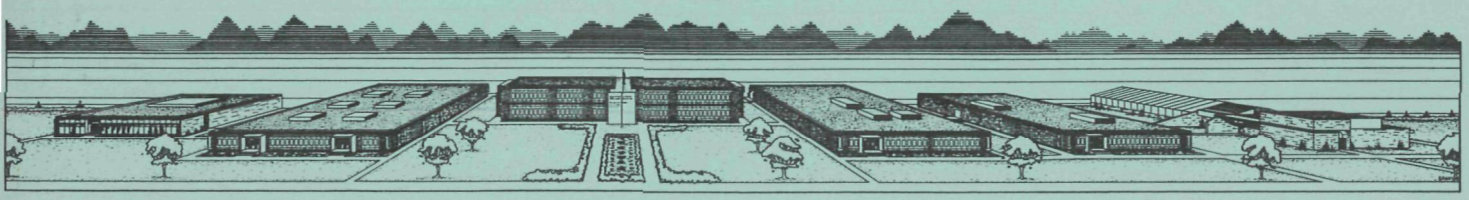
FINAL REPORT OF OFF-SITE SURVEILLANCE FOR THE PHOEBUS IB, EP-I, EP-II, EP-III, EP-IV REACTOR TEST SERIES

by the
Southwestern Radiological Health Laboratory

Department of Health, Education, and Welfare
Public Health Service
Consumer Protection and Environmental Health Service

July 1969

This surveillance performed under a Memorandum of Understanding (No. SF 54 373)
for the
U. S. ATOMIC ENERGY COMMISSION



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ABSTRACT

The Phoebus 1B reactor test series consisted of three calibration operations and a full power run. Effluent from the Experimental Plan III(EP-III) operation was detected off-site by one ground monitor and by the presence of 28 pCi/m^3 ^{139}Ba on a prefilter from a portable air sampler operating at an unpopulated location on Highway 95.

Effluent from the Experimental Plan IV(EP-IV) operation was detected in air, milk, and vegetation samples and by portable and fixed radiac instruments. The maximum concentration of ^{131}I in milk was 63 pCi/l at the Martin Ranch southwest of Eureka, Nevada. No fresh fission products were found in water samples.

In addition to the usual gaseous effluent from a reactor operation, the EP-IV operation resulted in the release of discrete particles of material that were found downwind as far as 80 miles from Test Cell "C". Only one particle was found beyond the Test Range Complex. This particle was found near Diablo, Nevada on Highway 25. This particle had a beta plus gamma reading of 7 mR/hr as measured with an E-500B survey instrument at approximately 1-inch above the ground. This particle was collected at about H + 48 hours.

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INTRODUCTION

This report presents the results of the off-site radiological surveillance program conducted by the Public Health Service (PHS) for the Phoebus 1B reactor test series (Experimental Plans I, II, III, and IV) at the Nuclear Rocket Development Station (NRDS).

Under a memorandum of understanding with the Atomic Energy Commission (AEC), the Public Health Service conducts a program of radiological monitoring and environmental sampling in the off-site area surrounding the Nevada Test Site(NTS) and the Nellis Air Force Range. This includes the NRDS and Tonopah Test Range. For simplicity, this combined area will be termed the Test Range Complex in this report.

The test schedule is given below.

Table 1. Reactor test schedule.

Experimental Plan	Approximate Power Integral Mw-sec	Date 1967	Detected Off-Site
EP-I	2.5	Jan 25-26	No
EP-II	300	Feb 2-3	No
EP-III	1.5×10^5	Feb 10(1311 PST)	Yes
EP-IV	3×10^6	Feb 23(1400-1430 PST)	Yes

The test series took place at Test Cell "C" with the hydrogen coolant and associated fission products exhausted upwards.

OPERATIONAL PROCEDURES

A. External Exposure Measurements

1. Ground monitoring

Ground monitors tracked the effluent cloud with the portable radiation detection instruments described below.

Table 2. Portable survey instruments used for ground and aerial monitoring.

Instrument	Range(mR/hr)	Scales	Detector	Emission
Baird-Atomic NE-148	0-3	3	1- by 1-inch crystal	Gamma only
Eberline E-500B	0-200	5	External Geiger tube	Beta and beta/gamma
	0-2000		Internal Geiger tube	Gamma only
Victoreen Radector	0.05-50,000	2	Ionization Chamber	Gamma only (as used)*
Victoreen Radector Mod. II (aerial use only)	0.1-1,000,000	3	Ionization Chamber	Gamma only (as used)*

*PHS monitors do not use the beta/gamma capabilities of this instrument.

2. Aerial cloud tracking

A U. S. Air Force U-3A aircraft, manned by two PHS monitors equipped with portable survey instruments identical to those of the ground monitors, tracked the effluent cloud to inform PHS personnel at the NRDS control point and to assist in

positioning ground monitors. Two PHS Turbo-Beech aircraft containing various sampling and measurement devices were also used as aids in cloud tracking. However, their primary purpose was cloud sampling and measurement to determine cloud size and content.

3. Exposure rate recorders

Eberline Model RM-11 exposure rate recorders were located at twenty-four stations around the Test Range Complex. These recorders use a Geiger tube detector and have a range of 0.01 to 100 mR/hr gamma only. Exposure rate is recorded on a 4-cycle log scale continuous strip chart with a capacity of up to 30 hours continuous recording. These recorders are accurate to within $\pm$ 20% as calibrated with a ^{137}Cs source.

4. Dosimetry

During the month of February 1967, eighty-six film badge stations with five badges at each location and 154 off-site residents with one badge each comprised the routine off-site film badge program maintained by the PHS. Dupont type 545 film is used which has a lower limit of detection of 30 mR with a reading accuracy of $\pm$ 50% from 30 to 100 mR and $\pm$ 10% from 100 to 2000 mR for gamma radiation above 50 keV. In addition, sixty-nine of these film badge stations were each equipped with three EG&G Model TL-12 thermoluminescent dosimeters (TLD). The TLD's have a low energy response threshold at 50 keV and are not energy dependent in the range from 50 keV to several MeV.

The film badges and TLD's normally remain in the field for a one month interval. In such a time period the TLD system

is capable of detecting a 10 mR increase of radioactivity above background.

