



DEPARTMENT OF NATURAL RESOURCES

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**PROJECT RULISON STUDY
 COLORADO OIL AND GAS CONSERVATION COMMISSION**

Brian J. Macke - May 5, 1998

Project Rulison was a part of the Atomic Energy Commission's Project Plowshare, which was designed to develop peaceful uses of nuclear explosive technology. The joint Atomic Energy Commission (now Department of Energy) and Austral Oil Company project was a nuclear gas stimulation experiment which took place in Garfield County near Rulison, Colorado on September 10, 1969. The experiment was conducted to test the technical and economic feasibility of detonating a nuclear explosive device in tight natural gas bearing rock formations to increase natural gas production.

During the experiment, a 43 kiloton fission-type nuclear explosive device was detonated at a depth of 8,426 feet within the Williams Fork geologic formation in the Mesaverde Group, which consists of thick sequences of tight, natural gas bearing sandstone bodies with limited areal extent. The experiment was the deepest nuclear detonation ever performed in the United States. The nuclear explosion produced a zone of fractured rock and a "chimney" of rock rubble around and above the detonation point. Because of extensive data regarding the extent of the chimney and fractures created by the nuclear explosion which was acquired by drilling a re-entry well into the chimney, the United States federal government has prohibited all drilling below 8,000 feet within the "Lot 11" quarter-quarter section of land containing the Project Rulison emplacement well (see attached annotated well survey plat.)

At the time of the experiment, there was a considerable amount of public concern about the project by environmental protection groups. In the nearly thirty years since the project, the Grand Valley area surrounding Project Rulison has experienced dramatic growth in both population and natural gas development. Because natural gas development is occurring within a few miles of Project Rulison, some members of the public are now concerned that natural gas wells could be drilled into rock formations contaminated with residual radioactive materials from the nuclear detonation and release the materials, threatening public health and safety.

Because of this concern, the Colorado Oil and Gas Conservation Commission (COGCC) representatives have discussed Project Rulison with scientists from the Department of Energy and natural gas well operators in the Rulison area, and have performed a literature search about Project Rulison. The purpose of this study has been to determine what restrictions should be placed on the drilling of natural gas wells into the Williams Fork Formation in the vicinity.

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Extent of Chimney Cavity Formation and Fracturing from Project Rulison

When an underground nuclear device is detonated, a supersonic shock wave moves out radially, vaporizing, melting, crushing, cracking, and displacing the rock. After the initial discharge of energy, the shock wave becomes elastic and vaporized rock expands to form a spherical cavity. Subsequent heat losses, gas leak-off through the fracture system, and vapor condensation reduce the pressure until the fractured rock above the cavity can no longer be supported. Rock collapses into the cavity and forms a complex chimney-rubble zone. Collapse continues until an arch forms with sufficient strength to withstand the load of the overlying rock, or until the rubble zone in the chimney can support it.¹

The Department of Energy has collected data for cavity radius and fracture radius from 921 underground nuclear tests in Nevada.² From this data, the various features of postshot geometry can be readily calculated as a function of detonation yield, depth of burial, and physical properties of rock using empirical equations developed from this large amount of data. For Project Rulison, the predicted cavity radius was a maximum of 108 feet, and the predicted fracturing radius was a maximum of 580 feet.³

The Project Rulison nuclear explosive device was detonated on September 10, 1969 in the Hayward #25-95 (R-E) emplacement well located in the NE $\frac{1}{4}$ SE $\frac{1}{4}$ Section 25, Township 7 South, Range 95 West, 6th P.M. in Garfield County in the Williams Fork Formation at a depth of 8,426 feet. Re-entry operations were performed through a separate directionally drilled re-entry well, the Hayward #25-95 (R-EX) well, which had a surface location 300 feet southeast of the emplacement well. The re-entry well, which was completed in July, 1970, was designed to production test the zones stimulated by the nuclear device detonation.⁴

The re-entry well penetrated a fractured zone at a true vertical depth of 8,151 feet below the surface of the emplacement well, and experienced a complete loss of drilling fluid returns upon this encounter. Based on the rapid increase in penetration rate observed in the re-entry well between the depths of 8,151 feet and 8,234 feet which was accompanied by loss of drilling fluid returns, it is believed that effective communication with the chimney fracture environment was achieved.⁵ The fractures encountered by the re-entry well indicate a fracturing distance of 275 feet vertically above the depth of the nuclear device detonation.

