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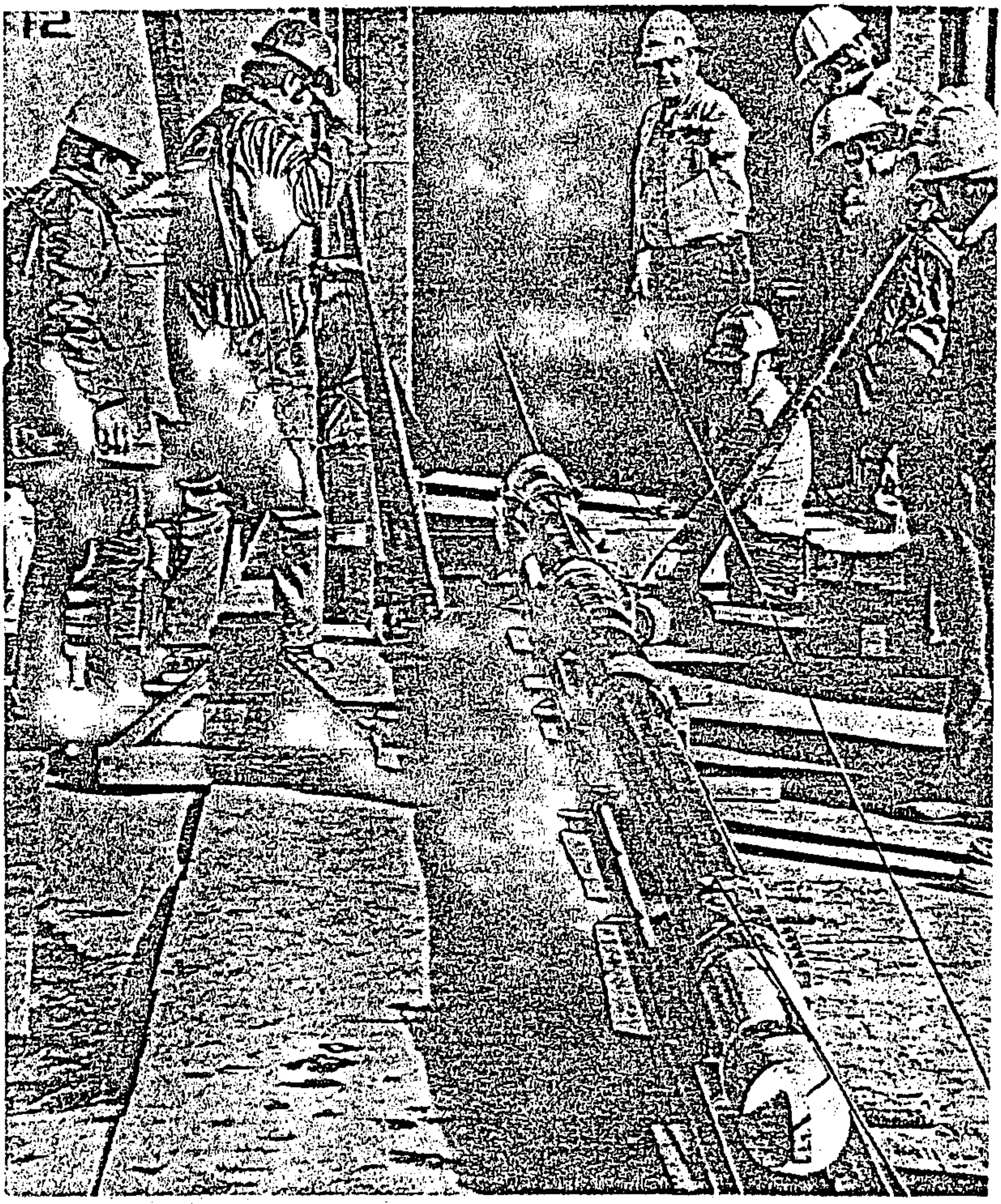


ONE OF THREE 30-kiloton explosives, 30 ft. long and 7 in. in diameter, used for simultaneous detonation in Rio Blanco gas stimulation experiment. Shot went off without a hitch, with almost no seismic effect and no radiation release. Story on p. 7.

Independent Safety Division Emerges from New AEC Reorganization

Rio Blanco Natural Gas Stimulation Shot Goes Off Without a Hitch

Rio Blanco Plowshare Shot:

A Flawless Performance

"It was great, just great! And you're great people, too."

"I really expected to be shaken up a little more."