B. Environmental Sampling

1. Air samples

During the time of these experiments, the Air Surveillance Network (ASN) operated by the PHS consisted of 105 air samplers operating in each state west of the Mississippi River except Montana and North Dakota. These stations are supplemented by ten standby stations located in Colorado, Idaho, Montana, Oklahoma, Utah, and Wyoming. These stations are operated only when the station operator is notified by the SWRHL to begin sampling. On February 24, all standby stations were activated except one each in Oklahoma, Wyoming, Idaho, and Colorado. In addition, there were seven temporary portable air samplers placed downwind along Highway 25 from Queen City Summit to Hancock Summit. This is approximately 65 miles from the reactor.

The air sampler used by the SWRHL for all stations except the temporary locations, is a Gelman "Tempest" which uses a Gast Model 1550 vacuum pump driven by an electric motor. The pump has a flow rate of approximately 10 cfm. The sampler is designed to use a 4-inch diameter filter paper (prefilter) and a 3-1/4-inch diameter by 1-inch thick charcoal cartridge. The ASN uses Whatman 541 filter paper for routine air sampling. The total volume of air sampled is calculated from an average vacuum reading (which in turn indicates the average flow rate) and the total time of sampling. Permanent air sampling stations are shown in Figures 1 and 2.

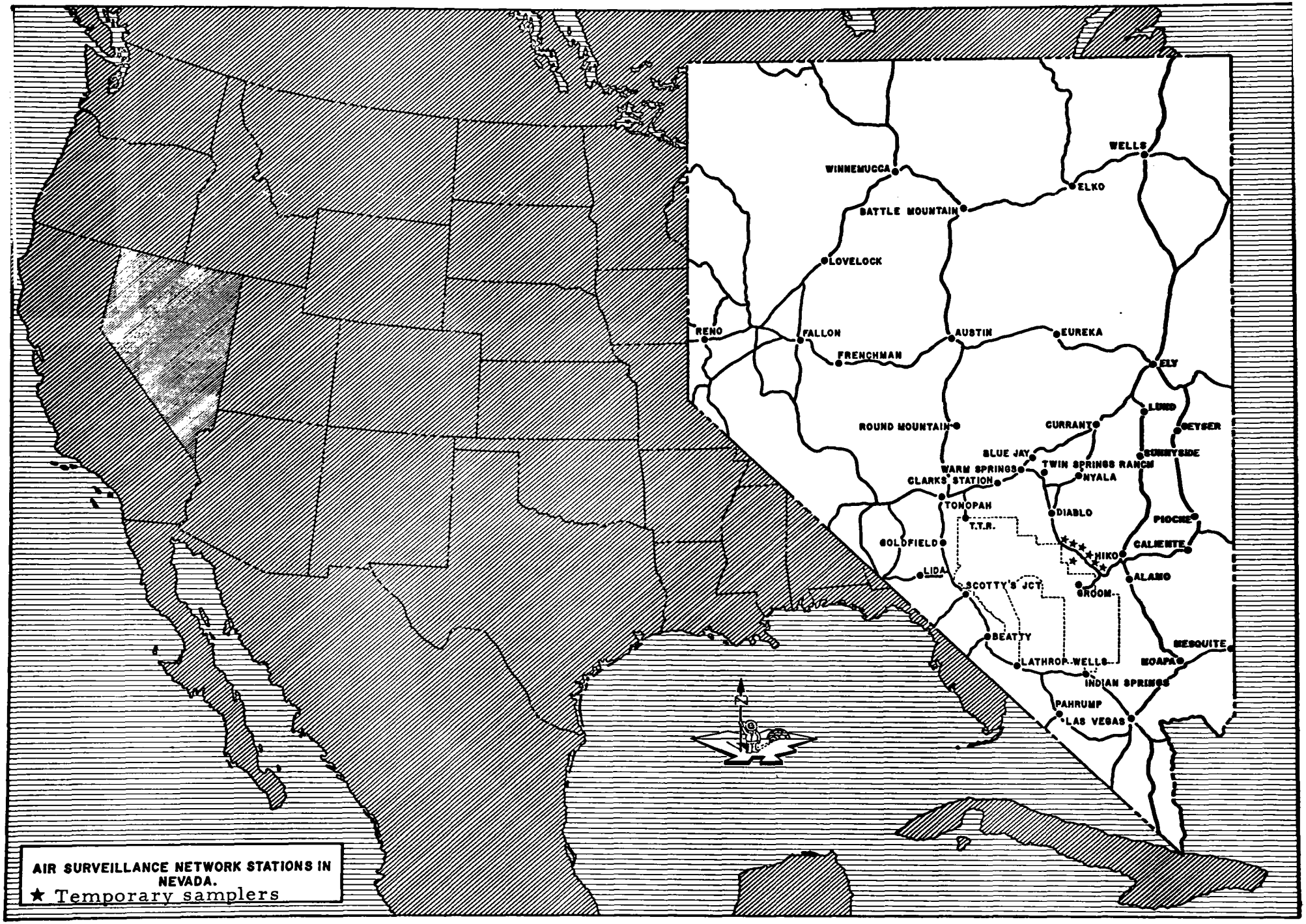
WELLS
WINNEMUCCA
ELKO
BATTLE MOUNTAIN
LOVELOCK
RENO
FALLON
AUSTIN
EUREKA
FRENCHMAN
ELY
LUND
ROUND MOUNTAIN
CURRANT
GEYSER
BLUE JAY
SUNNYSIDE
WARM SPRINGS
TWIN SPRINGS RANCH
NYALA
CLARKS STATION
TONOPAH
DIABLO
PIOCHE
T.T.R.
GOLDFIELD
CALIENTE
HIKO
LIDA
ALAMO
SCOTTY'S JCT.
BROOM
BEATTY
MESQUITE
LATHROP WELLS
MOAPA
INDIAN SPRINGS
PAHRUMP
LAS VEGAS
AIR SURVEILLANCE NETWORK STATIONS IN NEVADA.
★ Temporary samplers

Figure 1.