¹ "Current Status of Projects Gasbuggy, Rulison, and Rio Blanco and an Appraisal of Nuclear-Explosive Fracturing Potential for the Near Future" J.J. Stosur, July 1976

² Comments made by Peter Sanders, U.S. Department of Energy Environmental Restoration Geologist at a public meeting in Battlement Mesa, Colorado on August 10, 1997.

³ "The Nuclear Stimulation of a Natural Gas Reservoir" W.G. Frank, Austral Oil Company Incorporated

⁴ "Project Rulison Well Plugging and Site Abandonment Plan" United States Energy Research and Development Administration, Nevada Operations Office, August, 1976

Wellbore design provisions and plugging and abandonment operations have vertically isolated the chimney cavity and fracture zone to protect shallower geologic formations, groundwater, and the surface.

An extensive series of shut in pressure build-up and production flow testing was performed to provide data to determine chimney cavity and fracture geometry, permeability of the fracture zone and unstimulated reservoir rock, and the long term capability of the well to produce gas. The well was flow tested at rates from 1 million cubic feet of gas per day to 15 million cubic feet of gas per day during three separate flow periods between October 1970 until April 1971. Pressure and temperature measurements were also recorded during a final shut-in period which ended in September, 1971. During the production testing data concerning surface wellhead pressures, temperatures, separator gas gravity, and gas condensate and water production were recorded. In addition, subsurface pressure and temperature measurements were made at various times as conditions permitted. During the production testing samples of gas were collected and analyzed for composition analysis.⁵

The data gathered during the shut-in and production tests were entered into a sophisticated mathematical reservoir model to simulate the performance of the Rulison R-EX re-entry well. The model was constructed and operated by Computer Technical Services, Inc., of Dallas Texas, and the interpretations of the test data were made jointly by that firm and the respected reservoir engineering firm of DeGolyer and McNaughton.⁵

Using the reservoir model to obtain a history match of the observed pressure and production data, the following parameters were calculated:⁶

Chimney Cavity Radius	74 Feet
Outer Radius of the Fracture Zone	220 Feet

Another model calculation referenced in the United States Atomic Energy Commission Nevada Operations Office Project Rulison Manager's Report found the chimney cavity radius to be 78 feet and the outer radius of the fracture zone to be 213 feet. In addition, simple pressure-volume-temperature analysis of bottom-hole pressures measured during the second production flow test indicate a chimney cavity radius of approximately 76 feet, which helps to confirm the accuracy of the model calculations.⁵ The attached annotated well survey plat depicts the calculated chimney cavity radius, the fracture zone radius, and the "Lot 11" quarter-quarter section restricted from natural gas drilling. It is important to note that the distance from the emplacement well to the nearest Lot 11 boundary exceeds double the calculated fracture zone radius.

⁵ "Report on Interpretation of Test Data from Project Rulison in the Rulison Field, Garfield County, Colorado", DeGolyer and McNaughton, December, 1971

⁶ "Project Rulison Manager's Report", United States Atomic Energy Commission Nevada Operations Office, April 1973

The conclusion drawn from this information is that the chimney cavity and fracture zone created by Project Rulison in the Williams Fork Formation are horizontally isolated within the "Lot 11" quarter-quarter section of land containing the Project Rulison emplacement well.

Colorado Oil and Gas Conservation Commission Williams Fork Formation Well Density Orders

The Colorado Oil and Gas Conservation Commission (COGCC) approved a request in July, 1997 to allow 40 acre well density for the Williams Fork Formation in the Mesaverde Group for a 19 1/2 square mile area about 1 1/4 miles to the west of Project Rulison. This decision was based on engineering and geological information regarding the very limited ability of natural gas to move through the Williams Fork Formation, which is the formation where the Project Rulison detonation occurred. This information showed that the Williams Fork formation consists of lenticular sandstones with limited areal extent which results in natural gas wells draining less than 40 acres. In February, 1995 the COGCC approved a request for 40 acre well density for the Williams Fork formation for a 52,000 acre area, and in January, 1998 the COGCC approved a request for 20 acre well density for the Williams Fork formation for two areas which totaled 4,300 acres. All of these areas are in the vicinity of Project Rulison, and both of these decisions were based on similar engineering and geologic information. The information considered in these COGCC decisions also supports the conclusion that radionuclide contaminated gas from Project Rulison would not migrate laterally outside of the "Lot 11" quarter-quarter section of land containing the Project Rulison emplacement well.

