Rockwell International
Rocketdyne Division

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ABSTRACT

Data on employee exposures, bioassay results, effluent releases, in-plant airborne radioactivities, and environmental monitoring for Rocketdyne operations during 1986 are reviewed. This review is prepared, as required by Special Nuclear Materials License No. SNM-21, to determine (1) if there are any upward trends developing in personnel exposures for identifiable categories of workers or types of operations or effluent releases, (2) if exposures and effluents might be lowered under the concept of as low as reasonably achievable, and (3) if equipment for effluent and exposure control is being properly used, maintained, and inspected.

Personnel exposures have been carefully controlled.

Effluent releases are at insignificant levels compared to regulatory standards, do not show any upward trends, and do not appear to be reducible by reasonable means.

To the extent covered by this review, equipment for effluent and exposure control was properly used, maintained, and inspected.

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FORM 734-C REV. 12-84

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INTRODUCTION

The Rocketdyne special nuclear materials license[1] requires that an annual report be made to the Radiation Safety Committee of the Nuclear Safeguards Review Panel reviewing personnel exposure and effluent release data. The format and content of this report have been well established in prior issues.[2-12] While this report is prepared primarily to satisfy a requirement of the NRC license, all operations with radioactive material and radiation-producing devices have been included.

These reports for the years 1975 through 1985[2-12] provide a historical basis for the identification of trends. It should be noted that, in some instances, both NRC-licensed and non-NRC-licensed activities take place in the same building. In these cases, certain measurements (e.g., ventilation air exhaust radioactivity) have not been made separately for each type of activity.

Additionally, it is not possible to separate the integrated personnel radiological doses to that attributable to either nonlicensed activities for the DOE or the activities licensed by NRC or the State of California.

The following Rocketdyne facilities and operations are specifically covered in this report:

1) Rockwell International Hot Laboratory (RIHL) - Building 020, Santa Susana Field Laboratories

2) Nuclear Material Development Facility (NMDF) - Building 055, Santa Susana Field Laboratories

3) Radioactive Material Disposal Facility (RMDF) - Buildings 021, 022, and related facilities at Santa Susana Field Laboratories (DOE jurisdiction)

4) Applied Nuclear Research (ANR) - The Gamma Irradiation Facility and Laboratories in Building 104 at De Soto.

Work at various facilities during 1986 is briefly described below:

- RIHL--Considerable cleaning and modifications were done during the first half of the year in preparation for the Fermi fuel decladding project. The work performed in this project was changed from grinding the zirconium cladding off the fuel to simply disassembling the fuel and repackaging the rods. This change was due to a redirection of the fuel reprocessing from SRP to ICPP, where the process is not sensitive to the presence of UZr_x.

  Improvements and repairs were made to the ventilation exhaust system.

- NMDF - The residual NaK in the NaK bubblers was reacted. Final decontamination was completed, and a survey report was submitted to NRC requesting termination of the license. (The license for NMDF was terminated by NRC on October 7, 1987.)

- RMDF--Storage, transfer, and shipping of EBR-II fuel and scrap and Fermi fuel occupied most of the year. Radioactively contaminated water was evaporated. Shielding was added to the waste storage building to reduce the exposure rate outside the facility.

  Operations were halted by direction of DOE-SAN because of the lack of an approved Safety Analysis Report. The SAR was approved 1 week later, and operations were resumed.

- GIF--The window was refurbished to improve visibility. Several R&D irradiations were performed with Co-60 sources. The 12 WESF cesium-137 capsules were received and installed in the new cask. Leak tests were successfully performed on all capsules.

- Industrial Radiography--A pair of X-ray booths was constructed in CA001. A new pair of booths was also constructed in CA009.

- Miscellaneous--Generally, routine work was performed in all other operations. In-service inspection (ISI) at Chin Shan (Taiwan) resulted in exposures of RD personnel up to 1.2 rem and amounted to 7.2 person-rem group dose.

I. PERSONNEL DOSIMETRY

Personnel dosimetry techniques generally consist of two types: those which measure radiation incident on the body from external sources (film badges) and those which measure internal deposition of radioactivity via inhalation, ingestion, skin absorption, or through wounds (bioassays). These measurement methods provide a natural separation of the exposure modes to (1) permit an evaluation of the more significant exposure routes and (2) to allow a differentiation between those exposure sources which are external and controllable in the future and those which may continue to irradiate the body for some time period (i.e., internal deposits).

A. FILM/TLD DATA

1. Whole Body Monitoring

Personnel external radiation exposures for the pertinent activities for the year are shown in Figure 1 as a cumulative log-normal distribution. It should be noted (see Summary, Section VI) that all whole-body exposures were less than 2 rem and were well below the allowable annual occupational total of 12 rem for NRC and State-licensed operations and 5 rem for DOE operations. The highest exposure shown, 1.31 rem, resulted from 1.2 rem received during an in-service inspection operation at Chin Shan, Taiwan.

For comparison, the distributions of exposures reported for NRC licensees[13] and DOE contractors[14] for 1983 are shown as solid curves.

The Rocketdyne dose distribution is well below the NRC distribution and generally below the DOE distribution. A more significant comparison can be made in terms of the group dose. The group dose received by Rocketdyne employees in 1986 amounted to 22.7 person-rem. Of this total, 7.2 person-rem were received at the Chin Shan reactor. If the distribution of doses had been that shown for NRC licensees, the group dose would have been 108.2 person-rem. If the doses had been those shown for DOE, the group dose would have

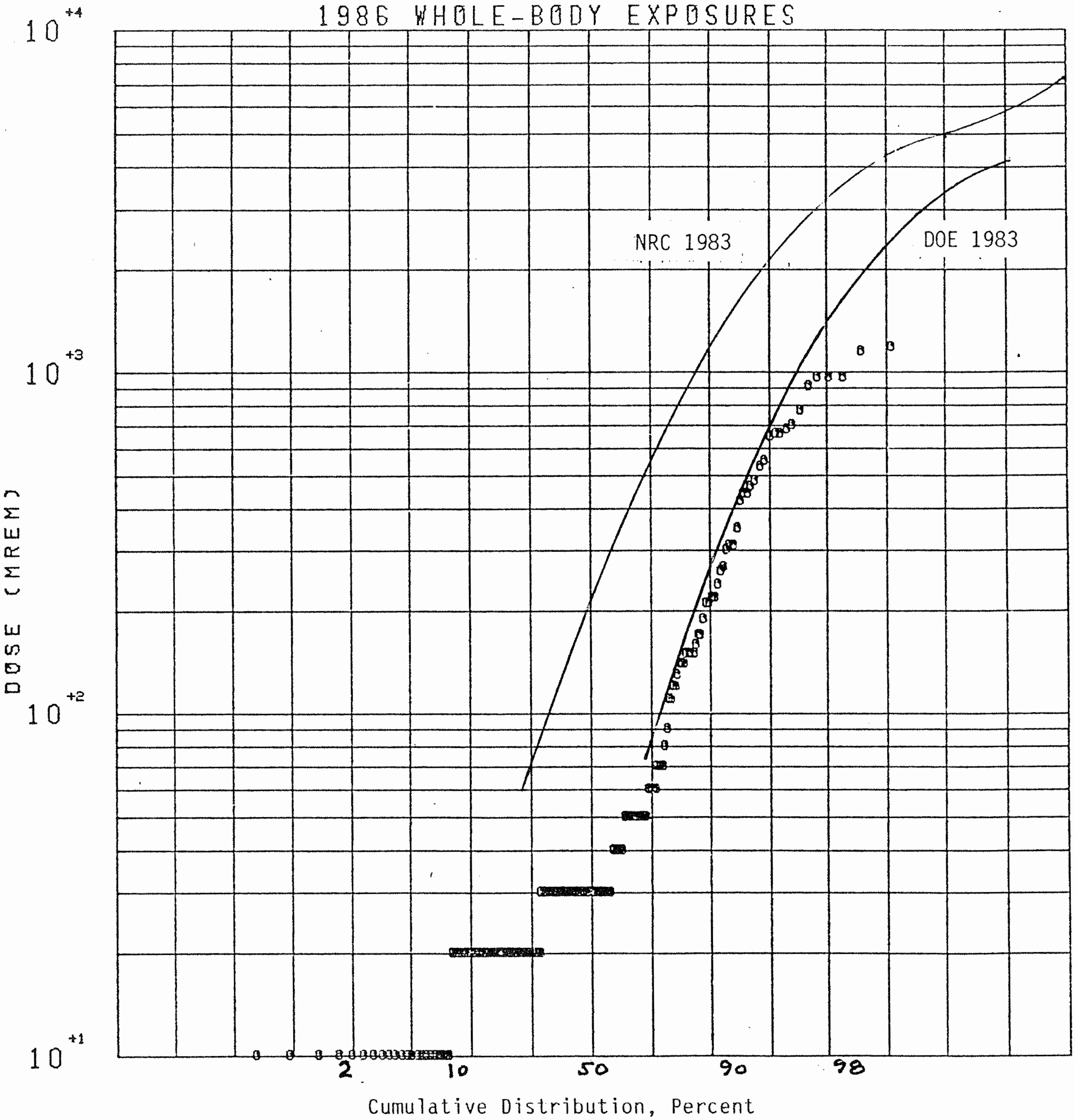

Figure 1. Cumulative Log-Normal Distribution for Whole-Body Radiation Exposures of Occupationally Exposed Individuals in 1986

been 34.2 person-rem. Comparisons such as these should be viewed with caution because of differences in the type of work between the Rocketdyne workforce and both the NRC licensees and the DOE contractors.

2. Extremity Monitoring

Operations with radioactive material that may involve locally high exposures are conducted with additional "extremity" monitoring, usually for the hands. "Whole-body" doses received when explicit extremity monitoring is not performed are assumed to represent the extremity doses and should be added to the recorded extremity doses. This is difficult to do, so for the purpose of monitoring extremity exposures, it is noted that neither extremity nor whole-body doses are high, and that even the sum of the maximum quarterly hand dose (674 mrem) and the maximum whole-body dose (1310 mrem) is approximately 10% of the NRC and State of California limits of 18.75 rem per quarter.

B. BIOASSAYS

Bioassays normally consist of analysis of urine and occasionally fecal samples. Personnel whose work assignments potentially expose them to respirable-sized radioactive aerosols are routinely evaluated in this manner. Normally, urinalyses are performed quarterly and fecal analysis only when gross internal contamination is suspected. A statistical summary of the results for 1986 appears in Table 1, while a detailed listing of the positive results are shown in Table 2. Only three types of analyses showed positive results this year: FP3A, FP3B, and UF. The UF analysis is chemically selective for uranium. The FP3A analysis is assumed to be indicative of Sr-90, although other radionuclides, such as Co-60, may also be detected. Further analysis could specifically quantify Sr-90, and identify interfering radionuclides, if significant activities were found. The FP3B analysis is radiometrically selective for Cs-137, using gamma-ray spectrometry to measure this radionuclide.

