papers for this post are:
M.A. Lekas and H.C. Carpenter "Fracturing Oil Shale with Nuclear Explosives for In-Situ Retorting", 2nd Symposium on Oil Shale, CSM, 1965.
H.F. Coffer and E.R. Spiess "Commercial Applications of Nuclear Explosives, the Answer to Oil Shale?", 3rd Symposium on Oil Shale, CSM, 1966.
M.E. Lekas "Economics of Producing Shale Oil, the Nuclear In-Situ Retorting Method,"
3rd Symposium on Oil Shale, CSM, 1966.

Previous posts in this short series on Oil shale dealt with

Where it is
Mining oil shale