SEATTLE
SPOKANE
WASHINGTON
MONTANA
MISSOULA
BOZEMAN
BILLINGS
NORTH DAKOTA
ABERDEEN
MINNESOTA
MINNEAPOLIS
WISCONSIN
MICHIGAN
MAINE
VT.
N.H.
MASS.
CONN.
R.I.
NEW YORK
OREGON
BURNS
MEDFORD
IDAHO
BOISE
IDAHO FALLS
MOUNTAIN HOME
TWIN FALLS
POCATELLO
PRESTON
LOGAN
WORLAND
WYOMING
CASPER
ROCK SPRINGS
SOUTH DAKOTA
RAPID CITY
SIOUX CITY
IOWA
IOWA CITY
PENNSYLVANIA
N.J.
MD.
DEL.
CALIFORNIA
NEVADA
WENDOVER
DUGWAY
SALT LAKE CITY
PROVO
ROOSEVELT
NEBRASKA
NORTH PLATTE
ILLINOIS
INDIANA
OHIO
WEST VIRGINIA
BERKELEY
DELTA
GARRISON
UTAH
RANGELY
DENVER
COLORADO
GRAND JCT
ST. JOSEPH
BISHOP
FRESNO
PAROWAN
MILFORD
CEDAR CITY
ENTERPRISE
CAPITOL REEF NATIONAL MON.
BRYCE CANYON
MONTICELLO
PUEBLO
KANSAS
DODGE CITY
ST. LOUIS
LONE PINE
FURNACE CREEK
ST. GEORGE
DEATH VALLEY JCT.
SHOSHONE
DURANGO
MISSOURI
JOPLIN
KENTUCKY
VIRGINIA
RIDGECREST
BAKERSFIELD
SILVER LAKE
BARSTOW
SELIGMAN
NEEDLES
KINGMAN
SAN BERNARDINO
INDIO
WINSLOW
ALBUQUERQUE
AMARILLO
MUSKOGEE
OKLAHOMA
NORMAN
LITTLE ROCK
TENNESSEE
NORTH CAROLINA
SOUTH CAROLINA
ARIZONA
PHOENIX
SAN DIEGO
NEW MEXICO
ARKANSAS
GEORGIA
CARLSBAD
ABILENE
FORT WORTH
MONROE
LOUISIANA
ALABAMA
MISSISSIPPI
TEXAS
AUSTIN
LAKE CHARLES
NEW ORLEANS
FLORIDA
N
AIR SURVEILLANCE NETWORK STATIONS
OTHER THAN NEVADA
---STANDBY SURVEILLANCE STATIONS

Figure 2.

In addition to the "Tempest" samplers, each mobile monitoring team was equipped with portable air samplers. The air mover is a Gast Model No. 7040 positive displacement pump with a Rockwell Model No. 415 gas meter for measurement of air flow. All portable air samplers are operated with Whatman 541 filters and charcoal cartridges. Flow rate of this system averages 6 cfm.

2. Milk samples

The SWRHL milk sampling program consists of a routine milk sampling network, a standby milk sampling network, and special sampling in the event of a release of airborne radioactivity from nuclear testing activities.

a. Routine milk sampling network

Twenty to thirty producing dairy farms and individual family cows in Nevada, western Utah, and eastern California are routinely sampled each month. The number sampled varies because of the varying availability of lactating cows on ranches producing milk for their own use. Normally these samples are collected by personnel from the laboratory.

b. Standby milk sampling network

Approximately 155 producing dairies in 11 western states are provided with mail-in milk sample containers and appropriate instructions. Any or all of these sampling locations can be activated by telephone through the regional offices of the Public Health Service. The samples are collected within 24 hours of the request; the samples arriving at SWRHL for analysis one to four days later. Thirty-four of these stations were activated for the EP-IV operation.

c. Special sampling

The SWRHL also conducts a continuous survey of off-site milk sampling locations. Possible sources for milk sampling are indexed and located on milk sampling maps. In the event of a release of radioactive effluent, monitors are able to begin sampling an area almost immediately.

3. Water samples

Approximately 90 water samples are routinely collected each month from wells, streams, ponds, lakes, and urban water systems. After a release of radioactivity, sampling can be expanded to include all human and livestock water sources in the area of concern. Water samples are collected at all locations where milk samples are collected, with the exception of the standby milk sampling network. Fifteen water samples were collected for the EP-IV operation.

4. Vegetation samples

Vegetation samples are collected only after a known release. These samples are collected to delineate the deposition pattern, to determine where milk samples should be obtained, and to estimate expected radioisotope concentrations in milk. In addition to natural plants such as creosote bush, pasture and milk cow feed samples are collected when available. Six vegetation samples were collected after the EP-III operation and 88 samples were collected following EP-IV.

ANALYTICAL PROCEDURES

A. Air Samples

All air sample filter papers and charcoal cartridges are returned to the SWRHL in Las Vegas for analysis. Filters are counted for gross beta activity in a Beckman "Wide Beta" low background (6 $\pm$ 1 cpm beta), proportional system which has an efficiency of 45% for 0.54 MeV betas. If significant radioactivity (10 pCi/m^3) is detected on the initial count, a minimum of two additional counts are made in the first 48 hours following collection. All other filters are recounted at five and twelve days after collection. Computation of activity is based on establishing a decay constant for each sample and this constant is used to extrapolate the activity to the end of the collection period. The decay equation used is $A/A_o = e^{-\lambda t}$.

Gamma emitting isotopes on filter papers and charcoal cartridges are identified and quantitated by placing them directly on a 4"x4" NaI(Tl) crystal coupled to a TMC Model 404-C gamma pulse height analyzer calibrated for energies of 0-2 MeV. Quantities determined are extrapolated to the end of the collection period using the individual decay constants.

Average concentration of activity during cloud passage cannot always be calculated since it is not possible to define the duration of cloud passage at all locations. However, the integrated air concentrations, expressed as pCi-hr/m^3, may be directly compared for the various stations, besides serving as a measure of the potential inhalation exposure.

B. Milk and Water Samples

Milk and water samples are collected in one gallon quantities. These samples are emptied into 3.5-liter Marinelli beakers and are counted on the gamma spectrometry system described above. If, for any reason, a full 3.5-liter sample cannot be obtained, the sample volume is increased to 3.5 liters by the addition of distilled water to maintain a uniform counting geometry, and appropriate adjustments are made to calculate the activity concentration in the original sample. When this is done, the threshold detectabilities given in Table 3 are proportionately increased. In addition to gamma spectrometry, most milk samples containing radioiodine are analyzed by radiochemistry for $^{89-90}Sr$ after gamma analysis.