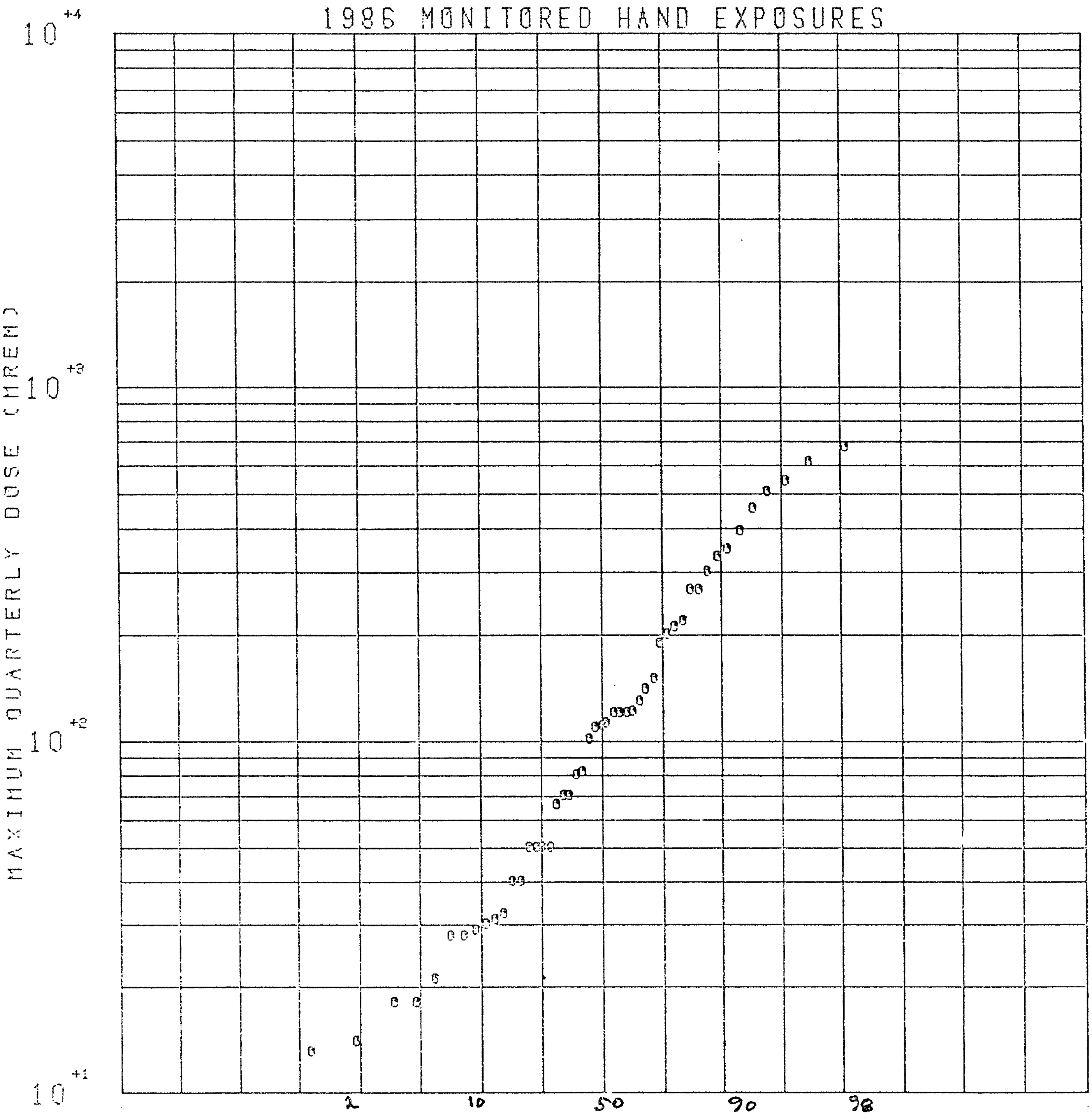

Figure 2. Cumulative Log-Normal Distribution for Quarterly Hand Exposures in 1986

Table 1. Summary of Bioassays - 1986

Measurement Type*	Total Tests	Total Positive Results	Total Individuals With Positive Results
Am241	4	0	0
UF	59	6	6
UR	55	0	0
PUA	35	0	0
FP3A	255	25	20
FP3B	255	8	8
Total	663	39	31

*UF = Uranium - Fluorometric
UR = Uranium - Radiometric
PUA = Gross Plutonium-alpha
FP = Fission Products

(For a discussion of specific analytical techniques employed, as identified by "TYPE," see Appendix B in Reference 9)

Table 2. Positive Bioassay Result Summary - 1986
(Sheet 1 of 3)

H&S Number	Sample Date	Analysis Type*	Results Per Vol. Anal.	Results Per 1500 ml-day	Assumed Specific Radionuclide	Assumed Critical Nuclide Equivalent MPBB (%)
4303	100686	FP3A	5.40	40.49	Sr-90	8.40
4303	113086	FP3A	1.74	-	Sr-90	0
4853	071386	FP3A	4.28	32.10	Sr-90	6.70
4932	-61686	FP3A	6.10	45.78	Sr-90	9.50
4160	082586	FP3A	12.90	96.75	Sr-90	20.20
4160	101486	FP3A	2.46	-	Sr-90	0
3983	082886	FP3A	6.45	48.40	Sr-90	10.10
3983	100886	FP3A	1.41	-	Sr-90	0
3499	031986	FP3A	4.76	35.68	Sr-90	7.40
3499	052186	FP3A	1.76	-	Sr-90	0
3499	060386	FP3B	10.39	77.93	Cs-137	0.01
3499	082	FP3B	4.13	-	Cs-137	0
1495	120386	UF	0.0003	0.45	U	0.40
4937	011386	FP3A	8.17	61.28	Sr-90	12.80
4390	030786	FP3A	6.19	46.39	Sr-90	9.70
4390	061686	FP3A	0	0	Sr-90	0
4390	061686	FP3B	13.57	101.78	Cs-137	0.02
4390	120986	FP3B	0	0	Cs-137	0
4893	071486	UF	0.0003	0.45	U	0.40
4893	110686	UF	0	0	U	0
4409	061786	UF	0.0002	0.30	U	0.30
3459	120886	UF	0.0003	0.45	U	0.40
3459	120886	UF	0.0001	-	U	0
3771	031086	FP3B	17.16	128.20	Cs-137	0.02
3771	051986	FP3B	0	0	Cs-137	0
4912	011286	FP3B	12.20	91.50	Cs-137	0.01

Table 2. Positive Bioassay Result Summary - 1986
(Sheet 2 of 3)

H&S Number	Sample Date	Analysis Type*	Results: Per Vol. Anal.	Results: Per 1500 ml-day	Assumed Specific Radionuclide	Assumed Critical Nuclide Equivalent MPBB (%)
3914	020386	FP3A	11.40	85.50	Sr-90	17.80
3914	091586	FP3A	5.28	43.33	Sr-90	9.00
3914	102886	FP3A	0	0	Sr-90	0
3922	031286	FP3B	8.09	60.68	Cs-137	0.01
3922	062486	FP3B	0	0	Cs-137	0
2041	063086	FP3A	5.24	39.28	Sr-90	8.20
3726	030986	FP3B	9.72	72.93	Cs-137	0.01
3726	051886	FP3B	6.75	-	Cs-137	0
4566	061786	FP3B	8.98	67.35	Cs-137	0.01
4566	111086	FP3B	0	0	Cs-137	0
4965	061786	FP3A	9.10	68.26	Sr-90	14.20
4965	091586	FP3A	3.71	-	Sr-90	0
2302	062586	FP3A	5.29	39.65	Sr-90	8.30
2302	091986	FP3A	1.38	-	Sr-90	0
4530	081486	FP3A	13.10	98.18	Sr-90	20.05
4530	100886	FP3A	5.00	37.50	Sr-90	7.80
4404	112686	UF	0.0003	0.45	U	0.40
4162	090886	FP3A	5.30	38.72	Sr-90	8.30
4162	101486	FP3A	2.44	-	Sr-90	0
3897	061586	FP3A	5.74	43.05	Sr-90	9.00
3897	082586	FP3A	6.02	45.13	Sr-90	9.40
3897	101086	FP3A	1.40	-	Sr-90	0
3912	072886	FP3A	5.47	41.02	Sr-90	8.50
3912	112486	FP3A	0.19	-	Sr-90	0
3702	061686	FP3A	6.37	47.77	Sr-90	10.00
3702	092186	FP3A	4.70	38.17	Sr-90	7.30
3702	112486	FP3A	2.56	-	Sr-90	0

Table 2. Positive Bioassay Result Summary - 1986
(Sheet 3 of 3)

H&S Number	Sample Date	Analysis Type*	Results Per Vol. Anal.	Results Per 1500 ml-day	Assumed Specific Radionuclide	Assumed Critical Nuclide Equivalent MPBB (%)
3703	041486	FP3A	4.05	30.38	Sr-90	6.30
3703	061686	FP3A	1.05	-	Sr-90	0
3703	082586	FP3A	13.33	99.97	Sr-90	20.80
3703	101086	FP3A	2.83	-	Sr-90	0
1254	041386	FP3A	4.60	34.49	Sr-90	2.20
1254	061686	FP3A	2.50	-	Sr-90	0
4971	112886	UF	0.0003	0.45	U	0.40
4971	112886	FP3B	8.37	62.79	Cs-137	0.01
4960	040386	FP3A	4.92	36.91	Sr-90	7.70
4960	091786	FP3A	1.89	-	Sr-90	0

UF: Fluorimetric Uranium
FP: Fission Products

(For a brief description of the specific analytical techniques, see Appendix B of Reference 9)

(FP3A is presumptively Sr-90; FP3B is specifically Cs-137)

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Followup results are shown, where available, to indicate the decrease of detected activity to negligible levels.

The excretion rates assumed to be indicative of 1 MPBB for various radionuclides and the minimum detectable activities (MDA) are:

Radionuclides	Standard Excretion Rate	MDA
Sr-90	480 dpm/day	30 dpm/day
Cs-137	660,000 dpm/day	60 dpm/day
U	100 ug/day	0.30 ug/day

These excretion rates are based on an assumption of equilibrium between intake and elimination. Transient elimination following an acute exposure will generally indicate a much higher body burden than actually exists.

The highest result shown for Sr-90, 20.8%, was essentially gone 46 days later, and may have resulted from an anomaly at the laboratory, or may have represented some other beta-emitting radionuclide, such as Co-60, which has a relatively short biological half-life (9.5 days). The apparent half-life of 18 pairs of measurable Sr-90 excretion ranges from 21 days to 223 days, with a mean of 58 days, and a standard deviation of 52 days. Some of the longer half-lives observed may have resulted from uptake between the times of the two samples used for this analysis. The reference effective half-life for Sr-90 (16) is 5700 days. The magnitude of the maximum % MPBB shown results from the relatively low value of MPBB for Sr-90. The analytical results suggest that the activity detected may not be Sr-90.

II. RADIATION/RADIOACTIVITY MEASUREMENTS

The measurements and surveillance performed to determine local radiation levels in the working areas where radioactive materials are used are described below.

A. AREA RADIATION LEVELS

Film badges ("location badges") are placed throughout the facilities, and are kept in place during the entire calendar quarter. Some of these are in nominally low-exposure areas while some are in relatively high-exposure (but low-occupancy) areas. The average and maximum exposure rates determined for each quarter are shown in Table 3.

The maximum values for the RMDF are associated with the evaporator and are in an unoccupied area. The reduction during this year reflects a generally more effective control of facility exposure rates. The high-exposure rate for the fourth quarter in the Applied Nuclear Research Laboratories is associated with the sandblaster.