"It was about what I expected. A little less, maybe."

Those were the reactions of Atomic Energy Commission Chairman Dixy Lee Ray, Sen. Peter Dominick (R-Colo.) and Colorado Gov. John Love at the Project Rio Blanco nuclear gas stimulation experiment observation point May 17, just moments after the three 30-kiloton nuclear devices were detonated more than a mile underground in the Piceance Basin of northwestern Colorado.

They were among more than 350 persons at the point 12 miles from Ground Zero for the test. The weather was perfect, security problems were nil, morale was high and the countdown went without a hitch. At precisely 10 a.m. MDT, right on schedule, the three explosives fired.

Those at the observation post saw a faint tendril of dust rise from the emplacement well site. About 10 seconds later, three gentle rolls could be felt at the control point. The seismic motion wasn't even sufficient to topple a stack of a dozen empty tin cans or splash more than a few drops of water from paper cups perched on rocks as makeshift seismographs. Most of the newsmen, about 100 residents of the area and even veterans of previous nuclear shots were somewhat surprised—even startled—at the lack of more seismic motion.

"I'm surprised that it all went so well, especially with so many, many different agencies involved," Charles Williams, project director, told *Nuclear Industry.* "The coordination problem is terrific."

"I'm a happy man," CER Geonuclear Corp. Vice President H. H. Aronson advised a few minutes after the test. "Everything looks good. All indications are that all three of the explosives fired as expected and there was no seepage of gas or radiation."

CER and Equity Oil Co. were industrial sponsors of the test, picking up 85% of the estimated $7.5 million cost with AEC carrying the balance.

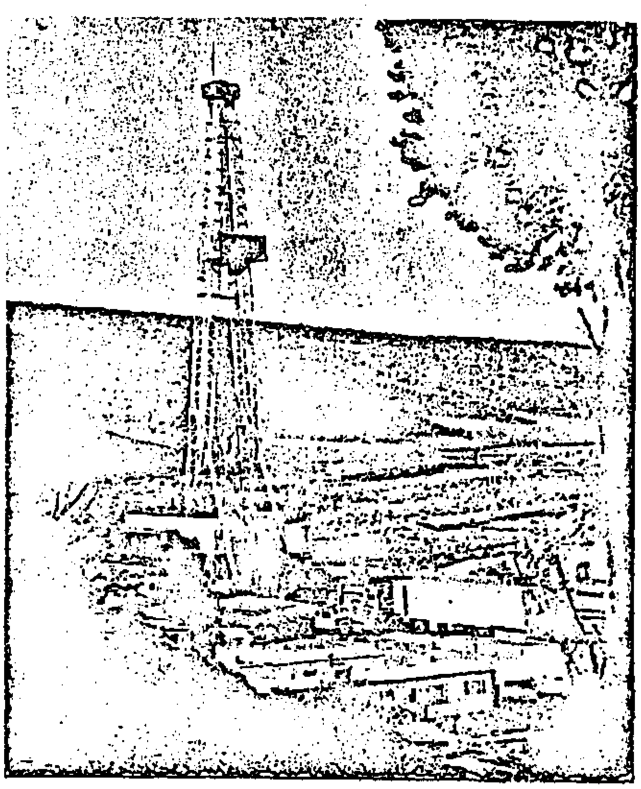
About two hours after the detonations, the first crews moved to the test well to verify on-site instruments that said seismic motion had died and that no radiation was released. Half a dozen helicopters and aircraft buzzed and clattered over the area, finding only background radiation and a bit of dust from minor rockfalls near the test well.

Shortly after reentry operations, the 75 residents of the area who had been asked to leave their homes for the test (each family was paid $50 "inconvenience money" by CER) returned home and follow-up crews soon checked for seismic damage. On-the-spot claims settlements were authorized if requested—but none were—and carpenter crews also were on hand to provide any urgent repairs.

The only urgent request was from a rancher who asked to have a large rock moved from his road so he could get to a sick calf.

Before-shot damage estimates ranged from $38,000 to $64,000. Early appraisal of damage and the lack of damage claims from outlying communities raised

STANDARD OIL FIELD DERRICK served for Rio Blanco and is intended for use in future commercial Plowshare shots.



hopes that the total probably would not exceed $20,-000.

"You know, after four years I'm kind of relieved that this has been culminated, but I'm sorry in a way, too," Aronson advised. "Now the real work begins for us, but we have surely enjoyed working with the people in Colorado, too."

