PROJECT RIO BLANCO
RADIOACTIVITY
AND THE ENVIRONMENT

RB-AR-2 ADDENDUM
OCTOBER 1975

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CER Geonuclear Corporation
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REPORTS FOR PLOWSHARE OPEN FILE - RIO BLANCO SECTION

Enclosed for the Rio Blanco Section of the Plowshare Open File are the following reports:

1. PNE-RB-63
Addendum Project Rio Blanco Radioactivity and the Environment - RB-AR-2 Addendum
2. PNE-RB-70 Project Rio Blanco Final Report - Reentry Drilling and Testing of RB-E-01 Well.

Robert R. Loux, Chief
Technical Information Branch

Enclosures:

1. PNE-RB-63 Addendum (In duplicate)
2. PNE-RB-70 (In duplicate)

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1. INTRODUCTION

This report is an addendum to a previous report (1), which documented the measurements of releases of radioactivity to the environment associated with the drawdown testing of the chimney resulting from the top explosion in the Project Rio Blanco nuclear gas stimulation experiment. Access to the chimney resulting from the top explosion in the Project Rio Blanco nuclear gas stimulation experiment. Access to the chimney associated with the bottom explosion was later obtained by drilling an alternate re-entry well, RB-AR-2. This addendum presents the results of measurement of releases of radioactivity to the environment in connection with the drawdown testing of the RB-AR-2. This addendum also includes the data obtained in radiological measurements of the environment and in documenting the transfer to a subsurface disposal well of radioactive water separated from the produced gas stream.

1.1 GENERAL

The location of the project site in Section 14, Township 3 South, Range 98 West of the 6th Prime Meridian is shown in Figure 1. The site is in the valley of Fawn Creek, a perennial stream in Rio Blanco County, Colorado. The large scale inset in Figure 1 shows the locations of the emplacement well, RB-E-01; the alternate reentry well, RB-AR-2; the flare stack on a ridge about 600 ft north of RB-E-01; and the water disposal well, Fawn Creek Government No. 1, about 150 ft south of RB-AR-2. The Fawn Creek well was dually completed for both the production of gas and the injection of water.

The RB-E-01 well, after completion of reentry drilling, was that used for production testing from the top chimney. From the RB-E-01 production testing it was learned that there was no significant communication between the top chimney and other chimneys. Furthermore, the stimulated reservoir, in communication with the top chimney, was found to have a much lower flow capacity than expected and for unknown reasons.

In consequence, the project plans were revised and expanded to include, among other things, the drilling and testing of an alternate reentry well, RB-AR-2, into the middle of the three apparently separate chimneys. The initial plans for this effort and later modifications are described in detail in two documents identified as Reference 2.

1.2 DRILLING RB-AR-2

The drilling of the RB-AR-2 well commenced in mid-June 1974 from a point on the Fawn Creek Government No. 1 well pad, about 1200 ft south of the RB-E-01 well surface location. The drilling plans specified a vertical hole to a kick-off point at a depth of about 4700 ft, below which the hole was to have been directionally drilled towards the middle detonation point to intercept the middle chimney at an angle of about 60° from the downward vertical. In practice, it was found not to be possible to achieve the desired inclination. Hence, at a measured depth of 6144 ft. the hole was plugged back to 5854 ft,

Figure 1. Location of Project Rio Blanco site with insert showing production wells and effluent disposal points.

at which point the hole inclination was a little less than 40° . The target was changed to the lower detonation point, which at that point in the hole, was about 850 ft away horizontally and about 965 ft vertically. The desired vector to complete the hole to the new target, then, made an angle of slightly more than 41° to the vertical.

In drilling ahead from the measured depth of 5854 ft, it was found possible to maintain approximately the desired inclination of the hole, which was finally completed to a total measured depth of 7077 ft in late October 1974, after penetrating a highly fractured region and losing returns of drilling mud at 6997 ft. The termination of drilling occurred at a point apparently just inside the chimney boundary, about 60 ft horizontally away and several feet above the bottom detonation point. The principal elements of the as-built configurations of the RB-AR-2 well are shown in Figure 2. The point of lost circulation shown was at a radial distance of about 145 ft from the bottom detonation point. The 5-inch liner, run into the hole to maintain its integrity, was terminated at a measured depth of 7069 ft, and perforated by explosive charges at 1-ft intervals from 7057 ft to 6957 ft. Radially from the bottom detonation point, the perforations extend from about 85 ft to about 185 ft.