B. INTERIOR AIR SAMPLES - WORKING AREAS

In those working areas where the nature of the tasks being performed and the materials in use might lead to the potential for generation of respirable airborne radioactivity, periodic local air sampling is performed. A summary of these results for 1986 is given in Table 4.

Table 3. Location Badge Radiation Exposure - 1986

Facility	Calendar Quarter Q1	Q2	Q3	Q4
	Average Exposure Rate (mR/h) / Maximum Exposure Rate (mR/h)			
RIHL (average)	0.06	0.06	0.06	0.07
RIHL (maximum)	0.52	0.49	0.58	0.70
Fenceline (average)	0.02	0.003	0.001	0.002
Fenceline (maximum)	0.03	0.014	0.009	0.014
RMDF (average)	5.30	3.20	1.60	1.60
RMDF (maximum)	23.00	11.90	5.20	5.10
Fenceline (average)	0.15	0.07	0.10	0.08
Fenceline (maximum)	0.52	0.16	0.43	0.31
GIF (average)	0.07	0.12	0.11	0.03
GIF (maximum)	0.22	0.37	0.16	0.11
ANRL (average)	0.21	0.08	0.20	0.43
ANRL (maximum)	0.81	0.42	0.82	2.19

Table 4. Interior Air Sample Summary - 1986

Area	Sample		Q1	Q2	Q3	Q4	MPC
			Average Airborne Activity Concentration (μCi/ml) — Calendar Quarter				
RIHL	Unposted alpha		1×10^{-15}	2×10^{-15}	8×10^{-15}	5×10^{-15}	2×10^{-12}
	beta		1×10^{-14}	1×10^{-13}	5×10^{-14}	2×10^{-14}	1×10^{-9}
	Posted alpha		2×10^{-14}	6×10^{-15}	8×10^{-15}	5×10^{-15}	2×10^{-12}
	beta		1×10^{-13}	5×10^{-13}	5×10^{-14}	2×10^{-14}	1×10^{-9}
	Maximum alpha		2×10^{-11}	2×10^{-14}	8×10^{-15}	1×10^{-14}	2×10^{-12}
	beta		3×10^{-11}	4×10^{-11}	1×10^{-12}	1×10^{-12}	1×10^{-9}
RMDF	T022 High Bay	beta	2×10^{-11}	3×10^{-12}	4×10^{-13}	1×10^{-12}	1×10^{-9}
	Decon Room	beta	1×10^{-10}	3×10^{-12}	1×10^{-11}	1×10^{-12}	1×10^{-9}
	Packaging Room	beta	1×10^{-10}	4×10^{-12}	6×10^{-12}	3×10^{-12}	1×10^{-9}

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III. EFFLUENT MONITORING

Effluents which may contain radioactive material are generated at certain Rocketdyne facilities as a result of operations performed either under contract to DOE, or under the NRC Special Nuclear Materials License SNM-21, or under the State of California Radioactive Material License 0015-70. The specific facility identified with the NRC license is Building 020 at the SSFL at Santa Susana.

An annual report of effluent releases, prepared by Radiation & Nuclear Safety in the Health, Safety, and Environment Department, describes in detail the monitoring program at Rocketdyne for gaseous effluents from the Rocketdyne facilities. The data reported in the 1986 edition of that report[15] for atmospherically discharged effluents for the facilities identified above is presented in Table 5. (No releases of radioactively contaminated liquids were made, either to the sewer or to the environment.)

Effluent releases are extremely low as a result of a combination of factors. Much of the radioactive material processed is in relatively undispersible form, many of the operations are conducted in glove boxes and sealed hot cells, and the effluent is filtered by pre-filters and HEPA filters. The HEPA-filter systems are tested annually by use of a polydisperse DOS aerosol. The test dates and filtration efficiencies for several exhaust systems, and the required efficiencies, are shown below:

		Measured	Required
NMDF	3/20/86	99.96%	99.95%
RMDF (Vault 14884)	4/11/86	99.93%	99%
RMDF (Vault 14885)	4/11/86	99.93%	99%
RMDF (Decon 14886)	4/14/86	99.87%	99%
RMDF (Decon 14887)	4/14/86	99.88%	99%
RIHL	11/5/86	99.99%	99.95%
ANR (EF-405)	3/3/86	99.97%	99%
GIF	4/23/86	99.91%	99%

All filter systems satisfied their requirements.

Table 5. Atmospheric Emissions to Unrestricted Areas - 1986

	Approximate Emissions Volume (m^3)	Activity Monitored	Approximate Minimum Detection Level (10^{-15} μCi/ml)	Annual Average Concentration (10^{-15} μCi/ml)	Sampling Period Maximum Observed Concentration (10^{-15} μCi/ml)	Total Radio-activity Released (Ci)	Percent of Guide[a]	Percent of Samples with Activity <MDL
104 De Soto	1.7×10^{8}	Alpha	0.38	0.46	0.84	7.6×10^{-8}	0.02	30
		Beta	1.40	4.76	25.50	7.8×10^{-7}	0.002	15
020 SSFL	5.0×10^{8}	Alpha	0.38	0.26	2.56	1.3×10^{-7}	0.43	82
		Beta	1.40	46.09	440.96	2.2×10^{-5}	0.15	4
021-022 SSFL	3.3×10^{8}	Alpha	0.38	0.14	0.47	4.6×10^{-8}	0.23	92
		Beta	1.40	39.90	279.86	1.3×10^{-5}	0.13	0
055[d] SSFL	1.1×10^{8}	Alpha	0.38	0.36	1.09	4.1×10^{-8}	0.60	65
		Beta	1.40	34.93	364.04	4.0×10^{-6}	1.2	0
Total	1.1×10^{9}				Total	4.0×10^{-5}	---	---
Annual average ambient air radio-activity concen-centration[b] - 1986		Alpha		2.3	Ambient			
		Beta		73.0	equivalent[c]	8.3×10^{-5}	---	---

[a]Assuming all radioactivity detected is from Rocketdyne nuclear operations.
Guide: De Soto site: 3×10^{-12} μCi/ml alpha, 3×10^{-10} μCi/ml beta; 10 CFR 20 Appendix B.
SSFL site: 6×10^{-14} μCi/ml alpha, 3×10^{-11} μCi/ml beta, 3×10^{-12} μCi/ml beta (055 only); 10 CFR 20 Appendix B, CAC-17, and DOE Order 5480.1 Chapter XI.

[b]Averaged result for 7-day (200 m^3) SSFL continuous air sampler.

[c]Natural radioactivity contained in equivalent volume of air discharged through exhaust systems after filtration.

[d]This facility was decommissioned during 1986. Exhaust system shut down in July.

Note: All release points are at the stack exit.

No.: N001TI000285

IV. ENVIRONMENTAL MONITORING PROGRAM

The basic policy for control of radiological and toxicological hazards at Rocketdyne requires that adequate containment of such materials be provided through engineering controls and, through rigid operational controls, that facility effluent releases and external radiation levels are reduced to a minimum. The environmental monitoring program provides a measure of the effectiveness of the Rocketdyne safety procedures and of the engineering safeguards incorporated into facility designs. Specific radionuclides in facility effluent or environmental samples are not routinely identified due to the extremely low radioactivity levels normally detected, but may be identified by analytical or radiochemistry techniques if significantly increased radioactivity levels are observed.

The annual report of environmental monitoring, prepared by Radiation & Nuclear Safety in the HS&E Department, describes in detail the Rocketdyne environmental monitoring program.

Some of the data reported in the 1986 edition of that report[15] are presented here. It is important to remember that the radiological activity levels reported can be attributed not only to operations at NRC licensed, DOE-sponsored, and State of California-licensed facilities, but also to external influences such as naturally occurring radioactive materials, the Chernobyl reactor accident, and fallout from nuclear weapon testing.

These data are:

- Soil gross radioactivity data presented in Table 6
- Soil plutonium radioactivity data presented in Table 7
- De Soto and SSFL Sites - Domestic water radioactivity data presented in Table 8
- Bell Creek and Rocketdyne site retention pond radioactivity data presented in Table 9
- Ambient air radioactivity data presented in Table 10 (and shown graphically in Figure 3)
- Ambient radiation data presented in Table 11.

Table 6. Soil Radioactivity Data - 1986

Area	Activity	Number of Samples	Gross Radioactivity (pCi/g)	
			Annual Average Value and Dispersion	Maximum Observed Value[a] and Month Observed
On-site (quarterly)	Alpha	48	26.7 ± 6.6	40.1 (April)
	Beta	48	26.1 ± 2.2	32.2 (April)
Off-site (quarterly)	Alpha	48	25.1 ± 5.9	39.0 (July)
	Beta	48	24.2 ± 1.3	30.4 (April)
Pond R-2A mud No. 55	Alpha	4	24.9 ± 1.9	26.7 (Apr/Oct)
	Beta	4	24.8 ± 0.5	25.4 (April)
Bell Creek upper stream bed soil No. 62	Alpha	4	15.4 ± 4.4	21.8 (April)
	Beta	4	24.2 ± 1.2	26.0 (April)

[a]Maximum value observed for single sample.

Table 7. Soil Plutonium Radioactivity Data - 1986

Sample Location	25 June 1986 Survey Results		8 December 1986 Survey Results	
	^{238}Pu (pCi/g)	^{239}Pu + ^{240}Pu (pCi/g)	^{238}Pu (pCi/g)	^{239}Pu + ^{240}Pu (pCi/g)
S-56	0 ± 0.0001	0.0007 ± 0.0004	0 ± 0.0002	0.0002 ± 0.0002
S-57	0.0004 ± 0.0003	0.0005 ± 0.0003	0.0003 ± 0.0002	0.0010 ± 0.0004
S-58	0.0003 ± 0.0003	0.0031 ± 0.0009	0.0003 ± 0.0002	0.0032 ± 0.0006
S-59	0.0002 ± 0.0002	0.0038 ± 0.0009	0.0003 ± 0.0002	0.0020 ± 0.0004
S-60	0.0003 ± 0.0002	0.0028 ± 0.0008	0 ± 0.0003	0.0006 ± 0.0003
S-61[a]	0 ± 0.0002	0.0005 ± 0.0004	0 ± 0.0002	0.0019 ± 0.0005

[a]Off-site location

Table 8. Supply Water Radioactivity Data - 1986

Area	Activity	Number of Samples	Gross Radioactivity (10^{-9} μCi/ml) Average Value and Dispersion	Gross Radioactivity (10^{-9} μCi/ml) Maximum Value[a] and Month Observed
De Soto (monthly)	Alpha	12	4.41 ± 2.53	8.70 (January)
	Beta	12	3.75 ± 0.62	4.69 (March)
SSFL (monthly)	Alpha	24	6.55 ± 9.09	45.77 (October)
	Beta	24	3.58 ± 0.95	6.75 (October)

[a] Maximum value observed for single sample.