From all indications, only a dozen environmentalists of the 200 who threatened a demonstration, and a handful of professional nuclear critics seemed to be sorry to see the shot. CER's extensive public information program was an unqualified, hands-down success in garnering not only local acceptance, but local support for Rio Blanco.

Even a last-minute lawsuit by environmentalists failed to dampen spirits too much. Filed on Apr. 26 by Citizens for Colorado's Future and other environmentalist groups, it was thrown out of the Colorado District Court in Denver by Judge Henry Santo. He ruled that while the group had a right to sue, it didn't have a case against issuance of the various state permits that are necessary.

Possibly setting some precedent, the judge declared, however, that—contrary to CER and AEC arguments —the state did, in fact, have control over the nuclear test.

"We are going to learn a lot from this test, and I think it is going to conclusively demonstrate whether this is a viable, commercially-applicable technology," AEC Chairman Ray told *Nuclear Industry*. "I am proud to be a part of it, and it will be interesting in the next few months or year to see the technical results of this experiment."

Elaborate Preparations

The three, 30-kiloton Diamond series explosives were readied and secretly (for security reasons) shipped to Rio Blanco from the Nevada Test Site. A conventional oil field drilling rig was erected over the emplacement well and mandrills—exact replicas of the explosives and related hardware—were repeatedly sent to the bottom of the well and extracted to verify AEC requirements that the well wasn't obstructed or too kinked to accept the explosives.

A microwave translator and relay station was quickly erected on a low hill overlooking the emplacement well and a companion control trailer was parked on another hill 12 miles away. Extensive instrumentation was moved to the site to test everything from ground motion at dozens of locations to the turbidity and flows of streams and springs to weather conditions and gas analysis. Along with the equipment were representatives of CER, Lawrence-Livermore Laboratory, which developed the explosives especially for gas stimulation, and AEC which is required by law to oversee the operation and conduct the actual firing.

Once everything and everyone was on site, the cased and grouted well that had been drilled two years earlier in anticipation of the test began receiving its first nuclear explosive.

The first of the three devices, gleaming cylinders of stainless steel, was removed from its shipping cradle and monitoring instruments on May 3. It was the third and lower-most explosive in a 1,000-ft.-long string of explosives, tracers and spacers to be lowered into the well. The third and last explosive was emplaced in the 7,000-ft.-deep well on May 5.

Utilized for this test, but probably not in commercial application, were test cannisters of tracer elements —xenon, krypton and neon—attached to the bottoms of the explosives. Migration of these harmless but readily identifiable gases, or the lack of it, will help determine the extent of communication between the three rubble-filled cavities, or "chimneys" created by the powerful blasts.

Each of the tracer cannisters is approximately 7 in. in diameter and 35 ft. long, attached with a conventional well collar to the explosive, which also is 7 in. in diameter and approximately 30 ft. long. Attached to the top of each explosive is a "water can," or cooling cannister containing water and equipment designed to provide up to eight weeks' cooling of the explosives without the requirement for refrigeration lines or other surface equipment.

Also part of the cooling system are three adsorber lime cannisters approximately 36 ft. long and 7 in. in diameter for each explosive. They are interconnected with couplings to the water cannister, explosive and tracer cans.

This unique cooling system is cited by LLL as a

THE SECOND of three 30-kiloton nuclear explosives to be emplaced is gently lifted from transport cradle at well site.

significant cost saver, and allows engineers to maintain electrical component circuitry at less than 160°F despite downhole temperatures of up to 220°F.

In the field, the various cannisters are coupled with conventional fittings while separated by about eight in.; they are then screwed together like pieces of ordinary drill pipe to form solid, single units about 200 ft. long.

Sections of standard drill pipe were used to separate the explosive chains at their proper spacing for burst points at 5,840, 6,230 and 6,690 ft. below the surface. With the last explosive on the drill string, more sections of drill pipe were added until the explosives were at the proper depths inside the 10¾ in. steel casing cemented into the solid rock formation. This left a 7-in. casing extending from the explosives chains to within a few feet of the surface. The annular section between the two casings was then filled with concrete.

Water-tight "packers" were inserted into the emplacement pipe, or the internal casing just above the top adsorber tank, and 500 ft. of water was pumped into the pipe. Above this, a 2,400-ft. plug of concrete was poured and the remainder of the casing was filled with water.

John Toman of LLL said that once stemmed in this manner, there was no reasonable way to remove the explosives, even if court orders halted the test. He said, however, that once the cooling period built into the explosives had been exhausted, the explosives would become inoperable; in no way could they be fired or detonate accidentally.