1.3 PRODUCTION TEST

The RB-AR-2 well was initially tested for good communication with the chimney on November 2, 1974, by flowing through a drilling well control (DWC) unit for three hours at a flow rate of up to 1.7 MMSCF per day. Having established that good communication existed with the bottom chimney, the well was shut in for demobilization of the rig and preparation of the production test system.

Analysis for radioactivity in the gas and water through the DWC unit revealed the expected presence of ^3H and ^{85}Kr in the gas and ^3H in the water. Additionally, in consequence of having drilled through the highly fractured region adjacent to the bottom cavity and apparently just into the rubble filled cavity, some particulate activity was also found in the water, but not in the gas. The radionuclides encountered were ^{137}Cs and ^{90}Sr , both of which have precursors which were gaseous for some minutes after the detonation. The particulate daughters therefore were free to adsorb at later times on rock surfaces in the chimney or the adjacent highly fractured region. In the brief DWC test, the ^{137}Cs and ^{90}Sr were apparently swept into the gas stream dissolved in water droplets. Prior experience in the production test of the top chimney showed an absence of these radionuclides when water left the chimney only as steam. ✓

Anticipating, then, the possibility of continuing production of these radionuclides during the ensuing drawdown of the bottom chimney, it became necessary to apply to the State for an amendment to the permit ⁽³⁾ for subsurface disposal, which originally covered only the disposition of tritiated water.

* HORIZONTAL SCALE OF WELL ILLUSTRATION
EXAGGERATED BY A FACTOR OF 5

Figure 2. As built configuration of the RB-AR-2 well.

Amendment No. 2 to the permit, issued on December 6, 1974, authorized the disposal of up to 34,000 bbls of contaminated water including up to 450 Ci of ^3H and with concentrations of other radionuclides not to exceed the limits specified in Reference 4. The latter restriction is comparable to those which pertain to disposal of radioactive materials into sanitary sewers.

With the completion of preparations for production testing and issuance of the amendment to the disposal permit, it became possible to start production testing on December 10, 1974. Testing was continued until the desired drop of bottom-hole pressure was achieved on December 16, 1974, when it was ended and measurement of the bottom-hole pressure build-up commenced.

2. PRODUCTION TEST AND DISPOSAL SYSTEM

The production test and disposal system has been described in some detail in Reference 1 and in greater detail in Reference 2, 5 and 6. Those descriptions will not be repeated in detail here. For convenience, however, a functional diagram of the production test and disposal system is included as Figure 3.

During the production test, the gas and associated water vapor and entrained water were normally routed through the fin-fan coolers to the three-phase separator. The fin-fan coolers were operated so as to drop the temperature of the flowing stream from its equilibrium value of about 280°F at the wellhead to about 120°F at the separator. This permitted operating well within the rated temperatures of the components of the production test system, maximized the separation of liquid water from the produced stream and avoided transferring the water to the storage tanks at a temperature above the local boiling point, about 200°F.

The three-phase separator was designed to separate the production stream into three separate streams: gas with water vapor and condensate fractions corresponding to the temperature and pressure conditions at the separator, liquid condensates (hydrocarbons), and liquid water. In practice, no hydrocarbon condensates were recovered and what little was present remained with the gas stream. The separated gas was flowed through a critical flow prover to provide flow rate data. Enroute to the flow prover, the gas stream was sampled approximately isokinetically for gas and particulate radioactivity determinations on site. The same sampling point permitted collection of gas samples at intervals for analysis by the Lawrence Livermore Laboratory (LLL) at their in-house radiochemical analysis facilities. The separated water was pumped to one of the water storage tanks. After each tank was filled, the contents were sampled and analyzed for radioactivity prior to authorization being given for disposal.

The water disposal system simply involves transfer of contaminated water by injection pump through a post-filter to the water disposal zone in the Fawn Creek Government No. 1 Well at rates of about 60 bbls/hr. As described in Reference 6, remedial work was done on this well in November 1974 to cure an apparent small leak of tritiated water from the water injection string into the gas producing portion of the well. The remedial work consisted of replacing the entire string of water injection tubing. This work was completed on December 5, 1974. In bringing the gas producing zone into production, the water produced was sampled for tritium with non-detectable results. In subsequent work to get the gas into production to serve the site for heating purposes the well was flowed to the mud pit for 6 hours on December 9, 1974 to clean the well up while other repairs were being made. As a precaution, snow samples were taken below the blooie line exit and analyzed for ^3H at about 1800 pCi/ml. The source of this ^3H was not well known, for the mud pit had been contaminated with ^3H of like concentration in a flow test in

Figure 3. Functional diagram of the production test and disposal system showing sampling points.