Table 9. SSFL Site Retention Pond, Site Runoff, and Well Water Radioactivity Data - 1986
(Sheet 1 of 4)

Area	Activity	Number of Samples	Gross Radioactivity Concentration (x 10^{-9} μCi/ml)		
			Annual Average Value and Dispersion	Maximum Value[a] and Month Observed	Percent of Samples With Activity <MDL[b]
Pond No. 6 (Monthly)	Alpha	12	2.51 ± 2.88	9.51 (December)	92
	Beta	12	2.92 ± 0.94	4.57 (January)	0
Pond No. 12 (R-2A) (Monthly)	Alpha	12	4.18 ± 2.70	8.7 (December)	92
	Beta	12	3.58 ± 1.14	5.93 (October)	0
Upper Bell Creek No. 17 (Seasonal)	Alpha	6	2.02 ± 2.08	5.90 (March)	100
	Beta	6	2.60 ± 0.52	3.66 (March)	0
Well WS-4A (Seasonal)	Alpha	2	9.94 ± 1.90	11.83 (October)	100
	Beta	2	4.43 ± 0	4.43 (Oct/Dec)	0
Well WS-5 (Seasonal)	Alpha	2	11.34 ± 1.84	13.18 (October)	50
	Beta	2	4.53 ± 0.38	4.91 (December)	0
Well WS-6 (Seasonal)	Alpha	2	12.98 ± 1.66	14.65 (October)	50
	Beta	2	5.80 ± 0.07	5.87 (October)	0
Well WS-7 (Seasonal)	Alpha	2	10.71 ± 4.44	15.15 (December)	50
	Beta	2	5.32 ± 0.01	5.32 (December)	0

Table 9. SSFL Site Retention Pond, Site Runoff, and Well Water Radioactivity Data - 1986
(Sheet 2 of 4)

Area	Activity	Number of Samples	Gross Radioactivity Concentration ($\times 10^{-9}$ μCi/ml)		
			Annual Average Value and Dispersion	Maximum Value[a] and Month Observed	Percent of Samples With Activity <MDL[b]
Well WS-8 (Seasonal)	Alpha	2	9.40 ± 4.68	14.08 (December)	50
	Beta	2	3.64 ± 0.06	3.70 (December)	0
Well WS-9 (Seasonal)	Alpha	2	22.86 ± 9.32	32.14 (December)	0
	Beta	2	5.86 ± 0.62	6.48 (December)	0
Well WS-9A (Seasonal)	Alpha	2	5.04 ± 0.96	6.00 (October)	100
	Beta	2	3.60 ± 0.24	3.84 (October)	0
Well WS-9B (Seasonal)	Alpha	2	14.64 ± 0.08	14.72 (October)	50
	Beta	2	6.88 ± 0.28	7.16 (October)	0
Well WS-11 (Seasonal)	Alpha	2	13.78 ± 8.16	21.94 (December)	50
	Beta	2	4.84 ± 0.15	4.99 (December)	0
Well WS-12 (Seasonal)	Alpha	2	7.79 ± 0.25	8.04 (December)	100
	Beta	2	4.93 ± 0.07	5.00 (December)	0
Well WS-13 (Seasonal)	Alpha	2	9.72 ± 0	9.72 (December)	100
	Beta	2	4.34 ± 0	4.34 (December)	0

Table 9. SSFL Site Retention Pond, Site Runoff, and Well Water Radioactivity Data - 1986 (Sheet 3 of 4)

Area	Activity	Number of Samples	Gross Radioactivity Concentration (x 10^{-9} μCi/ml)		
			Annual Average Value and Dispersion	Maximum Value[a] and Month Observed	Percent of Samples With Activity <MDL[b]
Well WS-14 (Seasonal)	Alpha	2	10.77 ± 2.19	12.96 (December)	50
	Beta	2	4.68 ± 0.23	4.91 (October)	0
Well OS-1 (Seasonal)	Alpha	2	4.05 ± 3.66	6.64 (December)	100
	Beta	2	3.20 ± 0.58	3.78 (December)	0
Well OS-2 (Seasonal)	Alpha	3	5.17 ± 5.38	11.30 (December)	100
	Beta	3	1.75 ± 0.22	1.96 (December)	0
Well OS-3 (Seasonal)	Alpha	3	6.66 ± 2.97	10.79 (December)	66
	Beta	3	3.47 ± 0.25	3.69 (June)	0
Well OS-4 (Seasonal)	Alpha	3	4.16 ± 1.39	6.09 (April)	100
	Beta	3	3.64 ± 0.07	3.72 (December)	0
Well OS-5 (Seasonal)	Alpha	3	6.76 ± 2.72	10.48 (June)	100
	Beta	3	3.69 ± 0.52	4.23 (December)	0
Well OS-8 (Seasonal)	Alpha	3	2.04 ± 3.91	6.05 (December)	100
	Beta	3	2.77 ± 0.46	3.26 (June)	0

Table 9. SSFL Site Retention Pond, Site Runoff, and Well Water Radioactivity Data - 1986
(Sheet 4 of 4)

Area	Activity	Number of Samples	Gross Radioactivity Concentration ($\times 10^{-9}$ µCi/ml) Annual Average Value and Dispersion	Maximum Value[a] and Month Observed	Percent of Samples With Activity <MDL[b]
Well OS-10 (Seasonal)	Alpha	3	1.89 ± 0.94	2.80 (December)	100
	Beta	3	0.71 ± 0.46	1.09 (June)	100
Well OS-13 (Seasonal)	Alpha	4	2.06 ± 2.56	4.68 (June)	100
	Beta	4	3.38 ± 0.49	3.77 (June)	0
Well OS-15 (Seasonal)	Alpha	4	19.68 ± 10.31	35.11 (December)	75
	Beta	4	6.54 ± 3.30	12.08 (December)	0
Well OS-16 (Seasonal)	Alpha	4	19.19 ± 5.46	25.98 (December)	25
	Beta	4	5.21 ± 0.67	6.16 (December)	0
Well RS-20 (Seasonal)	Alpha	2	-0.02 ± 0.38	0.36 (September)	100
	Beta	2	1.34 ± 0.44	1.78 (September)	50
Well RS-21 (Seasonal)	Alpha	2	42.54 ± 22.96	65.50 (September)	0
	Beta	2	3.59 ± 1.30	4.89 (September)	0
Well RS-22 (Seasonal)	Alpha	2	2.60 ± 1.94	4.54 (December)	100
	Beta	2	1.46 ± 0.26	1.72 (December)	50

[a]Maximum value observed for single sample.
[b]Minimum detection level: Approximately 0.4 x 10^{-9} µCi/ml alpha; 1.40 x 10^{-9} µCi/ml beta for water: approximately 3.1 µCi/g alpha; 0.42 µCi/g for soil.

Table 10. Ambient Air Radioactivity Data - 1986

Area (monthly)	Activity	Number of Samples	Gross Radioactivity Concentrations--Femtocuries per m^3 (10^{-15} μCi/ml)			
			Annual Average Value and Dispersion	Maximum Value[a] and Month Observed	Percent of Guide[b]	Percent of Samples With Activity <MDL[c]
De Soto on-site (2 locations)	Alpha Beta	687	2.9 ± 3.4 57.5 ± 103	22.0 (05/15) 1236.4 (05/14)	0.10 0.02	79 34
SSFL on-site (5 locations)	Alpha Beta	1755	2.8 ± 3.3 60.4 ± 93.5	37.0 (05/14) 1578.6 (05/12)	4.7 0.20	90 28
SSFL sewage treatment plant	Alpha Beta	336	3.2 ± 3.7 63.8 ± 89.8	33.3 (05/12) 1233.2 (05/12)	5.3 0.20	86 22
SSFL control center	Alpha Beta	324	2.7 ± 2.9 58.7 ± 89.2	27.1 (05/13) 1153.5 (05/13)	4.5 0.20	91 29
All locations	Alpha Beta	3102	2.8 ± 3.3 60.0 ± 15.2	---	---	---

[a]Maximum value observed for single sample.
[b]Guide De Soto site: 3 x 10^{-12} μCi/ml alpha, 3 x 10^{-10} μCi/ml beta; 10 CFR 20 Appendix B, CAC 17. SSFL site: 6 x 10^{-14} μCi/ml alpha, 3 x 10^{-11} μCi/ml beta; 10 CFR 20 Appendix B, CAC 17, DOE Order 5480.1A.
[c]MDL = 6.4 x 10^{-15} μCi/ml alpha; 1.3 x 10^{-14} μCi/ml beta.

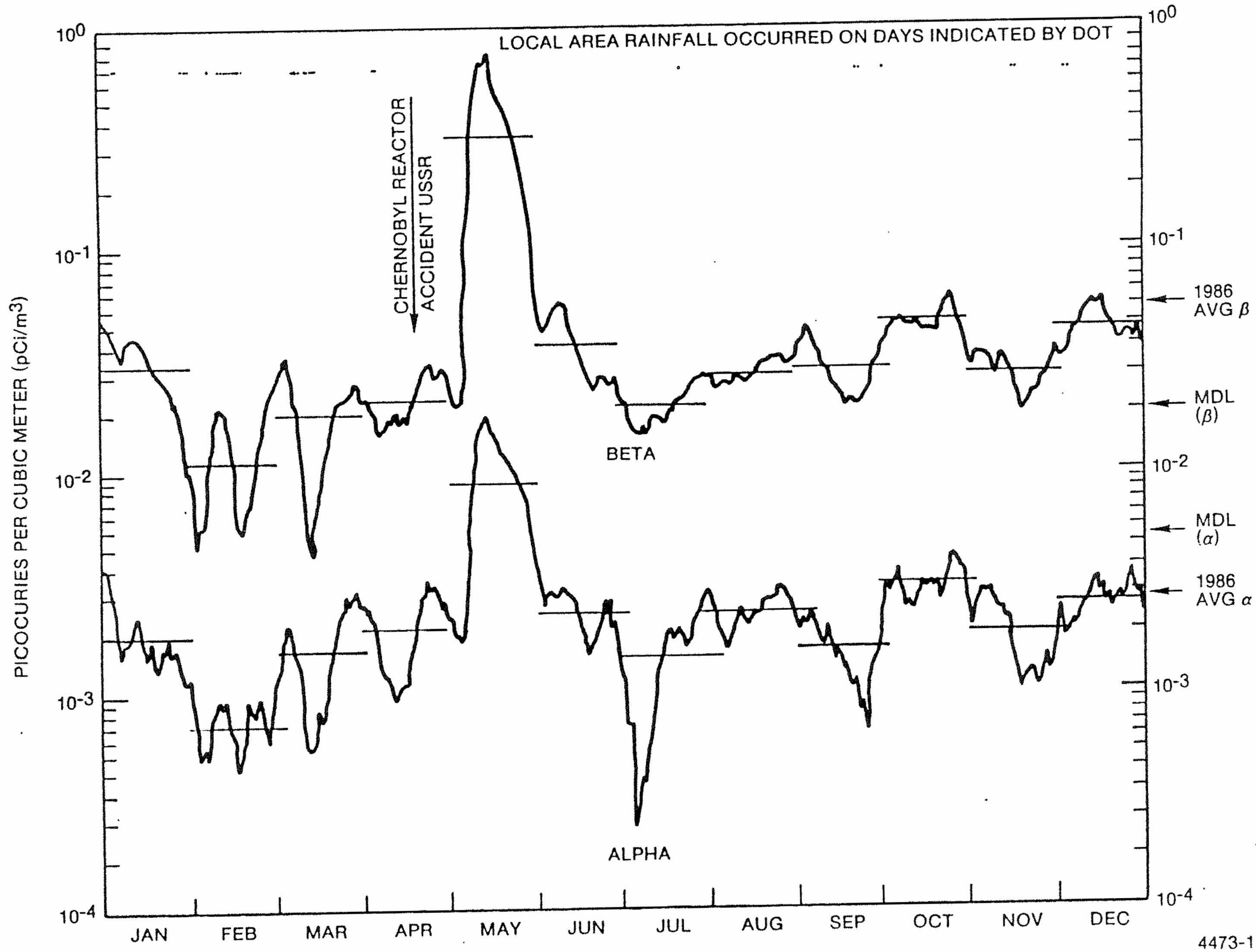

Figure 3. Average Long-Lived Airborne Radioactivity at the De Soto and Santa Susana Field Laboratories Sites - 1986