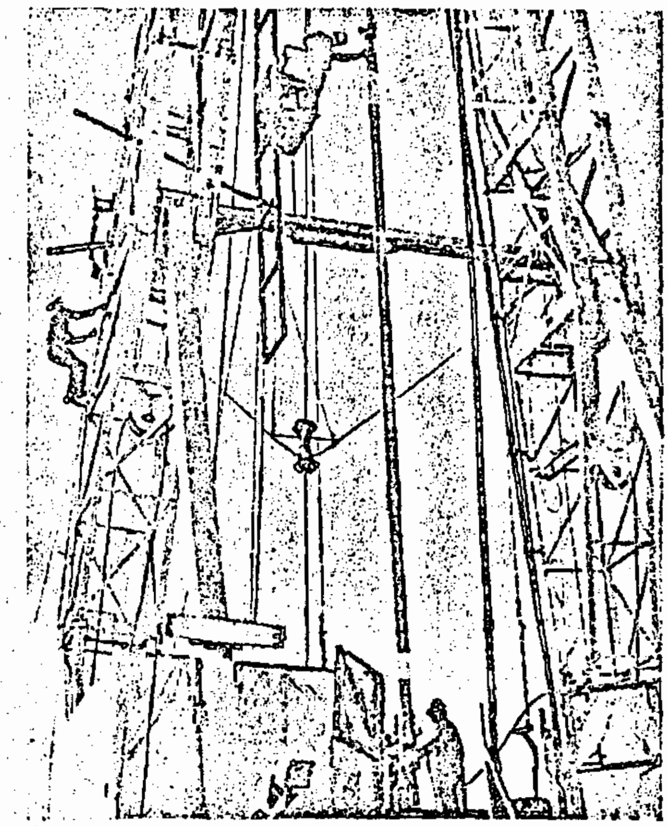
Aronson later told *Nuclear Industry* that extraction was "probably possible," but at a cost of not less than $10 million.

This form of stemming is both unique and vitally important to commercial application of nuclear stimulation technology. In earlier tests, at Gasbuggy in New Mexico in 1967, and at Rulison, about 50 miles from Rio Blanco in 1969, the explosives were stemmed solid with concrete, sand, gravel and other materials.

Reentry into the fracture zone created by the blasts required drilling new wells to the full depth and entering the chimneys at the sides—an expensive proposition.

Reentry plans for Rio Blanco call for running a small-diameter drill bit down the inside of the drill string and simply drilling out the 2,800-ft.-thick concrete plug. The lower 500 ft. of water is intended as a cushion and to assist in reentry. If the concrete plug extended into the nuclear chimney, twisted or disjointed drill pipe from the explosion could force drilling of another well.

"This way, we should be able to go through reentry in good shape," Aronson told *Nuclear Industry*. "It should work out real well, it should not compromise safety at all and it should be much more commercial."



WORKMEN aligning a nuclear explosive with section of drillstem attached to top of already emplaced explosive.

Test of Economics

Use of this reentry method is perhaps the most visible cost-saving feature of Rio Blanco, but it is only one of many incorporated in the test and intended for future projects.

From both Plowshare and industry standpoints, all efforts for Rio Blanco were aimed at proving not only that nuclear stimulation works—Gasbuggy and Rulison conclusively proved that, with five to 10-fold increases in gas production realized during production testing—but that it can be feasible with today's anticipated prices for natural gas.

Probably the most significant cost saving is in the design of the nuclear explosives. By utilizing a 7-in. cannister, emplacement well costs can be cut to perhaps a half of the cost of wells for a 12-in. cannister. The Rio Blanco well cost about $1 million.

Efforts also were made to standardize on components for future explosives construction and to fit the explosives to existing oil field equipment regarding such things as diameters, threading, weights and methods of handling. Future explosives can be scaled up or down in yield without appreciable change in any of these design parameters, according to Toman.

Technically, the explosives are all similar to Miniata, AEC's test of the new Diamond series explosives at the Nevada Test Site in July of 1971 (see NI for July '71, p. 27). Cannister size, oil field compatibility and low parameters.

These same basic explosives are now being revamped by LLL under a modest AEC budget to "harden" them enough to withstand sequential instead of simultaneous detonation to reduce seismic effects from the blasts.

Other significant savings, in addition to standardization, cannister size and speeded up reentry include the devices and method of firing. A microwave relay system has been developed so that, when nuclear stimulation gets to the commercial stage, more than one well can be stimulated from a single control point.