April 1974. Accordingly, after the separator repairs were complete, the well was flowed through the separator on December 17 at a high enough rate to get a liquid water sample. Analysis for ^3H gave a concentration of about 5000 pCi/ml. A gas sample was analyzed for ^3H with non-detectable results. Nevertheless, the well was shut in and not used as a source of site fuel during the operations.

3. RADIOLOGICAL MONITORING SYSTEM

Radiological protection and documentation of radioactive effluents were provided during the drilling of RB-AR-2 and during the production test of the well by the Eberline Instrument Corporation (EIC) under contract to CER Geonuclear Corporation and to the Continental Oil Company. Most of the field equipment used for this purpose was furnished by the Government on loan to CER for the use of EIC.

The monitoring system used for documentation of radioactive effluents has been described in detail in Reference 1 and will be described here only briefly. For convenience, a schematic of the production test gas sampling system is shown in Figure 4.

The production test sampling system dehydrator provided pressure reduction and cooling for complete liquid removal prior to the gas entering the radiation monitoring sections. After radiation measurements were made on the dry gas stream, the gas was released to the atmosphere through a 20-ft high vent at a rate of one or two cubic feet per minute. The sample line was kept warm with heat tapes to maintain the oil and moisture in vapor form and thus avoid the line freezing up during unfavorable conditions. The bulk liquids trap dropped out most of the liquids, which were transferred to the contaminated water storage tanks for injection into the disposal well. The remainder of the liquids were adsorbed on the molsieve towers, which were alternately in use or being regenerated. The shielded gamma scintillation detector was recorded and the alarm set at twice the normal upper level of background readings to alert for unexpected fission products in the gas in the flare line. The integrating flow meter was used to quantify the analyses of the particulate and charcoal samples. The sample manifold, exhaust and calibration system were so connected that each detector was independent of the operating condition of the other.

For the production test of RB-AR-2, two additional features were included in the effluent documentation system. As shown in Figure 3, a particulate sampler was included in a bypass line around the critical flow prover. An additional scintillation counter was mounted below the low pressure vessel of the separator and collimated with steel and lead shielding to enhance its sensitivity for detection of particulate activity which might drop out as sludge in the bottom of the low pressure vessel. The output of this scintillation counter was also recorded in the EIC laboratory trailer.

The EIC krypton chamber was operated and recorded continuously to provide data on ^{85}Kr concentrations. The EIC oxidizer was operated daily to provide combustion water samples of the sample gas. These were analyzed for ^3H concentration by liquid scintillation means. The CER TRY-KRY system was operated periodically each day to provide data on both ^{85}Kr and ^3H . In the absence of ^{37}Ar , which had decayed by a factor of 450 since the second

Figure 4. Production test gas sampling system.

production testing from the upper chimney, the TRY-KRY system was able to sense ^3H in the presence of ^{85}Kr . However, the low ^3H to ^{85}Kr ratio, about 1 to 11, gave rise to statistical counting errors in the range of 10 percent to 20 percent for ^3H even though those for ^{85}Kr were about 1 percent. Accordingly, the TRY-KRY data were used simply as a backup for the continuously recorded EIC krypton chamber and the more consistent oxidizer-scintillator data. The ^{85}Kr calibration gases for both systems were normalized to agree with a calibration sample provided by the Quality Assurance Branch, National Environmental Research Center, U.S. Environmental Protection Agency, Las Vegas, Nevada.

Because of apprehension that the government-furnished liquid scintillation counter system might break down during the production test run, a backup trailer-mounted system, the property of the El Paso Natural Gas Company (EPNG), was moved on to the site by EPNG and spotted next to the EIC trailers. It did not become necessary to make use of the liquid scintillation equipment, but EPNG did take the opportunity to sample the RB-AR-2 gas and run some tests on EPNG's equivalent of the TRY-KRY system, which is mounted in the same trailer.

Particulates in the dry conditioned gas were integrated over the production test period and subsequently counted with a sensitive Ge (Li) system in one of EIC's laboratories.