Table 11. De Soto and SSFL Sites - Ambient Radiation Dosimetry Data - 1986

TLD Location		Quarterly Exposure (mrem)				Annual Exposure (mrem)	Equivalent Exposure at 1000 ft ASL	
		Q-1	Q-2	Q-3	Q-4		(mrem)	(μrem/h)
De Soto	DS-1	21	29	28	26	104	106	12
	DS-2	19	25	25	b	92	94	11
	DS-3	19	28	26	27	100	102	12
	DS-4	25	30	29	29	113	115	13
	DS-5	20	25	26	b	95	97	11
	DS-6	21	27	27	28	103	105	12
	DS-7	19	23	24	25	91	93	11
	DS-8	18	23	26	26	93	95	11
Mean value		20	26	26	27	99	101	12
SSFL	SS-1	22	29	32	24	107	95	11
	SS-2	20	31	35	31	117	105	12
	SS-3	25	30	34	29	118	106	12
	SS-4	24	32	36	33	125	112	13
	SS-5	22	29	34	29	114	101	12
	SS-6	23	32	36	31	122	111	13
	SS-7	22	29	33	33	117	105	12
	SS-8	25	33	38	28	124	112	13
	SS-9	28	37	46	32	143	131	15
	SS-10	23	30	34	25	112	101	12
Mean value		23	31	36	30	120	108	13
Off-site	OS-1	23	30	31	32	116	118	14
	OS-2	20	25	25	b	93	91	10
	OS-3	20	25	25	26	96	98	11
	OS-4	21	29	30	b	107	105	12
	OS-5	22	30	31	32	115	116	13
Mean value		21	28	28	30	105	106	12

[a]Missing dosimeter; annual exposure estimated from data for three quarters.
[b]No data.

V. UNUSUAL EVENTS

There were several unusual events at facilities involving radiation or radioactive materials. These events are summarized below.

A. REPORTABLE INCIDENTS

On April 24 it was determined, as a result of a review of our radioactive materials inventory, that a Giannini Controls thickness gauge containing a 25-mCi americium-241 source was missing. This loss had actually been identified earlier, but no report had been filed with the State. The State was informed on April 28. Further investigation showed leak test records from January 1968 through January 1977. No later records could be found. The source is presumed to be lost.

On August 7, notification was received that a personally assigned TLD had shown 4950 mrem for the second calendar quarter, exceeding the allowable limit of 1250 mrem. This TLD was assigned to an X-ray machine operator who generally read film and only occasionally performed any machine radiography during the quarter. She stated that she always wore the TLD and a direct-reading pocket dosimeter during that work and read and recorded the dosimeter exposure results. Investigation showed that her dosimeter log sheet had been removed from the book and could not be found. Based upon employee interviews, it was judged that the TLD exposure was a deliberate act by an unknown person, performed to create trouble. The State accepted this judgment and approved expungement of this exposure and substitution of the average exposure of 20 mR for all the machine operators. Tighter control of the TLDs was instituted to prevent this from recurring.

On April 14, it was determined that a 1.57 mCi Sr-90 source, assigned to the RIHL, was missing. Investigation showed that it was probably disposed of in a container of radioactive waste generated during cleanup of the hot storage room. This was reported to the State.

B. NONREPORTABLE INCIDENTS

The Radiation and Nuclear Safety group provides radiological monitoring and safety guidance for operations with radioactive material (including Special Nuclear Material) and radiation-producing devices. As part of this function, "Radiological Safety Incident Reports" are written and distributed. The purpose of these reports is to record incidents that were not significant enough to require formal reporting to any regulatory agency (AEC, NRC, ERDA, DOE, State of California), assure communication among the R&NS personnel, and enhance hazard awareness within the operations groups. Reporting of this sort has been done throughout the operations of Atomics International and Energy Systems Group (California) and is continuing as part of the Rocketdyne safety program.

To promote the purpose of these reports, the reporting criteria have been deliberately left vague and general. Generally, a report is written for any injury occurring in a radioactively contaminated area, abnormal release of contamination, fire involving radioactive material, or exposure of personnel to radiation or abnormal radioactive contamination. These criteria are well below the regulatory agency reporting requirements. Judgment is required in determining when to write a report, and the goal has been both to inform workers and management and to record those events that might be questioned in the future but because of lack of consequence would not be otherwise recorded.

The reports are distributed to all members of Radiation and Nuclear Safety and generally to the individuals personally involved, their managers, and any related management. Each incident is reviewed at the time of reporting, and case-by-case corrective actions are implemented as appropriate.

1. February 4, 1986 — The breathing air supply compressor at RIHL shut down due to an electrical failure. A worker in an airline respirator in Cell 4 was instructed to exit. A survey and nasal smears showed no contamination. Urinalysis showed "less than detectable" for FP3A and "zero" for FP3B.

2.	February 12, 1986	A sharp piece of contaminated metal (in Cell 2, RIHL) cut through two plastic and one canvas shoe covers when stepped on. Shoe was contaminated and was confiscated. Employee was reimbursed.
3	February 20, 1986	While gamma radiography was being performed on the H2 heater at SCTI, a barrier was removed by other workers and the exclusion area was entered by three workers. Exposures to the three workers were less than 1 mrem.
4.	March 7, 1986	A licensed device, the Kevex X-site 9000, was taken to an unlicensed location in a private auto. Corrective action: A license amendment was requested to permit use of this device at off-site locations. ROP M-503 was revised to clearly prohibit transport of radioactive materials in personal autos.
5.	March 4, 1986	A worker splashed potentially contaminated wash solution into his left eye. He was wearing safety glasses and no detectable activity was found. He was sent to Medical to have his eye flushed.
6.	June 5, 1986	During washdown of the west high bay at T009, a smoke detector became flooded with water. This water spilled on the hands of an electrician, resulting in contamination from the Am-241 source in the detector. His hands were decontaminated. Corrective action: An authorization was established to monitor the routine preventive maintenance of the large number (approximately 300) of smoke detectors at RD that contain Am-241. Those containing Ra-226 were disposed of as radioactive waste.
7.	June 11, 1986	A direct-reading pocket dosimeter (200 mR range) was off scale during unloading of a Fermi fuel element at the RMDF. The worker was restricted until his film badge reading was determined. This was 20 mrem, indicating an accidental discharge or malfunction of the dosimeter.
8.	June 13, 1986	A worker contaminated his right hand while attaching a clean fixture to a contaminated cask. His hand was decontaminated.

9. June 25, 1986 — After work decontaminating the NAC/NLI cask, an extremely high activity (150,000 cpm with pancake GM) speck was detected on a worker's shoe. Attempts to decontaminate the shoe were unsuccessful and it was confiscated. The worker was reimbursed. This was our first encounter with "hot particles" from commercial power reactors.

10. July 14, 1986 — A worker was exposed to estimated airborne concentration of radioactively exceeding the maximum permissible concentration while surveying inside the SEFOR glove box in the RIHL. This resulted in an estimated exposure of about 8 MPC-hours. All bioassay results were below the minimum detection level. The expected airborne concentration had been 0.3 MPC (adjusted for respirator protection factor).

11. August 15, 1986 — A sink drain line being cut by a plumber in DS104 had mercury in it and was also contaminated. The area was cleaned and the contaminated material was disposed as radioactive waste.

12. August 29, 1986 — A small amount of water overflowed from the RMDF transfer tank when it was being filled with water from the NaK bubbler cleanout at NMDF. Due to the circumstances of the filling, no significant contamination was in the water.

13. September 15, 1986 — While bagging out radioactive material from Decon Room 1 at the RIHL, a worker contaminated his pants. The pants could not be decontaminated and were confiscated. The worker was reimbursed.

14. October 28, 1986 — Zirconium saw chips from the Fermi fuel disassembly work in Cell 4 at the RIHL ignited. The fire was immediately put out by inerting the cell atmosphere with nitrogen. Since the saw chips are too large to be pyrophoric, it is assumed that the saw struck some of the uranium fuel and the sparks ignited the zirconium.

    Corrective action: During saw cutting, the cutting area and the saw chips will be kept wet with a water drip system. Special limits were imposed for criticality control.

15. December 22, 1986 — Contaminated water sprayed from the lid cavity of a fuel shipping cask as the lid was removed at the RMDF. The worker involved was successfully decontaminated.

16. December 22, 1986 While transferring a fuel element from the shipping cask involved in the incident noted above, contaminated water dripped from the transfer cask. The worker involved was successfully decontaminated.

17. December 22, 1986 Following the above two incidents, a worker contaminated his pants and shoes. Walking away from the cask, he contaminated the nearby floor.

The last three incidents, and two related ones occurring early in 1987, were reviewed in detail by an ad hoc committee. The 17 incidents are categorized as:

Personal contamination (9 incidents)

2, 5, 6, 8, 9, 13, 15, 16, 17

Release of contamination (6 incidents)

6, 9, 11, 12, 15, 16

Respiratory protection (2 incidents)

1, 10

Loss of control of source/radiation area (2 incidents)

3, 4

Fire (1 incident)

14

Potential exposure (1 incident)

7

Some incidents are categorized twice (6, 9, 15, 16). As in the previous annual review, the most prevalent reported incidents are those involving personal contamination. In most of these cases, the protective clothing was appropriate for the normally encountered conditions of the job. Therefore, no changes in the protective clothing policies or practices are recommended. None of the other categories suggests any trends or general problems requiring correction.

VI. SUMMARY/TRENDS - EXPOSURE, EFFLUENTS

A. PERSONNEL EXPOSURES

Personnel exposures due to external radiation are summarized by year in the following table:

	Number of Persons in Exposure Range (rem)											
Year	>0 0.1	0.1 0.25	0.25 0.5	0.5 0.75	0.75 1.0	1.0 2.0	2.0 3.0	3.0 4.0	4.0 5.0	Total Exposed Persons	Group Dose (Person rems)	Average Dose (rems)
1986	134	20	11	7	5	3				180	23	0.126
1985	134	10	4	9	12	25				194	58	0.301
1984	178	16	14	5	8	14				235	45	0.192
1983	281	9	5	4	5	13	8	2	17	344	138	0.402
1982	349	29	8	3	6	15	4	7	8	429	116	0.271
1981	192	55	13	4	6	4				274	33	0.121
1980	357	39	10	3	5	9	3			426	56*	0.131*
1979	347	39	19	10	4	15	8	2		444	91*	0.204*
1978	432	60	18	16	4	18	9	1	1	559	110*	0.197*
1977	340	31	29	7	5	11	13			436	91*	0.209*
1976	295	38	17	14	5	9	2			380	59*	0.156*
1975	170	24	12	4	5	6	1	1		223	39*	0.175*

*Determined by use of mid-point of range

Data shown for 1980 and prior years include visitors. Visitor exposures rarely exceed 0.25 rem. Data for 1981 through 1985 represent occupationally exposed Rocketdyne employees excluding certain workers in Rocketdyne operations predating the merger, while 1986 shows all occupational exposures. The group dose was calculated exactly for the last six years. This results in values that are approximately 10% lower than those calculated by use of the mid point of the exposure ranges.