C. Vegetation Samples

Upon arrival in the laboratory, vegetation samples are placed in clean plastic bags and are given an immediate count for gross gamma activity on a 4- by 4-inch NaI(Tl) crystal, connected to a single-channel analyzer and scaler-timer. Vegetation samples showing higher than background activity are analyzed for specific gamma emitting isotopes.

D. Detection Sensitivity

Empirical values have been determined as the approximate threshold detectabilities for various isotopes on the sample types usually collected. These are listed in Table 3 and necessarily include the following conditions and assumptions:

a. Count time in days after fissioning as indicated by footnotes.

b. Prefilters collect unfractionated samples of fission products resulting in a complex spectrum.

c. MSA charcoal collects gaseous fission products only (primarily iodines).

d. An eight isotope matrix is employed for computation. Isotopes other than those included in the matrix are present in amounts which are small relative to those eight.

e. Natural activity on air samples is approximately five times system background.

Table 3. Estimated minimum sensitivity at time of count of several radionuclides in various samples.

Sample type	Notes	^{131}I	^{132}Te-I	^{133}I	^{135}I	^{137}Cs	^{140}Ba-La	Length of count
4" filter (pCi)	1	500	1000	500	1000		500	10 min.
	2	200		200			200	10 min.
Charcoal cartridge (pCi)	1	200		400	200		400	10 min.
	2	100			100			10 min.
Water (pCi/l)	3	20	40-50	20-30	40-50		20	40 min.
Milk (pCi/l)	4	20		20-30		10	20	40 min.

1 - Counted at less than 3 days after formation.

2 - Counted at 3 days or more after formation.

3 - With $^{137}Cs \leq 100$ pCi

4 - Assuming insignificant amount of unlisted nuclides, and all given isotopes are less than 10 times the detection limit.

RESULTS

A. Experimental Plans I and II

No radioactive effluent was detected on air samplers following the EP-I and II tests. Ground monitors were on standby but were not used, nor was aerial monitoring required.

B. Experimental Plan III, February 10, 1967

Effluent from the EP-III test was detected off-site by ground monitors, aerial monitors, vegetation sampling, and air sampling.

1. Ground monitoring

Six ground monitors were positioned along Highway 95 between the NRDS turnoff (approximately 2.5 miles west of the Mercury turnoff) and Lathrop Wells. A monitor located at the junction of Highway 95 and State Road 16 (Ash Meadows turnoff) observed a reading of approximately two times instrument background of .003 mR/hr on a scintillator. This was the only reading observed above background. The survey instrument returned to background levels within 30 minutes and a survey of the area around the truck showed no indication of ground deposition of radioactive material. The average transport speed of the effluent to this location was 25 mph.

2. Air sampling

Three portable air samplers with prefilters and charcoal cartridges were set up on Highway 95 in the projected cloud path at the NRDS turnoff, the Ash Meadows turnoff and 5 miles west of the Ash Meadows turnoff. The prefilter taken from the sampler located at the Ash Meadows turnoff showed 28 pCi/m^3 of ^{139}Ba. Because of the relatively short half-life of ^{139}Ba, it is reasonable to assume that this was the result of EP-III effluent and not residual radioactive material from foreign nuclear testing.

No radioiodines were detected on any air sample prefilter or charcoal cartridges.

3. Vegetation sampling

Six vegetation samples were collected along Highway 95 from the NRDS turnoff to 5 miles east of Lathrop Wells. No fresh fission products were detected on these samples that could be definitely attributed to the reactor operation.

Barely detectable levels of ^{131}I on vegetation had been noted for about a month before this reactor operation. The source of this iodine is presumed to be from foreign nuclear testing.

Gross gamma counting of the vegetation samples showed a peak approximately 18 miles southeast of Lathrop Wells on Highway 95.

4. Milk sampling

Milk samples were collected at the Mills Ranch (195° 25 miles from Test Cell "C") and at the Ishmael Ranch (160° 47 miles from Test Cell "C"). No fresh fission products were detected.

5. Water sampling

No water samples were collected for this event.

C. Experimental Plan IV, February 23, 1967

The EP-IV resulted in a release of radioactive effluent that was detected by aerial monitoring, ground monitoring, and in all environmental media sampled with the exception of water.

1. Ground monitoring

Initial on-site cloud tracking showed the cloud was moving along a trajectory of approximately 20° from Test Cell "C". Seven ground monitors were mobile between six miles southeast of

Hancock Summit, and Queen City Summit on Highway 25. Ground monitors at Queen City Summit and four miles southeast of Queen City Summit detected two to three times background levels during cloud passage. These readings were taken on a scintillation instrument with a background of approximately 0.008 mR/hr. Cloud arrival times at these locations was about 1830-1845 hours.

Primary effluent trajectory, as shown by air sampling and vegetation sampling was mostly northwest of Queen City Summit suggesting that slightly higher levels of activity would have been detected during cloud passage had ground monitors been stationed northwest of Queen City Summit.

Thermoluminescent dosimeters placed at two mile intervals from Hiko, Nevada to eight miles northwest of Queen City Summit showed no detectable exposures above normal background levels.

2. Exposure rate recorders

Twenty-four RM-11 stations were in operation at the time of this experiment.

Three stations showed gross gamma exposures above instrument background. To the northeast, the stations at Diablo (13°78 miles from Test Cell "C")and Twin Springs (5° 95 miles from Test Cell "C")showed a rise of about twice background. Estimated cloud arrival time at these locations was 2000 hours and 2030 hours respectively. The average transport speed was 15 mph based on these estimates. This trajectory of primary reactor effluent was confirmed by most of the other environmental sampling. Effluent from reactor pulse-cooling operations reached Lathrop Wells (157° 14 miles from

Test Cell "C") about 2030 hours. The maximum reading on the RM-11 was less than twice the background of 0.03 mR/hr. Low level night time drainage winds, which were about 180° from the primary wind direction during the day, were responsible for causing the reactor effluent to travel south.