Because of the detection of ^{137}Cs and ^{90}Sr in the water produced at the drilling well control unit during a test of the well prior to release of the drilling rig, an on-site capability for ^{90}Sr analysis was provided. A small radiochemical laboratory was set up in the access control trailer for this purpose. A carbonate precipitation technique was used with beta counting of the precipitate after filtration and drying.

Samples of water were taken from the separator daily and from each water storage tank after filling. Analyses were made for ^3H by liquid scintillation means, for ^{90}Sr as described above, for ^{137}Cs and any other gamma emitters by gamma spectrometry, and by gross beta and alpha counting. Stored contaminated water was held above ground until these analyses had been completed and it had been determined that the guidelines of References 3 and 4 were being adhered to.

During the production test, gas and liquid samples were taken at specified intervals by EIC in containers provided by LLL and turned over to the LLL representative for shipment to LLL.

4. EFFLUENT DOCUMENTATION

4.1 GAS AND WATER PRODUCTION

The RB-AR-2 well was produced first for an extended period, three hours, on November 2, 1974, to verify good communication with the bottom chimney. The pressure drawdown was started at 1145 MST, December 10, and continued until shut in at 1320 MST, December 16, 1974. During this period the bottom-hole pressure was monitored at a measured depth of 6450 ft, which was 507 ft (about 386 ft vertically) above the uppermost perforation in the production liner. The pressure decreased from an initial static value of 1865 psig to an instantaneous shut in pressure of 1126 psig. The maximum temperature observed at 6450 ft during the flow was 504°F. The flowing temperature at the wellhead stabilized in the range of 280-285°F after 3.5 days of flowing. Cooling of the flowing stream by operation of the fin-fan coolers kept the operating temperature of the separator below 150°F and generally in the range of 100-125°F. The separator was operated initially at a pressure of 680 psig, which was gradually decreased to 420 psig at the end of the production test. The initial specific gravity of the dry gas, as measured downstream of the EIC gas conditioning skid with a Ranarex instrument, was about 1.03 relative to air, decreasing slowly to about 1.01 at the end of the drawdown. A summary of the gas and water production data is given in Table 1.

Table 1. Gas and water production^a

24 Hours Ending 0800	Gas Flared (MMSCF ^b)		Water Vapor Flared (Bbls)	Liquid Water Separated (Bbls)
	Dry	Wet		
Nov. 2	0.176	0.176	Negligible	80
Dec. 11	4.236	4.243	0.95	252
Dec. 12	5.080	5.094	1.90	316
Dec. 13	4.712	4.721	1.22	356
Dec. 14	4.319	4.330	1.49	338
Dec. 15	4.094	4.053	1.49	302
Dec. 16	3.726	3.740	1.90	324
Dec. 17	<u>0.790</u>	<u>0.793</u>	<u>0.41</u>	<u>70</u>
	27.081	27.150	9.36	2038

a. No hydrocarbon condensates were encountered.

b. At 14.7 psia, 60° F.

4.2

RADIOACTIVITY CONCENTRATIONS IN GAS

Table 2 presents the results of field measurements of the concentrations of radionuclides in the gas stream, either as gas or water vapor. At no time were any measurable hydrocarbon condensates encountered. The tabulated

Table 2. Field measurements of radionuclide concentrations in gas stream.

1974 Date Ending At 0800	pCi/ml ^a of Dry Gas		pCi/ml ^b of Liquid ³ H in H ₂ O
	³ H	⁸⁵ Kr	
Nov. 3	34	380	17
Dec. 11	31	359	54 ^c
Dec. 12	32	340	78
Dec. 13	32	330	86
Dec. 14	29	331	90
Dec. 15	35	324	93
Dec. 16	32	326	94
Dec. 17	30	326	90

a. At 14.7 psia, 32° F.

b. As measured on DWC sample and daily separator samples.

c. Average of several on startup.

data cover the principal radionuclides in the produced gas, ³H and ⁸⁵Kr, which were those observable in the field. The values shown are to be interpreted as average values over the preceding 24 hours. The concentrations of ³H and ⁸⁵Kr in the dry gas are plotted in Figure 5 as a function of cumulative gas production. The value for ³H in water vapor is given as a concentration in the liquid phase. The concentration of ³H as water vapor in the wet gas was 1 percent or less of the ³H in the gas phase, primarily CH₄ or H₂.