In this system, the control trailer is located at a point giving microwave (line-of-sight or bounce line) signals to relatively inexpensive translator boxes, which in turn send signals to the explosives via a single cable and also send monitoring signals to the control point. This reduces costs significantly, according to AEC, and negates the problems and potential failure of multiple cables sometimes several miles long between control point and the explosives.

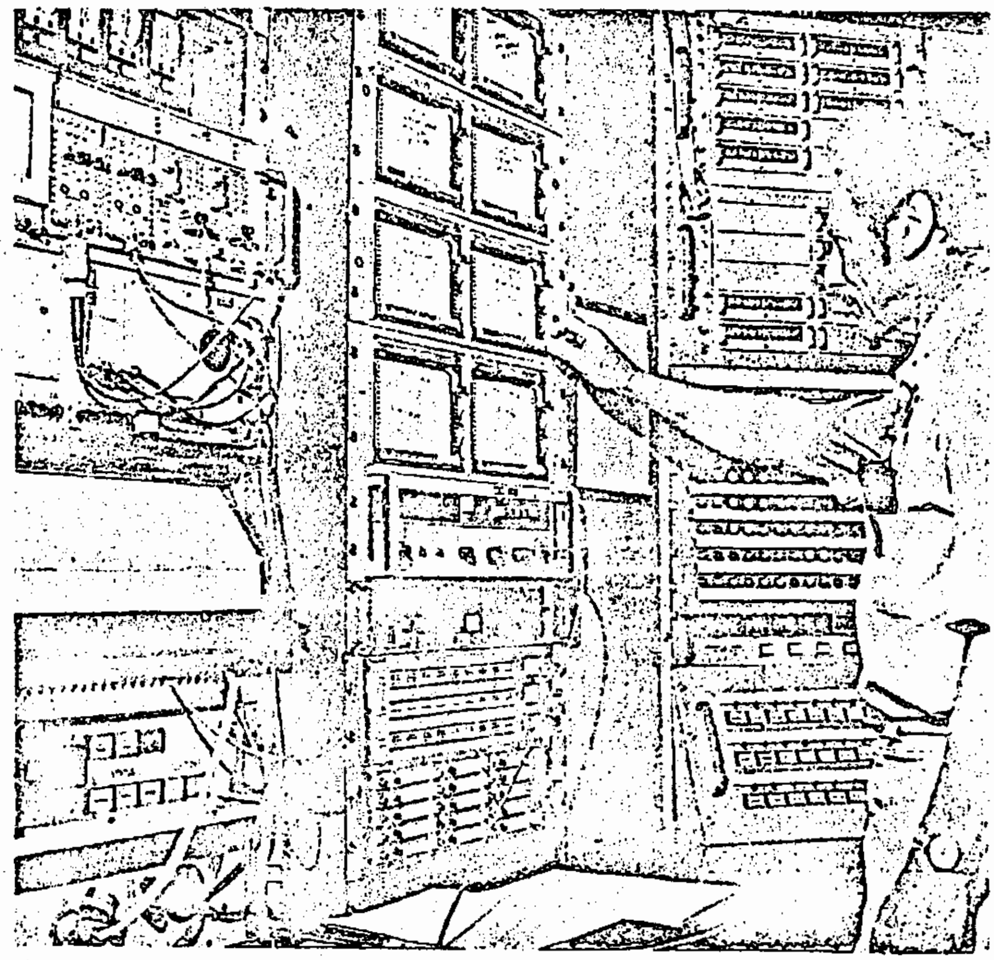
Impressive Results Forecast

Results from Rio Blanco won't be known for some time, but pre-shot predictions made by CER and LLL are optimistic, to say the least. This is because nuclear stimulation represents the same concept as conventional hydraulic or chemical fracturing, but on a larger scale, justifying expenditures of perhaps $2.5 million per well.

Natural gas is trapped within the minute pores of sandstone rather than as giant bubbles of gas far underground, as many laymen visualize a gas reservoir. In various formations, the rock is porous enough that the gas flows through it, much as water will seep through a sponge or piece of paper, to a low pressure area such as a well bore.