3. Air sampling

Thirty-six permanent and seven temporary air sampling stations were in operation in Nevada at off-site locations on the day of the test. The seven temporary samplers were set up on Highway 25 from Hancock Summit to 12 miles northwest of Coyote Summit. (Figure 1.) Sixty-four ASN stations were in operation in other states during the test, while on the following day two additional ASN stations and six standby stations were in operation.

Table 4 lists all stations where fresh fission products were detected or where gross beta concentrations were above one pCi/m^3. Table 5 lists the isotopic results from the six stations where the maximum amounts of fresh fission products were detected. The value of one pCi/m^3 is used as a cut-off in Table 4 because the great majority of routine air filter results are below this number. Figures 1 and 2 show the locations of all samplers operating on February 23 and 24. Figure 3 shows all locations at which fresh fission products were detected on any sampling media.

It is possible that small amounts of ^{131}I were residual on pastures from a foreign test in December 1966; however, there are no data to support this assumption. The source of all fresh fission products found in any environmental sampling is assumed to be due to the EP-IV operation.

Table 4. Air sampling stations having gross beta concentrations in excess of 1 pCi/m^3.

Location	February 23-24 On	Off	Gross Beta pCi/m^3	$pCi\text{-}hr/m^3$	February 24-25 On	Off	Gross Beta pCi/m^3	$pCi\text{-}hr/m^3$
Beatty, Nev.	0805	0723	1.0^{β}	24	0725	0720	1.1^{p}	25
Currant, Nev.	0715	0715	1.4^{p}	33	----	----	---	---
Death Valley Jct., Calif.	0645	0645	5.7^{β}	140	----	----	---	---
Diablo, Nev.	0640	0645	170^{β}	4000	0645	0700	2.5	60
Twin Springs, Nev.	0930	0845	2.3^{β}	54	0845	0945	1.6	39
Lathrop Wells, Nev.	0850	1605	230^{β}	7100	----	----	---	---
Shoshone, Calif.	1245	1317	2.4^{p*}	58	----	----	---	---
Warm Springs, Nev.	0900	0900	41^{β}	970	0900	0900	6.0^{p}	140
Eureka, Nev.	1950	0730	71^{β}	850	0730	0730	7.2^{β}	170
Blue Jay, Nev.	0730	0725	52^{p*}	1200	0725	0835	14^{p*}	340
Elko, Nev.	1326	1310	1.2	28	1310	1237	1.2^{p*}	28
Nyala, Nev.	0800	0800	5.9^{p}	140	0800	0800	6.0	96^{**}
Boise, Idaho	----	----	-----	----	0840	1100	2.2	59
Wells, Nev.	1701	1704	2.2^{p*}	52	----	----	---	---
Clark Sta., Nev.	0655	0700	1.7^{β}	40	0700	0710	1.4^{β}	33
Goss Ranch, Nev.	1640	1200	34^{β}	660	Not operated -- temporary sampler			
Queen City Summit, Nev., unpopulated	1705	1230	1.1	22	Not operated -- temporary sampler			
Bozeman, Mont.	----	----	-----	----	1110	1050	1.1	25
12 mi west Coyote Summit, Nev.	1645	2051^{A}	49^{p}	200	Not operated -- temporary sampler			

Table 4A. Stations showing detectable amounts of radioiodines with gross beta below one pCi/m^3.

Location	February 23-24 On	February 23-24 Off	Gross Beta pCi/m^3	Gross Beta $pCi\text{-}hr/m^3$	February 24-25 On	February 24-25 Off	Gross Beta pCi/m^3	Gross Beta $pCi\text{-}hr/m^3$
Goldfield, Nev.	0800	0800	0.3^p	7.4	----	----	----	----
Warm Springs Rn., Nev.	0700	0700	0.1^c	3.5	----	----	----	----
Tonopah, Nev.	1635	----	----	----	----	0930	0.9^β	35
Round Mtn., Nev.	1908	1137	0.1^c	1.2	----	----	----	----

Sampler (**) was operated for 15.9 hours during this period.

A. Sample removed at 2051 2/23/67.

β. Radioiodines on both prefilter and charcoal cartridge.

p. Radioiodines found on prefilter only.

c. Radioiodines found on charcoal cartridge only.

p*. Charcoal cartridge was not in use.

(The above notes refer to Table 4 and Table 4A as indicated.)

Table 5. Isotopic air results from the six stations having the highest concentrations, Phoebus 1B EP-IV.

Location Nevada	Time On	Time Off	Sample Vol. m^3	Col-lec-tor	Prefilter Gross Beta pCi/m^3	Prefilter Gross Beta $pCi\text{-}hr/m^3$	^{131}I pCi/m^3	^{131}I $pCi\text{-}hr/m^3$	$^{132}Te\text{-}I$ pCi/m^3	$^{132}Te\text{-}I$ $pCi\text{-}hr/m^3$	^{133}I pCi/m^3	^{133}I $pCi\text{-}hr/m^3$	^{135}I pCi/m^3	^{135}I $pCi\text{-}hr/m^3$	^{141}Ce pCi/m^3	^{141}Ce $pCi\text{-}hr/m^3$
Lathrop Wells,	0850 2/23	1605 2/24	662	PF			15	470	140	4400	58	1800	ND	----	83	2600
				CC	230	7100	12	390	4.5	140	68	2100	ND	----	71	2200
Diablo,	0640 2/23	0645 2/24	511	PF			14	240	48	1100	57	1300	ND	----	ND	----
				CC	170	4000	19	440	22	510	72	1700	24	570	ND	----
Blue Jay,	0730 2/23	0725 2/24	505	PF			4.7	110	15	360	16	380	ND	----	8.7	160
				CC	52	1200	ND	---	ND	----	ND	----	ND	----	ND	----
Blue Jay,	0725 2/24	0835 2/25	520 no	PF			3.1	78	11	280	8.2	210	ND	----	2.3	58
				CC	14	340										
Warm Springs,	0900 2/23	0900 2/24	485	PF			4.4	110	14	340	20	480	71	1700	ND	----
				CC	41	970	6.4	150	6.8	160	29	700	ND	----	ND	----
Warm Springs,	0900 2/24	0900 2/25	485	PF	6.0	140	1.4	34	5.2	120	3.8	91	ND	----	1.9	46
				CC			ND	---	ND	----	ND	----	ND	----	ND	----
Eureka,	1950 2/23	0730 2/24	249	PF			7.2	86	23	270	35	420	180	2100	ND	----
				CC	71	850	11	130	12	140	16	190	ND	----	ND	----
:ka,	0730 2/24	0730 2/25	497	PF			1.5	36	5.3	130	4.2	100	ND	----	1.1	26
				CC	7.2	170	2.6	62	2.8	67	8.2	200	ND	----	0.4	10
Ranch, :i S of lo	1640 2/23	1200 2/24	203	PF			2.4	46	8.0	150	6.2	120	8.7	170	2.6	50
				CC	34	660	4.0	77	3.0	58	7.7	150	3.0	58	ND	----