Table 3 presents the results of the LLL gas sampling program, extracted from Reference 7. In addition to ⁸⁵Kr analyses for all samples, selected samples were analyzed for ³H, ³⁹Ar, ¹⁴C and ²²²Rn. The values for ¹⁴C include only that in the CO₂. ¹⁴C data for the hydrocarbons are not yet available.

The LLL value for ⁸⁵Kr and ³H are also plotted in Figure 5 as a function of cumulative gas production, with separate linear least square fits for each set of data. A systematic and unresolved difference is noted for the field and laboratory ⁸⁵Kr data, the field data being about 10 percent higher than

Figure 5. Gas sample radioactivity concentrations vs cumulative production, both field and laboratory data.

the laboratory. For the purpose of effluent documentation, the higher field data are used here. The ^3H data sets are essentially identical.

Table 3. LLL laboratory measurements of radionuclide concentrations.

1974 Date Ending At 0800	Cumulative Dry Gas MMSCF	pCi/ml of dry gas				
		^{85}Kr	^3H	^{39}Ar	$^{14}\text{C}^*$	^{222}Rn
Nov. 2	0.018	335	---	---	---	---
Nov. 2	0.070	372	36.1	0.32	0.157	---
Nov. 2	0.176	350	---	---	---	---
Dec. 11	1.4	320	33.1	0.29	0.21	0.047
Dec. 12	5.36	320	---	---	---	---
Dec. 13	10.6	317	31.3	0.27	0.156	0.018
Dec. 14	15.0	320	---	---	---	---
Dec. 15	19.4	303	30.0	0.28	0.165	---
Dec. 16	23.4	300	---	---	---	---
Dec. 17	26.1	293	28.4	0.23	0.19	---

- a. ^{14}C in CO_2 only. ^{14}C in CH_4 not significantly different from background; 3 sigma upper limits range from 0.031 to 0.040 pCi/ml.

4.3 RADIOACTIVITY CONCENTRATIONS IN SEPARATOR WATER SAMPLES

Table 4 presents the results of field and laboratory measurements of radioactivity concentrations in water samples taken at intervals from the low pressure side of the separator. These data are essentially instantaneous values, in that the residence time of the water in the separator was a fraction of an hour. Tabulated are observed data for ^3H , ^{137}Cs , ^{134}Cs , and ^{90}Sr . A few early non-representative data points have been omitted.

In addition to the data shown, LLL reports traces of 120-day ^{75}Se and 368-day ^{106}Ru in tank bottom sediments recovered on December 19, 1974. Referenced to ^{137}Cs at 100 percent, the concentrations were about 4 percent ^{106}Ru and 0.3 percent ^{75}Se .

The LLL data for ^{90}Sr , which were obtained by beta counting the ^{90}Y daughter after ingrowth to equilibrium and separation, is considered more reliable than the data acquired in the field. The latter, for expediency, was based on the much more rapid carbonate precipitate technique. The field data are regarded as upper limits to the real ^{90}Sr concentrations.

The ^3H and ^{137}Cs data are plotted in Figure 6 as a function of water production, cumulative to the sample time, with non-linear least square fits as appropriate. The equilibrium value for ^3H seems to be about 93 nCi/ml of water, while the ^{137}Cs concentration was decaying exponentially with water production.

Figure 6. Water sample radioactivity concentrations vs cumulative production, both field and laboratory data.

Table 4. EIC and LLL separator liquid sample analyses. ^a

Time	Date	Lab. ^b	Cum. H ₂ O Production This Test Bbls. ^c	nCi/ml ³ H	pCi/ml		
					¹³⁷ Cs	¹³⁴ Cs	⁹⁰ Sr ^d
1800	Dec. 10	E	60	64.6	---	---	---
1800	Dec. 10	L	60	---	29	0.27	0.60
1945	Dec. 10	L	84	74	90	0.83	---
2200	Dec. 10	L	119	---	28	0.32	0.11
0200	Dec. 11	L	171	---	27	0.32	0.12
0700	Dec. 11	E	236	77.0	22.6	---	1.3
1430	Dec. 11	L	337	86	---	---	---
0830	Dec. 12	E	581	79.0	16.0	---	1.4
1430	Dec. 12	L	663	86	11.9	---	0.28
0830	Dec. 13	E	807	92.3	12.6	---	0.1
1145	Dec. 13	L	949	90	---	---	---
0830	Dec. 14	E	1223	87.4	8.0	---	1.9
1400	Dec. 14	L	1292	87	6.6	ND ^e	0.048
0830	Dec. 15	E	1530	97.4	5.3	---	2.27
1400	Dec. 15	L	1600	93	---	---	---
0830	Dec. 16	E	1828	89.6	3.9	---	0.76
1305	Dec. 16	L		94	3.6	ND	0.014

a. Some early non-representative data omitted.

b. E = EIC; L = LLL.

c. As measured by separator water meter.

d. EIC, beta counting of carbonate precipitate. LLL, beta counting of separated ⁹⁰Y in secular equilibrium with ⁹⁰Sr.

e. ND means not detected.