In some areas, however, the rock is so nearly impermeable that the flow rate is insufficient to justify drilling a well, much less running a pipeline to it. In the main basins of western Colorado, parts of Wyoming, Utah and New Mexico, an estimated 600 trillion

CONTROL CENTER utilizes microwave relay, allowing several wells to be detonated from one point. Actual firing panel is at lower right. Adjustments are being made by LLL technician.



mations. About 317 trillion cubic ft. of it—twice the nation's proven natural gas reserves—are recoverable by nuclear stimulation, according to AEC. These formations are not amenable to hydraulic or chemical fracturing because of their great depths—5,000 to more than 10,000 ft.—and the fact that the gas is in numerous discontinuous lenses ranging from a few inches to several feet in thickness. Only one lens can be stimulated at a time, if at all, conventionally.

At the Rio Blanco site, 21 different lenses were shown on core samples and logging, covering a total pay sand thickness of 480 ft. in a 1,300-ft. interval. With nuclear stimulation, it is anticipated that all 21 of these lenses will be fractured or "stimulated" and interconnected.

If production testing proves out early estimates, the gas flow at Rio Blanco should increase from its present 40,000 cubic ft. a day (about two weeks' supply for a two-bedroom home in Colorado in the winter) to more than eight million cubic ft. a day.

Equally as optimistic as gas flow projections are those for the amount of radioactive tritium and krypton-85 entrained in the gas following the explosions.

Projections call for a level of 132 to 200 picocuries (pCi) of krypton per milliliter of dry gas and only 21-52 pCi/ml of tritium. By comparison, initial gas flows from the Rulison well, which utilized a single 43-kiloton explosive, contained about 175 pCi/ml each of tritium and krypton. Krypton exposure is considered almost inconsequential.

Plans call for reentry into the well in three to six months, or as soon as short-lived radionuclides have decayed. These have half-lives ranging from fractions of seconds to many years. Most of the solid fission products will be trapped in the glass-like "melt" at the bottom of each chimney and only the tritium and krypton are expected to be entrained in the gas in appreciable volumes.

Production testing to determine the amount of gas production increase and the effectiveness of the underground fracturing is scheduled to begin shortly after reentry. Flow rates of up to 30 million ft. a day to exhaust the three interconnected chimneys are planned, with drawdown pressures and gas flow used to make a computer model of the reservoir characteristics after the shot.

During the production testing, an estimated 800 million cubic ft. of gas will be burned on a flaring stack, releasing some radioactivity into the atmosphere. The amount is small, with the maximum credible dose for someone living five miles downwind (only 150 persons live within a 20-mile radius of the well) only 1 millirem, even including food chain buildup. This is only 1/150th of the normal background radiation in the area. Actual exposures are expected to be on the order of 0.003 millirem, or about the equivalent of a 20-second exposure to the sun at the test well elevation.

A full analysis of Rio Blanco will require from a year to two years, Aronson said. But if—and it's a big if, according to CER—Rio Blanco proves that nuclear stimulation is as effective as projections say, and if seismic effects are reasonable and the gas is usable (sale authorization and standards have not yet been drawn), CER would like to move into a second phase in the same area.

Coming probably in 1975, this would involve the stimulation of four to six wells utilizing the same basic setup, but with explosives that can be fired sequentially instead of simultaneously, thus cutting the seismic factor by perhaps 50% or allowing the use of larger yields with no greater seismic repercussions.

After more review of gas production, costs, prices and the prospect that nuclear explosives will be made available to industry and that the gas could be sold, CER would like to follow with a phase leading to full field development. As many as 20 to 60 wells might be stimulated in a single year, leading to 146 to 220 wells on the 94,000-acre gas lease unit controlled by CER and Equity.

CER estimates there are 74 billion cubic ft. of gas in place per section in the unit, and that each well would have a life of 50 years or more, producing at least 17.5 billion feet of gas in its first 25 years.

The Rio Blanco shot culminates six years' investigation and work in the Piceance Basin by CER, and more than that for Equity. CER first investigated the field in 1967, and later signed an agreement with Equity to investigate the potential for nuclear stimulation. A joint venture agreement between the companies was signed in March of 1970, and CER began advising the AEC and state entities of its intentions.

A project definition agreement with AEC was signed by CER in December of 1970 and CER began informational meetings in the area shortly thereafter. The shot date was tentatively set for February of 1972 at that time, but postponed for study by a special advisory committee appointed by Colorado Gov. John Love, for extra data compilation and for Interior Department and AEC reviews.

The governor's committee recommended the shot be approved in July of 1972, shortly after the affirmative draft environmental statement was published. The final statement was published in April of 1972, following formal AEC hearings in Meeker and Denver, Colo. CER received its contract with AEC on Apr. 12, 1973.