Exposures during 1986 showed a significant reduction in group dose and average dose from prior years. This reflects changes in work load, inclusion of certain groups of workers with typically low exposures, and continuing improvement in the effectiveness of the ALARA program.

Internal dosimetry for the estimation of organ doses or dose commitments that have been received from internally deposited radioactive material has not been generally done. It is complicated and time consuming, and the detected amounts of radioactive material have been so small as to not warrant it.

Internal depositions of radioactive material, as monitored by the bioassay program, are shown in the table below.

Year	Number of Tests Performed	Number of Tests with Positive Results	Percent Positive
1986	663	39	5.9
1985	644	69	10.7
1984	373	48	12.9
1983	527	30	5.7
1982	742	66	8.9
1981	768	66	8.6
1980	864	44	5.1
1979	1099	79	7.2
1978	1022	80	8.7
1977	1272	158	12.4
1976	1481	67	4.5
1975	1483	57	3.8

This table shows, for the past 12 years, all the tests performed and the number of tests that were considered to be "positive." A "positive" result is one that exceeds the minimum detectable activity (MDA) for the particular analysis. During the time covered by this series of reports, the number of bioassays has generally declined as the number of people working with unencapsulated radioactive material has decreased. Tests were increased in 1985 and 1986 to provide more detailed information for the purpose of future dose evaluations. The reduction in percentage of positive results for 1986 appears to be significant compared to 1985. Following tables show the distribution for the two major radionuclides tested during this time period: Cs-173 (FP3B) and Sr-90 (FP3A). While the FP3A analysis is not specifically selective for Sr-90, that is the most restrictive radionuclide likely to be present and detected.

Cs-137

Year	Number of FP3B Tests	Number with Positive Results	Fraction of Positive Results with less than 0.01% MPBB	Maximum % MPBB
1986	255	8	0.250	0.02
1985	256	49	0.082	0.03
1984	136	30	0.656	0.72
1983	76	6	0.833	0.02
1982	171	4	0.667	0.03
1981	141	3	0	0.02
1980	116	4	0	0.04
1979	233	27	0	1.2
1978	271	22	Incomplete data	
1977	298	43	Incomplete data	
1976	171	6	0	0.02
1975	190	1	1.0	0.01

Sr-90

Year	Number of FP3A Tests	Number with Positive Results	Fraction of Positive Results with less than 10% MPBB	Maximum % MPBB
1986	255	25	0.720	20.8
1985	256	19	0.842	14.5
1984	136	15	0.800	45.0
1983	74	0	None	
1982	174	32	0.407	59.8
1981	141	31	0.485	61.9
1980	116	7	0.286	58.8
1979	233	14	Incomplete data	
1978	271	45	Incomplete data	
1977	298	62	Incomplete data	
1976	169	10	0	21.7
1975	194	4	0.333	14.4

B. WORK PLACE RADIATION AND RADIOACTIVITY

The general radiation levels in the work place, as determined by readings from location badges averaged over the calendar year, are summarized in the table below:

Year	Facility Average Exposure Rate (mR/h) / Maximum Exposure Rate (mR/h) GIF	RIHL	ANR	RMDF
1986	0.08 / 0.22	0.06 / 0.57	0.23 / 1.06	2.92 / 11.3
1985	0.16 / 0.23	0.13 / 0.87	0.97 / 4.00	2.74 / 29.42
1984	0.49 / 0.80	0.13 / 1.15		1.72 / 7.06
1983	0.001 / 0.004	0.47 / 6.42		0.82 / 4.15
1982	0.02 / 0.06	0.10 / 0.21		4.24 / 42.4

Variations reflect changes in workload, with a significant problem at the RMDF in 1985 having been reduced in 1986, due to processing of radioactive water and the accumulation of the resultant sludge.

Airborne radioactivity, in terms of the average percentage of the maximum permissible (occupational) concentration (MPC) is shown for monitored areas below:

	Percent of MPC	
Year	RIHL	RMDF
1986	0.2	6.3
1985	0.5	4.4
1984	0.5	-
1983	0.5	-
1982	0.06	-
1981	0.05	-
1980	0.20	-

C. ATMOSPHERIC EFFLUENT RELEASES

Atmospheric effluent releases are monitored by use of stack samplers at the major facilities. The results are shown below in terms of the total activity released. In some cases, the releases were at concentrations less than the ambient (natural) airborne radioactivity; in others, much of the activity is from natural sources, resulting from the use of unfiltered bypass air in the exhaust system.

A significant change has been made in the manner in which those releases are calculated from the effluent sampling measurements. Prior to 1982, all concentration values less than the minimum detection level (MDL) were set equal to the MDL in calculating the average concentration release. This was done on the basis of DOE requirements. It was recognized that this practice biased the reported results upwards by a considerable amount, and DOE changed its guidance. Now, all measured values, even zeroes and negative ("less than background") values, are used in the calculation.

The major fluctuation observed in the beta activity released from the RIHL is due primarily to changes in the work in the hot cells. The increase in beta activity released from the RIHL this year is mainly due to work being performed on the ventilation exhaust system. With these exceptions, a major fraction of the activity reported as discharged from the RIHL and the NMDF actually came from natural radioactivity in the unfiltered bypass air taken into the exhaust systems near the blowers to prevent excessive suction.

RADIOACTIVITY DISCHARGED TO ATMOSPHERE

(microcuries)
(Sheet 1 of 2)

	De Soto		Santa Susana		
	101	104	RIHL	RMDF	NMDF
1986					
Alpha	-	0.08	0.13	0.05	0.04
Beta	-	0.78	22.0	13.0	4.0
1985					
Alpha	-	0.15	0.45	0.04	0.05
Beta	-	0.45	9.0	9.0	1.5
1984					
Alpha	-	0.44	0.10	0.074	0.04
Beta	-	0.59	4.5	3.7	0.98
1983					
Alpha	52.0	1.1	0.024	0.047	0.08
Beta	19.0	1.1	1.3	1.1	1.1
1982					
Alpha	1.2	0.24	0.03	0.024	0.023
Beta	0.94	1.1	14.0	0.61	1.0
1981					
Alpha	2.8	0.39	0.069	0.087	0.059
Beta	2.7	4.1	14.0	4.0	2.0
1980					
Alpha	5.3	1.0	0.17	0.061	0.082
Beta	4.3	4.9	17.0	1.7	1.1
1979					
Alpha	2.1	1.1	0.18	0.085	0.053
Beta	5.8	5.7	44.0	2.7	0.21
1978					
Alpha	16.0	0.65	0.13	0.1	0.081
Beta	5.0	4.3	59.0	11.0	-
1977					
Alpha	10.0	0.88	0.1	0.11	0.15
Beta	4.1	7.5	13.0	3.0	-

RADIOACTIVITY DISCHARGED TO ATMOSPHERE

(microcuries)
(Sheet 2 of 2)

	De Soto		Santa Susana		
	101	104	RIHL	RMDF	NMDF
1976					
Alpha	64.0	8.1	0.15	0.23	0.15
Beta	17.0	8.9	5.8	1.1	-
1975					
Alpha	3.7	5.4	0.15	0.45	0.19
Beta	2.6	12.0	6700.0*	10.0	-

*Released from burned fuel slug.

5046Y/jbv

D. AMBIENT (ENVIRONMENTAL) RADIATION EXPOSURE

Ambient (environmental) radiation exposure rates as measured by CaF_2:Mn TLDs and averaged for all locations are shown below.

	Quarterly Dose (mrem)				Annual Dose (mrem)
	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	
1986	21.8	28.7	30.9	28.7	110.1
1985	21.8	32.2	26.6	29.0	109.6
1984	29.9	30.1	25.6	19.6	105.2
1983	30.1	28.9	30.2	27.4	116.6
1982	29.1	30.8	31.8	31.9	123.8
1981	38.2	33.5	35.2	43.9	150.8
1980	35.0	34.4	37.7	49.1	157.3
1979	32.1	38.1	38.0	39.4	147.8
1978	27.3	35.5	33.4	36.6	133.1
1977	24.2	29.2	32.9	30.9	117.5
1976	21.6	24.8	22.5	25.0	93.9
1975	21.3	24.6	26.2	25.4	97.6

The quarterly doses are plotted as a histogram in Figure 4. This graph, and the tabulated annual doses, show a clear increase from 1976 to 1980, followed by a decrease for 1981, 1982, 1983, and 1984. The data for 1985 and 1986 suggest a leveling off of this decline. All data prior to 1982 were obtained using an EG&G TL-3 reader. Data for 1982 and later were obtained using a Victoreen Model 2810. This is a new reader, built on the basic design of the TL-3 reader, but with modern electronics and digital adjustments and readout.

The increasing trend (from 1976 to 1980) was also observed in data for the Rocky Flats Plant, the only other DOE facility where the same type

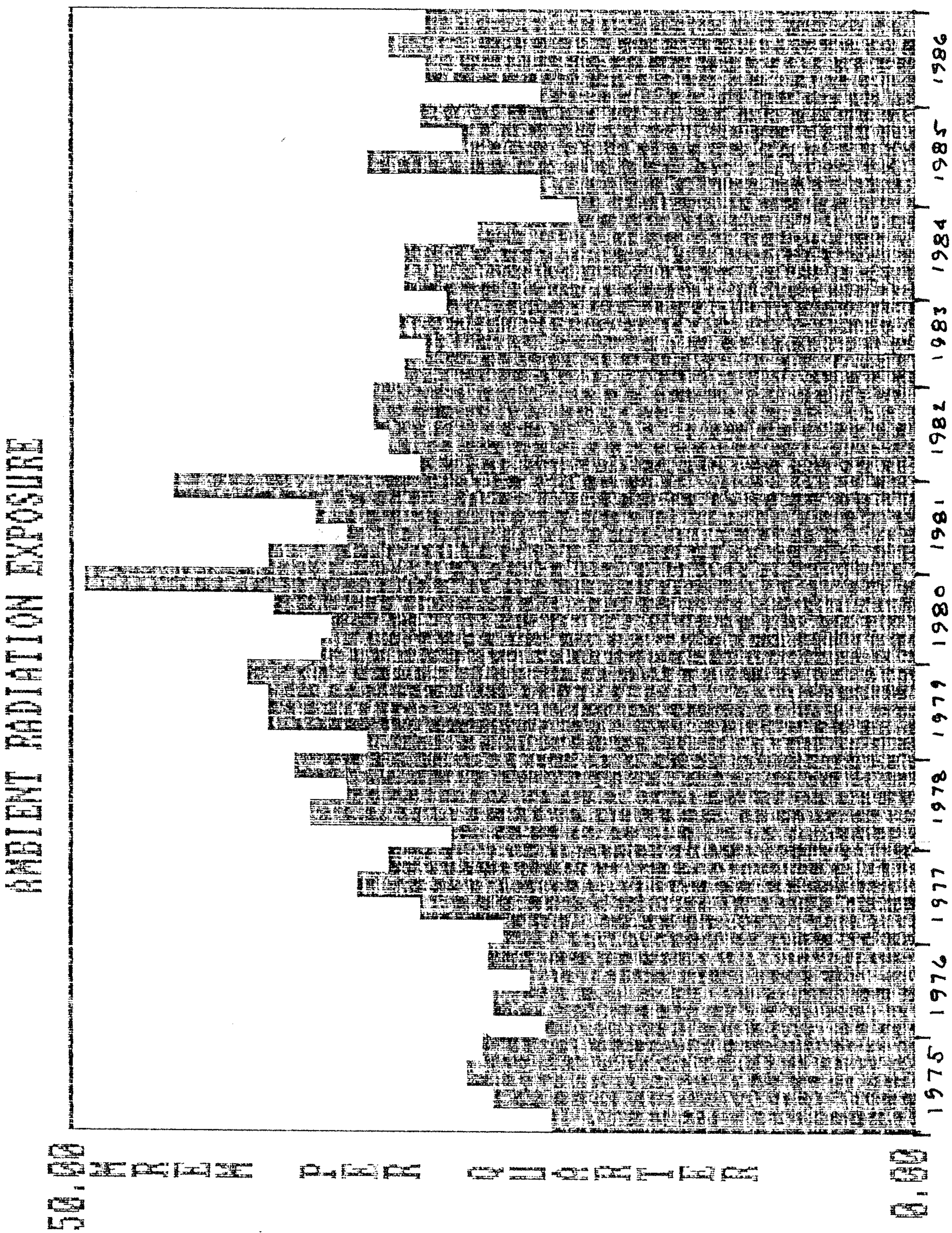

Figure 4. Averaged Quarterly Dose Recorded by Environmental TLDs

dosimeters are used, but not at any other facility. The cause has not been identified, but since the trend exists equally for the De Soto, Santa Susana, and off-site TLDs, at this time it is assumed to be either a true environmental effect, or an artifact of the TLD reading or calibration.