4.4 RADIOACTIVITY CONCENTRATIONS IN INJECTED WATER VOLUMES

Table 5 presents the results of field measurements of the concentrations of the principal radionuclides, ³H, ¹³⁷Cs and ⁹⁰Sr, found in the separated water stored for disposal. The values shown were ascertained prior to the batchwise injection into the disposal well to assure adherence to the stipulations of References 3 and 4. The corresponding volumes of water are also listed in Table 5. The total volume of water injected during this test exceeds that produced by the separator because of the use of 474 bbls of fresh water for decontamination and system flushing purposes. The aggregate quantity

of water injected into the disposal well as a result of testing both the RB-E-01 and RB-AR-02 wells was 23,349 bbls after the December 1974 operations, where the limit of Reference 3 is 34,000 bbls.

Table 5. Water injection volumes and radioactivity concentrations.^a

1974 Date Ending At 0800	Storage Tank No.	Bbls. Injected	nCi/ml ³ H	pCi/ml	
				¹³⁷ Cs	⁹⁰ Sr
Dec. 11 ^b	3, 4	171	3.4	0.8	0.8
Dec. 12	4	261	45	13	2.1
Dec. 13	2	203	92	21	7.8
Dec. 14	4	258	78.2	13	3.2
Dec. 14	3	211	69	12	0.52
Dec. 15	2	249	95	17	0.92
Dec. 16	4	226	91.2	13	2.4
Dec. 17	3	147	82.4	7.7	4.7
Dec. 18	3	37	82.4	7.7	4.7
Dec. 18	4	74	86	9.2	0.98
Dec. 19	4	107	86	9.2	0.98
Dec. 19	2	47	88.9	8.8	3.4
Dec. 20	2	274	88.9	8.8	3.4
Dec. 21	3	73	82.4	7.7	4.7
Dec. 22	1	174	---	---	---

2512^c

- a. EIC measurements - ⁹⁰Sr by beta counting of carbonate precipitate
- b. Included injections of Dec. 9-10.
- c. Injected water volume exceeds produced water volume because of use of 474 bbls of fresh water for decontamination and system flushing purposes.

4.5 DISPOSITION OF RADIOACTIVITY

Table 6 presents the values for the principal curie releases of gaseous radioactivity to the atmosphere through the flare stack and curie injections into the disposal well. In summary, slightly over 23 Ci of ³H and about 244 Ci of ⁸⁵Kr were released, while about 28 Ci of ³H and millicurie quantities of ¹³⁷Cs and ⁹⁰Sr were injected.

At the end of the December 1974 operations, the aggregate quantities of ³H and ⁸⁵Kr released to the atmosphere from the top and bottom chimneys were about 75 and 1020 Ci, respectively. The aggregate quantity of ³H injected was 178 Ci, compared with the 450 Ci limit in Reference 3.

Table 6. Disposition of principal radionuclides. ^a

1974 Date Ending 0800	Curies Released to Flare Stack			Disposal Well Injections		
	³ H(gas)	³ H(H ₂ O)	⁸⁵ Kr	³ H in Ci	¹³⁷ Cs in μ Ci	⁹⁰ Sr in μ Ci
Nov. 3	0.16	---	1.7	---	---	---
Dec. 11	3.520	0.008	40.8	0.092 ^b	22 ^b	22 ^b
Dec. 12	4.357	0.024	46.3	1.867	540	87
Dec. 13	4.041	0.017	41.7	2.969	680	252
Dec. 14	3.357	0.021	38.3	5.523	936	148
Dec. 15	3.791	0.022	35.1	3.761	665	36
Dec. 16	3.195	0.028	32.7	3.277	453	87
Dec. 17	<u>0.635</u>	<u>0.006</u>	<u>6.9</u>	<u>10.379</u> ^c	<u>1030</u> ^c	<u>390</u> ^c
	23.056	0.126	243.5	27.868	4326	1022

a. EIC Field measurements - ⁹⁰Sr by beta counting of carbonate precipitate

b. Activity from DWC operation and decontamination.

c. Includes injections during roll-up operations.