prefilter
charcoal cartridge
no detection

NOTE: Integrated concentrations are calculated using the elapsed time as shown on the timer attached to the air sampler. The times shown in column 2 are clock times as noted by the station operator.

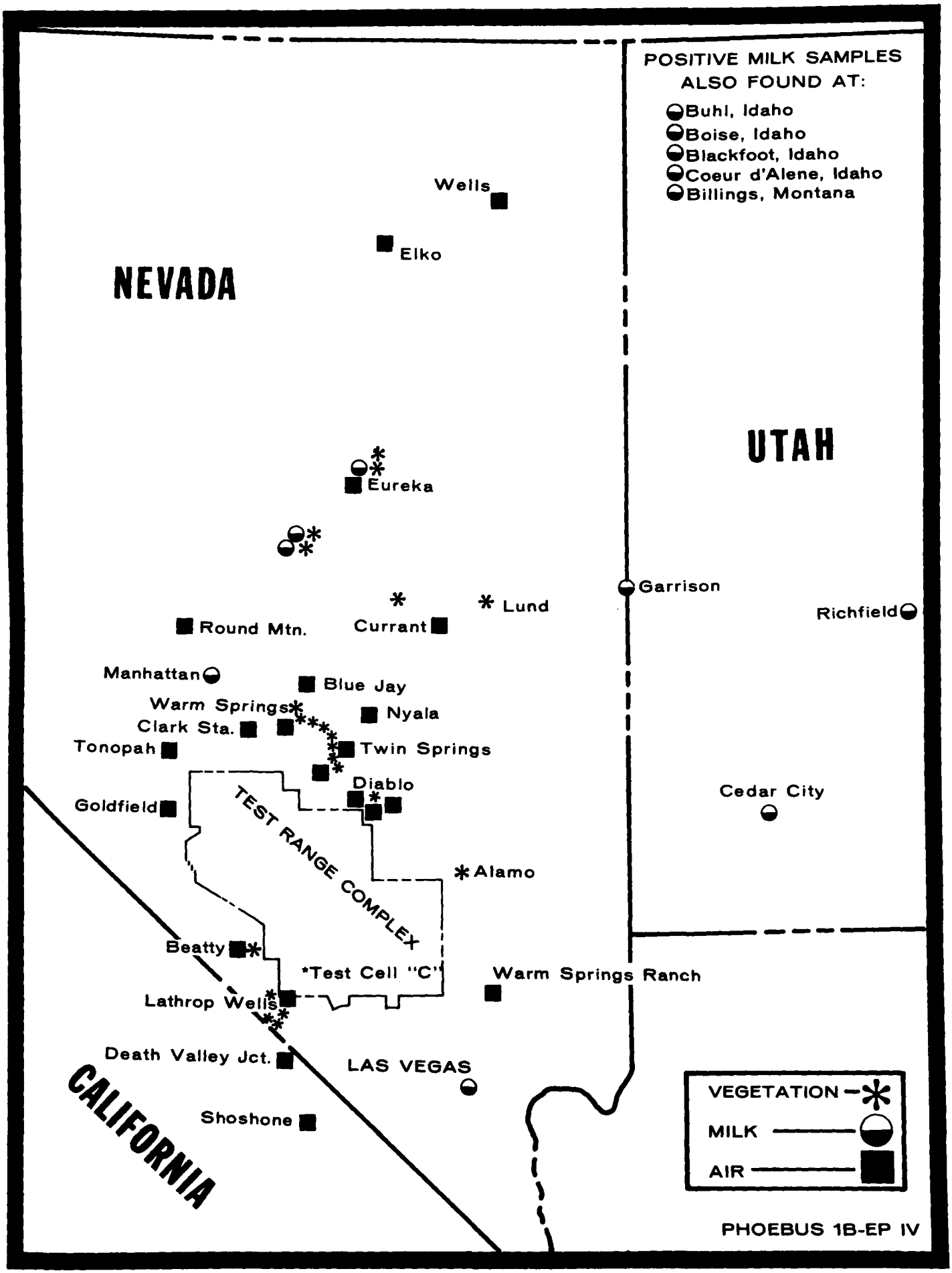

Figure 3. Locations where fresh fission products were detected.

Air samples from 19 Nevada stations, two California stations, one Idaho station, and one Montana station showed the presence of fresh fission products following the test. In addition, the filter from Twin Falls, Idaho had a gross beta concentration of 0.9 pCi/m^3. This is above normal, but no fresh fission products could be identified by gamma spectrometry. The highest integrated exposure, for radioiodines, was found at Lathrop Wells, Nevada, where the maximum calculated inhalation dose to an adult thyroid was 3 mRad.

Fresh fission products were detected on air sampling filters in all directions from Test Cell "C", except the 110^o - 170^o sector. Using Weather Bureau wind directions[1], aerial cloud tracking, and other environmental sampling, the pattern of deposition can be approximated as follows: The main portion of the cloud moved north to northeast over Diablo, Warm Springs, Eureka, and Wells. A higher than normal gross beta concentration of the filter from Boise, Idaho would suggest that the movement of the cloud was closer to true north.

During the night of February 23, pulse-cooling[2] of the reactor was started and fresh fission products were carried to the south, southwest by low level drainage winds. Wind direction changed on the morning of February 24 carrying some of the effluent northwest over Beatty and Goldfield.