Radionuclides Remaining Underground at Project Rulison

The radionuclides produced by the type of nuclear device used at Project Rulison that could potentially appear as contaminants in natural gas are Tritium, Krypton-85, and Carbon-14, which are primarily beta radiation emitters. Only about 5 percent of the total Tritium produced from the detonation is contained in the gaseous phase, and it is estimated that about 40 percent would be trapped in the melted rock and about 55 percent in water. Most of the molten material and radioactive fission products collect in the bottom of the chimney in the form of glassy slag.⁷

To place the amount of radiation created by Project Rulison into perspective, if it were assumed that all of the gas from Project Rulison containing radionuclides were burned and mixed with the air above the ground within one mile of the well (a very conservative estimate), it could be calculated that the concentration of radioactivity in the air would be many times below the levels allowed by the federal government. If a person were to breathe this air continuously for one year, the total amount of radiation which he would receive would be less than 1/30th the amount they would receive from one chest x-ray, or less radiation

⁷ "Current Status of Projects Gasbuggy, Rulison, and Rio Blanco and an Appraisal of Nuclear-Explosive Fracturing Potential for the Near Future" J.J. Stosur, July 1976

than they would receive from flying from Las Vegas to New York in a jet airplane. It is also the same amount of radiation a skier spending two weeks or seven weekends at a mountain ski resort would be exposed to.⁸

Using the values for subsurface pressure and temperature obtained at the beginning of the first production test, the gas in place in the chimney cavity and fracture zone was calculated to be 176 million cubic feet. During the entire three periods of production testing from October 1970 until April 1971, a total of 430 million cubic feet was produced from the Project Rulison R-EX re-entry well. The analysis of the gas samples taken during the production tests indicate that the hydrogen gas concentration declined linearly with cumulative production to approximately three percent of its initial concentration. Since all of the hydrogen gas contained in the produced gas (not associated with the hydrogen atoms in the natural gas molecular structure) was generated at the time of the nuclear explosion, the hydrogen concentration represents the relative remaining concentration of chimney cavity and fracture gas.⁹

This data shows that the underground concentration of the radioactive gas created by the detonation was greatly diluted down to approximately 3 percent of its original concentration by flushing nearly 2½ times the natural gas volume of the chimney cavity and fracture zone out of the re-entry well during the production tests in 1970 and 1971.

Radionuclide analysis of the gas produced and flared into the atmosphere from the re-entry well during the production tests in 1970 and 1971 also exhibited a great deal of reduction in the radionuclide concentrations in the gas during the production flow tests.¹⁰

Radionuclide	Radionuclide Concentration in Produced Gas at Beginning of Production Tests October 1970 pCi/cc (Pico-Curie per Cubic Centimeter)	Radionuclide Concentration in Produced Gas at End of Production Tests April 1971 pCi/cc (Pico-Curie per Cubic Centimeter)
Krypton-85	145	2.8
Tritium	185	3.3
Carbon-14	.35	.07

⁸ "Project Rulison and the Economic Potential of Nuclear Gas Stimulation", H.F. Coffer, G.W. Frank, and B.G. Bray

⁹ "Report on Interpretation of Test Data from Project Rulison in the Rulison Field, Garfield County, Colorado", DeGolyer and McNaughton, December, 1971

¹⁰ "Project Rulison Manager's Report", United States Atomic Energy Commission Nevada Operations Office, April 1973

lower limit of detection, confirming that there was no radioactivity in the gas from the producing wells.¹²

At the time of the gas analysis results, the COGCC committed to providing notification to the U.S. Department of Energy Nevada Operations Office whenever a natural gas well is permitted within a three mile radius of Project Rulison. The purpose of this notification is to provide the DOE the opportunity to take natural gas samples to monitor the wells for radiation activity.¹² As of May, 1998, two new natural gas wells have been permitted and drilled approximately 2¼ miles northeast of Project Rulison. The DOE was notified and plans to collect gas samples during May, 1998. If the sampling of any gas well were ever to detect the presence of any radionuclides, the well could be ordered shut in by the COGCC and the Bureau of Land Management (BLM) in their respective jurisdictions. For the reasons stated throughout this report, the likelihood of this occurring is extremely remote, however, the sampling program is a reasonable response to the public concern about Project Rulison.