Estimates of other minor releases of gaseous radioactivity to the atmosphere have been made and are listed in Table 7. The ^{37}Ar , ^{39}Ar and ^{14}C values are based on the mean of ratios to ^{85}Kr calculated from the LLL data. The ^{37}Ar estimate is based, in addition, on a ratio to ^{39}Ar from the testing of the RB-E-01 well, as derivable from LLL data, decayed to the RB-AR-2 release dates. The $^{131\text{m}}\text{Xe}$ estimate is based on a ratio to ^{85}Kr derivable from LLL RB-E-01 data, also decayed to the RB-AR-2 release dates.

Table 7. Estimated minor releases.

<u>Radionuclide</u>	<u>Estimated Release in Curies</u>
^{37}Ar	2.7×10^{-2}
^{39}Ar	2.1×10^{-1}
^{14}C	$*1.3 \times 10^{-1}$
$^{131\text{m}}\text{Xe}$	8.9×10^{-11}

* ^{14}C in CO_2 only. ^{14}C in CH_4 not significantly different from background; 3-sigma upper limit is about 20 percent of value for CO_2 .

5. ENVIRONMENTAL MONITORING, RB-AR-2 DRILLING AND TESTING

The environmental monitoring program for the reentry drilling and production testing of the RB-AR-2 well was defined in Reference 2. It was somewhat more extensive than that carried out for the second production testing of the RB-E-01 well because the planned drilling program was such that particulate activity might be produced from the well, as in fact occurred. The program was started on September 17, 1974 at the start of the final phase of the drilling program. It was suspended from September 27, 1974 to October 8, 1974 because of a delay in the drilling schedule, and from November 10, 1974 to December 7, 1974 during the period of rig-down and prepare-to-test activities. Except for these suspensions, the monitoring program continued to the completion of the production test on December 16, 1974. This environmental monitoring was supplemented by a single aerial mission in surveillance of the plume from the flare stack. The mission was flown by a team from the National Environmental Research Center, Las Vegas, of the Environmental Protection Agency.

5.1 AIR SAMPLING

Air samplers were operated at the Massive Hydrofracture Site (MHF), Norell Ranch, and Brennan Ranch (Figure 7). These samplers pumped 1 to 10 CFM in series through a 9-cm diameter Whatman No. 41 filter paper and a charcoal cartridge. The paper filters were changed every two days and were analyzed for gross beta activity, and were gamma scanned. The charcoal cartridges were changed every six days and were gamma scanned. The equipment and procedures used gave a detection sensitivity above background of about 1 pCi/m³ for both beta and gamma referenced to ⁹⁰Sr and ¹³⁷Cs, respectively. For all of the 75 paper filters and 27 charcoal cartridges analyzed, the concentration of radioactivity was either less than the detection sensitivity or was identified as naturally occurring or worldwide fallout. No radionuclides were detected in filtered air that could be attributed to Project Rio Blanco.

5.2 AIR MOISTURE AND PRECIPITATION SAMPLING

Air moisture samplers (molsieve in a long mesh basket) were exposed to the atmosphere at five locations: the RB-AR-2 drill site, the MHF site, Brennan Cabin (3.5 miles down Fawn Creek), Norell Ranch, and Berthelson (P-L) Ranch. The sample collectors were changed daily at the drill site and every two days at the other locations.

Precipitation samples were collected at the flare stack, 1.5 miles upstream 0.8 miles downstream (MHF site), and at the Norell Ranch as opportunity permitted.

Liquids collected in air moisture and precipitation sampling were analyzed for tritium by liquid scintillation means with a detection sensitivity of 2 pCi/ml. No tritium was detected at or above this threshold in samples

Figure 7. Close-in environmental monitoring points - production testing.

collected at the drill site and flare areas did give detectable, but not significant tritium indications. Positive air moisture samples were collected at the drill site on December 11, 12, and 14, 1974, yielding ^3H values in the range of 2.1 to 2.6 pCi/ml, barely detectable. Positive precipitation samples were collected at the flare stack on December 14, 15, and 16, 1974, yielding ^3H values in the range of 3.5 to 64.9 pCi/ml.