The annual ambient exposure rates (mrem/year) measured at De Soto, SSFL, and the several offsite locations are shown below:

	De Soto		SSFL		Offsite	
Year	Average	Maximum	Average	Maximum	Average	Maximum
1986	99	113	120	143	105	116
1985	100	107	124	152	105	112
1984	98	106	117	126	100	108
1983	110	123	126	136	115	123
1982	118	135	132	144	124	128
1981	144	159	162	188	148	162
1980	164	193	166	184	163	166
1979	138	149	161	193	131	140
1978	128	140	143	149	126	131
1977	116	125	121	138	106	108
1976	89	99	101	124	91	101
1975	96	105	104	123	94	105

Comparison of the average values and the maximum location values for the three types of sites shows the same increase from 1976 to 1980 and then a decrease to 1984. The cause of this behavior is under continuing study with no definite conclusions produced as yet. The values at SSFL are all somewhat greater than De Soto and the offsite locations due to the significantly greater elevation of the SSFL site, and possibly also due to the greater outcropping of uranium-mineral-bearing sandstone. There is no indication of significant exposure resulting from operations with radioactive material.

Average and maximum values for soil readioactivity are shown in Table 12. This table shows the change in reported alpha activity resulting from adoption of a calibration factor for thick soil samples. Prior to 1984, only relative values were reported, which served the function of monitoring for changes quite well but produced values that did not reflect the correlation of alpha and beta activity from naturally present radioactive elements (potassium, 0 alphas, 1 beta per decay; uranium chain, 8 alphas, 6 betas; thorium chain, 6 alphas, 4 betas).

Four high values of soil beta activity have been detected onsite (out of 1440 samples): those are shown as maximum values for the years 1978-1981. The maximum values for 1979 and 1980 were along the southwest side of the RMDF and may have resulted from a cleanup of the so-called "West Bank" near the RMDF just prior to these years. The 1978 and 1981 values were from samples taken near the SS Vault (T064). Follow-up surveys failed to locate additional, significant contamination. (It should be noted that only the 1980 value exceeds the working limit of 100 pCi/g gross detectable beta activity adopted for our decontamination work.)

Results for the semiannual plutonium soil analyses are shown in Tables 13 and 14. The onsite averages are generally higher than offsite but not greatly so. This may represent differences between the set of five onsite locations and the single offsite location. While plutonium is found in low concentrations everywhere as a result of atmospheric nuclear weapons tests at several different locations around the world, the concentration at a given location is affected by meteorological conditions following the test explosion and after deposition. Comparison of the onsite values shows no systematic variation with location relative to the NMDF.

After review of the results of vegetation sampling conducted over the prior 28 years, it was determined that this sample class did not provide significantly useful data. Fallout is more accurately assessed by measurement of airborne radioactivity and soil radioactivity. Therefore, the vegetation sampling was discontinued.

Table 12. Soil Radioactivity Summary
1975–1986
(pCi/g)

		Onsite				Offsite			
		Alpha		Beta		Alpha		Beta	
	Year	Average ± Dispersion	Maximum Value	Average ± Dispersion	Maximum Value	Average ± Dispersion	Maximum Value	Average ± Dispersion	Maximum Value
	1986	26.7 ± 6.6	40.1	26.1 ± 2.2	32.2	28.1 ± 5.9	39.0	24.2 ± 1.3	30.4
	1985	25.2 ± 7.3	48.4	24.2 ± 1.9	32.7	26.3 ± 7.8	46.0	23.9 ± 3.3	30.2
	1984	25.8 ± 6.0	43.4	24.2 ± 2.0	30.1	26.2 ± 7.2	51.3	23.3 ± 2.9	28.2
a	1983	0.6 ± 0.2	1.1	24.2 ± 2.0	29.7	0.6 ± 0.2	1.1	23.0 ± 2.8	27.8
	1982	0.7 ± 0.2	1.2	24.6 ± 2.3	30.1	0.7 ± 0.2	1.2	23.3 ± 3.7	32.9
	1981	0.7 ± 0.2	1.3	25.4 ± 3.5	38.2	0.6 ± 0.2	1.3	22.8 ± 4.5	33.2
b	1980	0.6 ± 0.2	1.1	24.0 ± 1.0	110.0	0.6 ± 0.2	1.0	23.0 ± 1.0	30.0
	1979	0.6 ± 0.2	1.1	25.0 ± 1.0	97.0	0.5 ± 0.1	0.8	23.0 ± 1.0	29.0
	1978	0.6 ± 0.2	1.0	24.0 ± 0.9	48.0	0.5 ± 0.1	1.0	24.0 ± 0.9	34.0
	1977	0.6 ± 0.2	1.1	24.0 ± 0.9	31.0	0.5 ± 0.2	0.8	23.0 ± 0.8	27.0
	1976	0.6 ± 0.2	0.8	25.0 ± 1.0	32.0	0.6 ± 0.2	1.0	24.0 ± 1.0	30.0
	1975	0.6 ± 0.1	1.0	25.0 ± 1.0	35.0	0.6 ± 0.2	1.0	24.0 ± 1.0	27.0

[a]Values reported for alpha activity in soil before 1984 are relative values only. The 1984 values reflect correction for self absorption of alpha particles by the thick soil samples.

[b]Prior to 1981, data less than the MDL were treated as equal to the MDL. For 1981 and later, actual measured values were used.

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Table 13. Plutonium in Soil Summary
1978-1986
(Pu-239 + Pu-240, fCi/g)

	Onsite		Offsite
Year	Average ± Dispersion	Maximum Value	Average ± Dispersion
1986	1.8 ± 1.3	3.8	1.2 ± 1.0
1985	2.6 ± 1.5	5.1	0.4 ± 0.2
1984	3.1 ± 1.3	5.2	0.4 ± 0.2
1983	5.2 ± 4.4	14.4	7.0 ± 0.2
1982	4.0 ± 2.4	7.3	2.7 ± 3.3
1982	4.2 ± 4.5	15.9	1.2 ± 1.0
1980	8.4 ± 8.5	29.5	1.3 ± 0.9
1979	7.0 ± 6.7	18.9	2.6 ± 1.3
1978	4.5 ± 2.9	9.0	4.4 ± 1.6
Grand Average	4.5 ± 4.7		2.4 ± 2.8

Table 14. Summary of Plutonium in Soil
(Pu-239 + Pu-240, fCi/g)

	Location	Average ± Dispersion	Maximum Value	Date
S-56	1100 ft NW NMDF	4.1 ± 4.5	14.4	December 1983
S-57	900 ft SE NMDF	3.6 ± 2.3	9.5	June 1980
S-58	500 ft SE NMDF	5.2 ± 4.4	18.9	December 1979
S-59	900 ft ESE NMDF	4.6 ± 4.1	18.6	December 1979
S-60	2000 ft SE NMDF	5.2 ± 7.0	29.5	December 1980
S-61	2.7 mi. NE NMDF	2.4 ± 2.8	7.1	June 1983

5046Y/sjh

Alpha and beta radioactivity in the supply water at the De Soto and SSFL sites are shown in Table 15. Water for the De Soto site is supplied by the Los Angeles Department of Water and Power from the Metropolitan Water District. Water for the SSFL site is supplied by Ventura County Water District No. 17, with varying amounts of supplemental water (up to 100%) from onsite wells operated by Rocketdyne. The water at De Soto is consistently, but not significantly, more radioactive than that at SSFL.

A change in the method of correcting for alpha attenuation in the mineral deposit from the water samples permits more accurate reporting of the alpha activity since 1983.

Alpha and beta radioactivity in environmental waters is shown in Tables 16A and 16B. The radioactivity concentrations in all three water sources sampled are quite similar. (Pond R-2A receives runoff and effluent from the Santa Susana nuclear facilities, while Pond 6 receives runoff and effluent from the other facilities. The Bell Creek sample, from the location sampled prior to 1986, appears to be mostly seepage from the Bell Canyon community. After 1985, water was automatically sampled at the head of Bell Creek.) The results for the pond water are very nearly the same as the supply water for 1986. No radionuclides present at the nuclear facilities have been found.

Tables 17A and 17B show the results of alpha and beta radioactivity measurements on ambient air samples. An apparent extreme decrease in alpha radioactivity after 1981 is due simply to a change in the method of treating the very low-level values. Until the end of 1981, each value that was less than the MDL for a single measurement was set equal to the MDL before inclusion in the average. This artificially elevated the average value. This effect was not nearly so great for the beta activity measurements. The beta values for De Soto, SSFL, and offsite samples are essentially identical. (The "offsite" samples are located at SSFL but at a considerable distance from the nuclear facilities.)

Table 15. Supply Water Radioactivity Summary
1975-1986
(pCi/L)

		De Soto				SSFL			
		Alpha		Beta		Alpha		Beta	
	Year	Average ± Dispersion	Maximum Value	Average ± Dispersion	Maximum Value	Average ± Dispersion	Maximum Value	Average ± Dispersion	Maximum Value
	1986	4.41 ± 2.53	8.70	3.75 ± 0.62	4.69	6.55 ± 9.09	45.77	3.58 ± 0.95	6.75
	1985	2.76 ± 1.82	5.73	3.17 ± 0.78	4.6	2.45 ± 2.61	8.6	2.80 ± 0.52	3.95
	1984	3.82 ± 0.93	5.87	3.40 ± 0.45	4.3	3.53 ± 3.94	13.3	2.93 ± 0.60	4.01
a	1983	0.34 ± 0.23	0.88	3.53 ± 0.97	5.1	0.12 ± 0.13	0.41	3.00 ± 0.60	4.45
	1982	0.36 ± 0.23	0.79	3.97 ± 1.19	6.6	0.14 ± 0.12	0.38	3.01 ± 0.67	4.91
	1981	0.36 ± 0.20	0.77	3.78 ± 0.68	4.7	0.11 ± 0.12	0.44	2.79 ± 0.55	3.65
b	1980	not analyzed				0.22 ± 0.27	0.22	2.4 ± 0.7	3.4
	1979	not analyzed				0.23 ± 0.27	0.23	1.8 ± 0.7	3.9
	1978	not analyzed				0.26 ± 0.28	0.44	3.0 ± 0.8	3.6
	1977	not analyzed				0.25 ± 0.29	0.30	2.5 ± 0.7	3.6
	1976	not analyzed				0.25 ± 0.29	0.42	2.0 ± 0.7	2.5
	1975	not analyzed				0.24 ± 0.27	0.55	2.3 ± 0.7	3.2

[a]Values reported for alpha activity in water before 1984 are relative values only. Subsequent values reflect correction for self absorption of alpha particles by the thick mineral deposit of the counting sample.