Fission products from the reactor operation were found on air sampler filters collected in the area northeast of NTS for at least twenty-four hours, as fresh fission products were found on filters from both

[1]Synopsis of the meteorological conditions associated with the Phoebus 1B Reactor Experimental Plan IV.
U.S. Department of Commerce, Environmental Services Administration, Air Resources Field Research Office, Las Vegas, Nevada, March 1967.

[2]Pulse-cooling is the process of removing decay heat of the reactor core by flowing intermittant pulses of nitrogen gas through the core and exhausting the coolant gas out the rocket nozzel. This coolant gas picks up fission products from the core and exhausts them into the atmosphere.

the February 23-24 and the February 24-25 sampling periods at Warm Springs, Clark Station, Blue Jay, and Eureka. Higher than normal gross beta concentrations on the February 24-25 filters from Diablo, Nyala, and Twin Springs, tends to confirm this. The presence of ^{131}I on the charcoal cartridge at Warm Springs Ranch from the February 23-24 sampling period is difficult to understand since other stations in the area did not show detectable concentrations of any fresh fission products.

4. Vegetation sampling

A vegetation sample collected at Alamo with detectable ^{131}I would suggest the possibility that a portion of the upper cloud, which moved to the northeast, may have been carried south over Alamo and Warm Springs Ranch by night-time winds, or perhaps the radioactive material was from pulse-cooling of the reactor during the night following the run. Winds at the time were extremely variable. The concentration of ^{131}I on the Warm Springs Ranch filter was only 0.3 pCi/m^3. It is possible that other stations, such as Alamo and Hiko, may have been in the cloud path, but the levels of radioiodines were so low as to have been below detection limits.

Eighty-eight vegetation samples were collected at seventy-two off-site locations. Samples were collected at five-mile intervals from Crystal Springs(Hiko) to Warm Springs along Highway 25; from Warm Springs to 36.5 miles northwest of Warm Springs along Highway 6; and from 12 miles southeast of Lathrop Wells to Beatty along Highway 95. The remainder of the samples were collected at, or near, milk sampling locations. Other than pasture and feed samples, the most frequently collected vegetation was creosote bush (Larrea divaricata). Past experience has shown this common desert shrub tends to catch and hold fallout better than most other available

plants. Nineteen samples from separate locations had detectable amounts of one or more radioiodine isotopes.

Table 6 lists those locations where fresh fission products were found on vegetation samples.

Table 6. Vegetation samples containing detectable fresh fission products.

Location	Date Collected	Location	Date Collected
Alamo, Nevada	2/24	20 mi NW Queen City Summit	2/24
20 mi S Beatty, Nevada	2/24	25 mi NW Queen City Summit	2/24
25 mi S Beatty, Nevada	2/24	30 mi NW Queen City Summit	2/24
Springdale, Nevada	2/24	35 mi NW Queen City Summit	2/24
5 mi W Lathrop Wells, Nev.	2/24	40 mi NW Queen City Summit	2/24
Selbach Ranch (Lathrop Wells)*	2/24	Bradshaw Ranch (Duckwater, Nev.)*	2/28
5 mi E Coyote Summit	2/24	Sequra Ranch (Eureka, Nev.)*	3/1
10 mi NW Queen City Summit	2/24	Gardners Ranch (Preston, Nev.)*	2/28
15 mi NW Queen City Summit	2/24	Cold Creek Ranch (Strawberry, Nev.)*	3/1
Warm Springs, Nev.	2/24		

*Nearest map location.

5. Water sampling

Fifteen water samples from thirteen separate locations were analyzed for specific gamma emitting isotopes. No fresh fission products were detected. Table 7 lists locations, sources, and gross beta concentrations, from all water samples collected.

Table 7. Water sampling results.

Location	Source	Date Collected	Gross Beta pCi/l
TTT Ranch Austin, Nevada	Pond	2/25	3
Cummings Ranch Baker, Nevada	Pond	2/25	2
Blue Eagle Ranch Currant, Nevada	Spring	2/26	6
Currant Creek Reservoir	Pond	2/24	3
Diablo	Tap	2/26	10
Bradshaw Ranch Duckwater, Nev.	Tap	2/25	14
Gardner Dairy Lund, Nevada	Tap	2/25	4
Gardner Dairy Lund, Nevada	Tap	2/25	3
McKenzie Dairy Lund, Nevada	Tap	2/25	ND
Scow Dairy Lund, Nevada	Tap	2/25	3
Yelland Ranch McGill, Nevada	Stream	2/25	1
Yelland Ranch McGill, Nevada	Stream	2/26	2
Fallini's Pond Twin Springs, Nevada	Pond	2/24	72
Fallini's Pond Twin Springs, Nevada	Pond	2/26	63
Pruess Reservoir Garrison, Utah	Pond	2/25	13

6. Milk sampling

Two hundred and eighty milk samples were collected from seventy-six individual ranches, producing dairies, or processing plants following the EP-IV reactor operation. All were analyzed for specific gamma emitting isotopes and sixteen were processed and analyzed for $^{89-90}Sr$. Fourteen samples contained detectable amounts of one or more radioiodine isotopes. The maximum concentration of any one radioiodine isotope was 92 pCi/l ^{133}I from Garrison, Utah, and the maximum concentration of ^{131}I was 63 pCi/l from a sample collected at the Martin Ranch, close to Eureka, Nevada.

Detectable amounts of fresh fission products in milk (^{131}, ^{133}I) were found as far north as Coeur d'Alene, Idaho, and Billings, Montana. This would indicate the deposition pattern to be in a sector of approximately 0 - 25° from Test Cell "C". The Nevada air sampler filters having concentrations of radioiodines would tend to confirm this approximation.

Table 8 shows four milk samples with the maximum concentrations of ^{131}I. Appendices A and B list all milk sampling results. Because of expected low levels of activity in the milk samples, the samples were counted for longer than usual on the gamma spectrometer. These long count times resulted in lowering the minimum detectable amounts below the values given in Table 3.

Table 8. Four highest ^{131}I concentrations in milk samples.