5.3 SOIL SAMPLING

Before and after production testing, soil samples were collected from the surface at 12 locations around the flare stack: upridge (WNW), downridge (ESE), NNE along contour lines, and SW across the gulch at 100, 200, and 400-foot radii. These samples were analyzed for ^{137}Cs and for tritium in soil moisture. Results of these analyses are illustrated in Figure 8. Tritium concentrations were either not detectable or far below applicable guides for tritium in water. Concentrations of ^{137}Cs were what was expected from worldwide fallout and were not increased by the flaring operation. Accordingly, no samples were analyzed for ^{90}Sr . The detection sensitivity for tritium was 2 pCi/ml and for ^{137}Cs was 2 pCi/g.

5.4 WATER SAMPLING

Every two days, a sample of surface water was taken from Fawn Creek one mile above and one mile below the RB-AR-2 well location. These samples were analyzed for tritium and gamma scanned with detection sensitivities of 2 and 1 pCi/ml, respectively. Results of these analyses were all not detectable at those sensitivities. Since no ^{137}Cs was detected, these samples were not analyzed for ^{90}Sr .

The three water wells (RB-D-01, RB-W-01, RB-S-03) on the Rio Blanco site were being, and are continuing to be, sampled on a monthly schedule. This schedule was increased to weekly at the start of waste water injection into the subsurface disposal well. The weekly schedule was continued for one month after the injection stopped. The monthly schedule will be discontinued one year after the injection was stopped. These samples were analyzed for tritium by liquid scintillation means with a detection sensitivity of 2 pCi/ml. No tritium has been detected in any of these well water samples.

5.5 FAWN CREEK SEDIMENTS AND ALGAE/MOSS SAMPLES

Samples of sediment from the bottom of Fawn Creek and samples of algae/moss growing in the creek were taken at four locations: adjacent to the RB-AR-2 well, 100 feet downstream, 0.5 and 1.0 miles downstream. Collections were made prior to the start of the final drilling phase, and before and after flaring. These samples were analyzed for tritium and were gamma scanned with detection sensitivities of 2 and 1 pCi/ml or g, respectively.

Figure 8. Soil moisture analyses near flare stack before and after RB-AR-2 flaring.

Results of these analyses were all not detectable at those sensitivities. Since no ^{137}Cs was detected, these samples were not analyzed for ^{90}Sr .

5.6 BIOASSAYS

Project-related personnel provided a urine sample on arrival and on permanent departure from the site. A total of 206 samples were analyzed for ^3H by liquid scintillation means with a sensitivity of 10 pCi/ml. All results were negative except four low level values not attributable to the project because they applied to samples collected on arrival or before production of any radioactivity from the well.

5.7 AERIAL SURVEILLANCE MISSION

At the request of the Nevada Operations Office of the Atomic Energy Commission (AEC), now the Energy Research and Development Administration (ERDA), the Environmental Protection Agency's Las Vegas office made use of one of its sampling and monitoring aircraft to investigate the plume from the flare stack on the afternoon of December 11, 1974. The report of this mission is included in Reference 8.

Three samples of compressed air, atmospheric moisture and filtered particulates were collected in the plume. The only radionuclide detected above background concentrations was ^{85}Kr , with a maximum observed net concentration of 8×10^{-4} pCi/ml of air, well below the uncontrolled radioactivity concentration guide of 6.7×10^{-2} pCi/ml of air for ^{85}Kr . This sample was collected at an altitude of about 1200 ft above the flare stack and between one and two miles to the southeast. At the time of this sampling mission the flow rate was about 5 MMSCF/D.

5.8 POTENTIAL ENVIRONMENTAL RADIATION DOSES

The paucity of positive data in environmental radiological monitoring for Project Rio Blanco precludes meaningful calculation of dose to persons in the environment and confirms the predictions of the Environmental Statement⁽⁹⁾ that the dose would be so low as to be unmeasurable. The gamma scan of air particulate, soil, water, creek sediments, and algae/moss samples confirm that no measurable quantities of long-lived particulate fission products were added to the environment. The TLD data are in the same range as those previously reported in the reports collectively identified as Reference 10. The limited aerial surveillance data show no surprises.

It is concluded that the environmental impact of the releases of radioactivity to the atmosphere in the flaring operations of Project Rio Blanco is not measurable above the stated sensitivities. Therefore, it is estimated that the potential radiation dose equivalents, considering the sensitivities of the analytical procedures, were a very small fraction of the Radiation Protection Standards of ERDA-HQ Manual Chapter 0524.

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