[b]Prior to 1981, data less than the MDL were treated equal to the MDL. For 1981 and later, actual measured values were used.

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Table 16A. Environmental Water Radioactivity Summary
1975-1986
(Alpha, pCi/L)

		Pond R-2A		Pond 6		Bell Creek	
	Year	Average ± Dispersion	Maximum Value	Average ± Dispersion	Maximum Value	Average ± Dispersion	Maximum Value
c	1986	4.18 ± 2.70	8.70	2.51 ± 2.88	9.51	2.02 ± 2.08	5.90
	1985	3.07 ± 1.94	6.61	1.06 ± 4.44	13.6	1.38 ± 7.09	19.7
	1984	0.15 ± 1.70	2.70	4.90 ± 9.11	25.9	4.15 ± 8.30	28.7
a	1983	0.13 ± 0.12	0.35	0.12 ± 0.11	0.27	0.08 ± 0.12	0.39
	1982	0.11 ± 0.13	0.28	0.17 ± 0.08	0.35	0.03 ± 0.06	0.14
	1981	0.07 ± 0.15	0.37	0.05 ± 0.08	0.17	0.05 ± 0.06	0.20
b	1980	0.23 ± 0.27	0.23	0.23 ± 0.27	0.23	0.23 ± 0.27	0.23
	1979	0.23 ± 0.27	0.25	0.25 ± 0.28	0.55	0.23 ± 0.27	0.24
	1978	0.25 ± 0.28	0.27	0.25 ± 0.28	0.35	0.24 ± 0.28	0.24
	1977	0.25 ± 0.29	0.28	0.24 ± 0.29	0.25	0.24 ± 0.29	0.24
	1976	0.28 ± 0.30	0.53	0.24 ± 0.29	0.24	0.25 ± 0.29	0.28
	1975	0.31 ± 0.29	1.2	0.24 ± 0.27	0.55	0.22 ± 0.27	0.28

[a]Values reported for alpha activity in water before 1984 are relative values only. Subsequent values reflect correction for self absorption of alpha activity by the thick mineral deposit of the counting sample.

[b]Prior to 1981, data less than the MDL were treated as equal to the MDL. For 1981 and later, actual measured values are used.

[c]Prior to 1986, Bell Creek was sampled at the eastern boundary of the residential community of Bell Canyon. In 1986, an automatic water sampler was installed that collects water only when water is present in the upper part of Bell Creek, immediately downstream from the discharge of Pond R-2A.

5046Y/rmr

Table 16B. Environmental Water Radioactivity Summary
1975-1986
(Beta, pCi/L)

	Year	Pond R-2A Average ± Dispersion	Pond R-2A Maximum Value	Pond 6 Average ± Dispersion	Pond 6 Maximum Value	Bell Creek Average ± Dispersion	Bell Creek Maximum Value
b	1986	3.58 ± 1.14	8.93	2.92 ± 0.94	4.57	2.60 ± 0.52	3.66
	1985	3.49 ± 0.79	5.56	3.58 ± 0.96	4.92	2.49 ± 0.75	3.79
	1984	4.25 ± 0.85	5.87	4.58 ± 0.75	5.66	2.88 ± 0.58	4.60
	1983	4.44 ± 1.84	9.15	3.57 ± 0.92	4.80	3.30 ± 0.60	4.20
	1982	3.93 ± 0.83	5.81	3.91 ± 1.08	5.34	3.29 ± 0.70	4.40
	1981	5.16 ± 1.22	8.30	4.25 ± 0.63	5.26	3.78 ± 0.65	5.00
a	1980	3.9 ± 0.8	5.70	2.9 ± 0.7	4.7	2.9 ± 0.8	5.2
	1979	4.5 ± 0.8	10.0	3.1 ± 0.8	4.7	3.2 ± 0.9	8.2
	1978	4.6 ± 0.8	6.3	4.3 ± 0.8	7.0	2.5 ± 0.8	3.5
	1977	5.2 ± 0.9	13.0	4.3 ± 0.8	6.4	1.8 ± 0.8	2.6
	1976	4.4 ± 0.8	7.0	4.3 ± 0.8	5.5	2.2 ± 0.8	2.9
	1975	4.5 ± 0.8	5.4	4.2 ± 0.8	5.5	2.4 ± 0.8	3.4

[a]Prior to 1981, data less than the MDL were treated as equal to the MDL. For 1981 and later, actual measured values are used.

[b]Prior to 1986, Bell Creek was sampled at the eastern boundary of the residential community of Bell Canyon. In 1986, an automatic water sampler was installed that collects water only when water is present in the upper part of Bell Creek, immediately downstream from the discharge of Pond R-2A.

5046Y/rmr

Table 17A. Ambient Air Radioactivity Summary
1975-1986
(Alpha, fCi/m^3)

	De Soto		SSFL		Offsite	
Year	Average ± Dispersion	Maximum Value	Average ± Dispersion	Maximum Value	Average ± Dispersion	Maximum Value
1986	2.9 ± 3.4	22	2.8 ± 3.3	37	2.9 ± 3.3	33
1985	2.7 ± 2.2	38	2.0 ± 1.6	44	2.0 ± 1.9	25
1984	1.9 ± 9.3	32	1.4 ± 3.4	29	1.4 ± 3.0	16
1983	2.4 ± 3.8	60	0.9 ± 5.4	24	1.2 ± 2.9	11
1982	1.7 ± 3.1	39	1.1 ± 2.6	30	1.7 ± 2.9	16
[a] 1981	6.9 ± 7.7	25	6.8 ± 7.9	35	6.8 ± 7.2	22
1980	6.5 ± 7.7	45	6.4 ± 7.8	25	6.3 ± 7.8	20
1979	6.6 ± 7.8	45	6.5 ± 7.6	40	6.2 ± 7.9	34
1978	8.4 ± 8.1	95	7.2 ± 7.9	21	7.2 ± 7.3	44
1977	6.6 ± 7.7	39	6.6 ± 7.5	35		
1976	6.7 ± 8.4	140	6.5 ± 7.2	53		
1975	6.3 ± 6.8	60	6.0 ± 6.3	88		

[a]Prior to 1982, data less than the MDL were treated as equal to the MDL. For 1982 and later, actual measured values are used.

5046Y/klp

Table 17B. Ambient Air Radioactivity Summary
1975–1986
(Beta, fCi/m^3)

	De Soto		SSFL		Offsite	
Year	Average ± Dispersion	Maximum Value	Average ± Dispersion	Maximum Value	Average ± Dispersion	Maximum Value
1986	58 ± 103	1236	60 ± 94	1579	60 ± 90	1233
1985	44 ± 14	180	40 ± 13	170	40 ± 14	240
1984	27 ± 27	250	23 ± 14	200	24 ± 20	200
1983	26 ± 21	130	23 ± 17	180	25 ± 12	280
1982	26 ± 14	260	21 ± 16	180	22 ± 12	88
a 1981	120 ± 20	1100	120 ± 20	1100	120 ± 20	1600
1980	39 ± 14	380	36 ± 14	450	34 ± 15	360
1979	21 ± 13	100	21 ± 13	110	19 ± 15	100
1978	91 ± 17	1400	88 ± 17	1500	86 ± 16	1300
1977	170 ± 20	3000	170 ± 20	2800		
1976	96 ± 18	3700	110 ± 20	3400		
1975	76 ± 16	460	73 ± 15	730		

[a]Prior to 1982, data less than the MDL were treated as equal to the MDL. For 1982 and later, actual measured values are used.

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VII. ANTICIPATED ACTIVITIES DURING NEXT REPORTING PERIOD (1987)

Building 104 (GIF and ANR)

Continuation of low-level research with activated materials and operation of the Gamma Irradiation Facility.

Building 020 (RIHL)

Complete Fermi fuel disassembly project. Cleanup cells in preparation for next project.

Buildings 021/022 (RMDF)

Shipment of declad EBR-II fuel and scrap. Receive, store, and transfer Fermi fuel for disassembly. Storage and transfer of disassembled Fermi fuel and scrap.

Building 055 (NMDF)

A confirmatory survey of the decontaminated facility by NRC and subsequent termination of the SNM license and release for unrestricted use are expected.

REFERENCES

1. U.S. Nuclear Regulatory Commission - Special Nuclear Materials License No. SNM-21, USNRC (June 28, 1984)

2. "Annual Review of Radiological Controls - 1975," R. S. Hart, Atomics International, Rockwell International, N001TI990002, July 2, 1979

3. "Annual Review of Radiological Controls - 1976," R. S. Hart, Energy Systems Group, Rockwell International, N001TI990003, April 2, 1980

4. "Annual Review of Radiological Controls - 1977," R. S. Hart, Energy Systems Group, Rockwell International, N001TI990098, May 27, 1980

5. "Annual Review of Radiological Controls - 1978," R. S. Hart, Energy Systems Group, Rockwell International, N001TI990104, August 6, 1980

6. "Annual Review of Radiological Controls - 1979," R. S. Hart, Energy Systems Group, Rockwell International, N001TI990113, September 15, 1980

7. "Annual Review of Radiological Controls - 1980," R. R. Eggleston, Energy Systems Group, Rockwell International, N001TI990144, July 14, 1981

8. "Annual Review of Radiological Controls - 1981," R. R. Eggleston, Energy Systems Group, Rockwell International, N001TI990176, January 21, 1983

9. "Annual Review of Radiological Controls - 1982," R. J. Tuttle, Rocketdyne Division, Rockwell International, N001TI000238, January 29, 1985

10. "Annual Review of Radiological Controls - 1983," R. J. Tuttle, Rocketdyne Division, Rockwell International, N001TI000256, January 27, 1986

11. "Annual Review of Radiological Controls - 1984," R. J. Tuttle, Rocketdyne Division, Rockwell International, N001TI000257, March 30, 1986

12. "Annual Review of Radiological Controls - 1985," R. J. Tuttle, Rocketdyne Division, Rockwell International, N001TI000260, July 4, 1986

13. "Occupational Radiation Exposure (1982 and 1983)," NUREG-0714, Vols. 4 and 5, B. Brooks, S. McDonald, E. Richardson, Division of Radiation Programs and Earth Sciences, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, October 1985

14. "Sixteenth Annual Report - Radiation Exposures for DOE and DOE Contractor Employees - 1983," DOE/PE-0072, October 1984

15. "Rocketdyne Environmental Monitoring and Facility Effluent Annual Report - 1985," J. D. Moore, Rockwell International, Rocketdyne Division, RI/RD86, March 1986

16. "Report of Committee II on Permissible Dose for Internal Radiation (1959)," ICRP Publication 2