Location	Date of Milking	pCi/l				
		^{131}I	^{133}I	^{137}Cs	^{89}Sr	^{90}Sr
Martin Ranch Eureka, Nev.	2/24/67 a.m.	22	47	37	4	16
	2/28/67 a.m.	63	ND	26	4	14
Ideal Dairy Richfield, Utah	2/27/67 p.m.	39	ND	20	ND	6.8
Cammack Dairy Blackfoot, Idaho	2/25/67 a.m.	21	ND	16	ND	5.7

CONCLUSION

The radiation exposure to the off-site population was well below the guidance contained in Standards for Radiation Protection, U. S. Atomic Energy Commission Manual Chapter 0524, November 8, 1968.

APPENDICES

APPENDIX A

All milk samples containing fresh fission products($^{131,133}I$), Phoebus 1B, EP-IV

Location	Date of Collection	pCi/l				
		^{131}I	^{133}I	^{137}Cs	^{89}Sr	^{90}Sr
Blackfoot, Idaho	2/25/67	21	ND	16	0	5.7
Couer D'Alene, Idaho	2/28/67	ND	9.6	15	1	17
Boise, Idaho	3/01/67	ND	17	ND	0	6.0
Buhl, Idaho	2/27/67	ND	12	11	0	5.3
Billings, Montana	3/01/67	ND	16	11	0	4.3
Sequra Ranch Near Eureka, Nev.	2/25/67	ND	24	12	0	11
Martin Ranch Near Eureka, Nev.	2/24/67	22	47	37	4	17
Martin Ranch Near Eureka, Nev.	2/28/67	63	ND	26	4	14
Martin Ranch Near Eureka, Nev.	3/03/67	12	ND	16	0	12
Manhatten, Nev.	2/25/67	ND	21	ND	0	8.7
Strawberry, Nevada	3/01/67	14	ND	20	0	11
Cedar City, Utah	2/26/67	10	ND	5	1	4.2
Garrison, Utah	2/24/67	9.4	92	ND	1	3.1
Richland, Utah	2/27/67	39	14	20	0	6.8

APPENDIX B

Milk samples showing no fresh fission products($^{131, 133, 135}$I), Phoebus 1B, EP-IV

Location	Number of samples	Inclusive dates of Collection
California		
Bakersfield	7	3/01/67-3/07/67
Barstow	7	2/28/67-3/07/67
Hanford	8	2/28/67-3/07/67
Newhall	7	2/27/67-3/05/67
Riverside	5	2/28/67-3/03/67
Idaho		
Blackfoot	3	2/25/67-3/02/67
Boise	6	2/24/67-3/02/67
Buhl	6	2/24/67-3/03/67
Burley	7	2/24/67-3/02/67
Couer D'Alene	5	2/24/67-3/02/67
Grangeville	7	2/25/67-3/04/67
Idaho Falls	7	2/24/67-3/03/67
Jerome	6	2/24/67-3/01/67
Lewiston	6	2/25/67-3/03/67
Mountain Home	7	2/24/67-3/02/67
Pocatello	6	2/23/67-3/02/67
Montana		
Big Timber	7	3/01/67-3/07/67
Billings	6	3/01/67-3/07/67
Bozeman	7	2/28/67-3/07/67
Miles City	7	2/27/67-3/05/67
Missoula	7	2/26/67-3/05/67
Utah		
Cedar City	6	2/24/67-3/02/67
Minersville	9	2/24/67-3/05/67
Mt. Pleasant	7	2/24/67-3/02/67
Ogden	7	2/24/67-3/03/67
Richfield	5	2/25/67-3/08/67
St. George	4	2/24/67-3/01/67
Smithfield	6	2/24/67-2/28/67
Spanish Fork	4	2/24/67-3/03/67
Wyoming		
Cheyenne	6	2/24/67-3/05/67
Powell	4	2/24/67-2/27/67
Rawlins	4	2/25/67-3/04/67

APPENDIX B (continued)

Location	Number of samples	Inclusive dates of Collection
Wyoming (cont'd)		
Riverton	4	2/25/67-3/02/67
Sheridan	5	2/25/67-2/27/67
Nevada		
Alamo	2	2/24/67-2/25/67
Young Ranch Austin	3	2/24/67-3/01/67
TTT Ranch Austin	1	2/26/67
Willow Creek Rn. Austin	1	2/25/67
Heffern Ranch Austin	2	2/26/67-2/26-67
Cummings Rn Baker	1	2/25/67
Eldridge Rn Baker	2	2/25/67-2/25/67
Blue Eagle Rn Currant	2	2/24/67-3/01/67
Bradshaw Rn Duckwater	2	2/25/67-2/28/67
Sequra Ranch Eureka	2	2/25/67-3/15/67
Martin Ranch Eureka	1	3/14/67
Hiko	2	2/24/67-2/25/67
Las Vegas	2	2/28/67-2/28/67
Selbach Ranch Lathrop Wells	3	2/24/67-2/27/67
Cypert Ranch Lathrop Wells	1	2/27/67
Nevada		
Nickell Farm Lathrop Wells	3	2/24/67-2/26/67
Gardner Ranch Lund	1	2/25/67
McKenzie Rn Lund	1	2/25/67
Scow Ranch Lund	1	2/25/67
W. Gardner Rn Lund	1	2/25/67
Jurey Ranch Lund	1	2/28/67
Larsen Ranch McGill	1	2/25/67
Henroid Ranch McGill	1	2/25/67
Yelland Ranch McGill	2	2/25/67-2/26/67
Hiatt Ranch Manhatten	2	2/24/67-2/28/67
Sharp Ranch Nyala	2	2/24/67-3/03/67
Casey Ranch Nyala	2	2/25/67-3/03/67
Anderson Rn Pahrump	1	2/25/67
Owens Ranch Pahrump	1	2/24/67
Wilson Creek Rn Potts	1	2/26/67
Gardners Ranch Preston	1	2/28/67
Bergs Ranch Round Mountain	2	2/25/67-2/26/67

APPENDIX B (continued)

Location	Number of samples	Inclusive dates of Collection
Nevada (cont'd)		
Pope Ranch Round Mountain	3	2/24/67-2/26/67
Rhodes Ranch Shoshone	1	2/25/67
Peacock Ranch Springdale	1	2/24/67
Circle Ranch Strawberry	1	3/03/67
Cold Creek Rn Strawberry	1	3/01/67
Pumping Station Tonopah	1	2/25/67

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