¹² "DOE Releases Rulison Site Gas Analysis" United States Department Of Energy News Release, October 10, 1997

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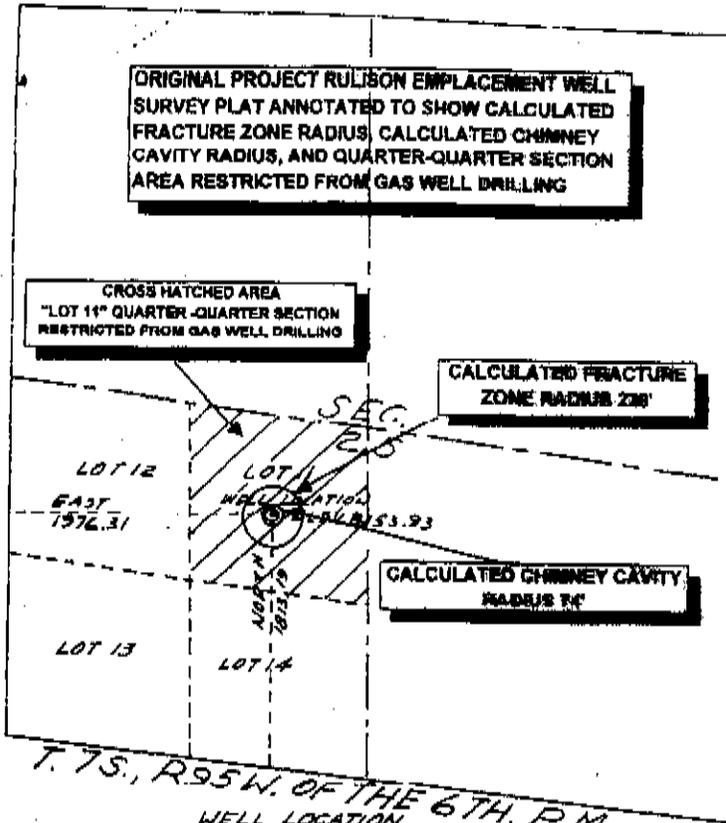
COLO. OIL & GAS CONS. COMM.

ORIGINAL PROJECT RULISON EMPLACEMENT WELL SURVEY PLAT ANNOTATED TO SHOW CALCULATED FRACTURE ZONE RADIUS, CALCULATED CHIMNEY CAVITY RADIUS, AND QUARTER-QUARTER SECTION AREA RESTRICTED FROM GAS WELL DRILLING

CROSS HATCHED AREA "LOT 11" QUARTER-QUARTER SECTION RESTRICTED FROM GAS WELL DRILLING

CALCULATED FRACTURE ZONE RADIUS 200'

CALCULATED CHIMNEY CAVITY RADIUS 75'



T. 7S., R. 95W. OF THE 6TH. P.M.
WELL LOCATION

HAYWARD A/25-95

AUSTRAL OIL COMPANY

HOUSTON, TEXAS

SITUATED IN LOT 11 SECTION 25

T. 7S., R. 95W. OF THE 6TH. P.M.

GARFIELD COUNTY, COLORADO

SCALE - 1 INCH = 1000 FEET

THIS IS TO CERTIFY THAT THE "WELL LOCATION" SHOWN ON THIS PLAT WAS PLOTTED FROM FIELD NOTES OF ACTUAL SURVEYS MADE BY ME OR UNDER MY SUPERVISION AND THAT THE SAME ARE TRUE AND CORRECT TO THE BEST OF MY KNOWLEDGE AND BELIEF.
DATE SURVEYED: SEPT. 9, 1967

Robert D. Scarrow
ROBERT D. SCARROW
REGISTERED LAND SURVEYOR
GLENWOOD SPRINGS, COLO.
CERTIFICATE NO. 3317