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RADIATION MONITORING POLICY AT THE ADVANCED LIGHT SOURCE*

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Radiation Monitoring Policy at The Advanced Light Source*

Rick Donahue, Keith Heinzelman, Georgeanna Perdue

I. Introduction

When the accelerator first began operation it was decided that, until we had the necessary dosimetry data to decide otherwise, we would badge the entire worker and experimental population. Each person was issued a dosimetry badge that contained 4 TLD elements. Badges were processed on a monthly basis.

After three years of analyzing a total of 65,000 TLD elements, the decision was made to modify the radiation monitoring policy at the ALS. Only those individuals in the workforce that have any potential for exposure, no matter how small, would be badged.

Subsequently, DOE conducted an independent review of the ALS radiation monitoring and dosimetry program. This review concluded that the ALS program, if expanded as proposed, would be adequate under the 10 CFR 835 Rule to establish radiation exposures to an acceptable level of confidence. The review team recommended the ALS provide more comprehensive documentation on the basis for its radiation protection and monitoring program. This document describes the technical justification for that program.

II. Description of Facility

The Advanced Light Source (ALS) is a national facility for scientific research and development located at the Lawrence Berkeley National Laboratory of the University of California. Its purpose is to generate beams of very bright light in the far ultraviolet and soft x-ray regions of the spectrum. Within these regions, the ALS produces the world's brightest light available as an experimental tool. This national user facility, funded by the US Department of Energy, is available to qualified researchers from industry, universities, and government laboratories.

The ALS produces light in the form of bright beams of x-rays using a synchrotron storage ring. A hair-thin beam of electrons is generated by an electron gun and accelerated to 50 MeV in a linear accelerator, and then to 1.5 GeV in a booster synchrotron. The electrons are then transferred to the 200-meter storage ring. After the 10-minute filling time, the electrons remain stored for about 4 hours. As they travel around the storage ring, the electrons emit synchrotron radiation–energy in the form of photons–which is directed by specialized optics down 12-meter long beamlines to experiment endstations.

Since the light is produced continuously while the electrons circulate in the ring, many beamlines (presently about 16) can be used simultaneously for different experiments. This bright x-ray light is used for research in materials and surfaces, combustion dynamics, protein crystallography, biological microscopy, and many other fields.

III. Description of Radiation Hazards

There are two different sources of ionizing radiation at the ALS which can pose a hazard if not properly dealt with: bremsstrahlung radiation and synchrotron radiation. Bremsstrahlung radiation consists of high energy photons produced when high energy electrons interact with matter. Synchrotron radiation is produced when an electron beam is deflected by magnets, producing very intense, low energy photon beams.

Both of these direct sources of ionizing radiation, and their scattered radiations as well, can pose unique and distinct radiation hazards and are therefore discussed separately below.

Bremsstrahlung Radiation Hazards

There are two common forms of bremsstrahlung radiation at electron storage rings: thin target (gas) bremsstrahlung, and thick target bremsstrahlung. When a high energy electron interacts in a thick target, one or more bremsstrahlung photons are created. These photons can have energies up to the energy of the incident electron. Low level neutron radiation fields are also generated. On the experimental floor these levels are lower than the bremsstrahlung levels. The two are about equal only on the roof where the shielding is thinner.

In addition to interaction via bremsstrahlung, the incident electron or secondary electrons undergo many coulomb collisions with the surrounding atoms. This influences the angular distribution of the bremsstrahlung photons created, producing photons at all angles.

The walls and roof of the storage ring are designed mainly to attenuate these high energy, thick target photons. Thin target bremsstrahlung is a special condition whereby the target is so thin that coulomb interactions can be neglected, resulting in the production of bremsstrahlung photons at very small angles in the direction of the electron beam. An example of this in storage rings is the interaction of the electron beam with the residual gas molecules inside the vacuum chamber - hence the term "gas bremsstrahlung". This may seem like a rare occurrence given that the vacuum pressure is on the order of 10^{-9} torr, but there are about 10^{12} electrons stored in the ring which circulate about 1 million times per second, giving many opportunities for interaction with the residual gas molecules. In a storage ring the gas bremsstrahlung production is directly proportional to the gas pressure and the target thickness. Therefore, one should expect gas bremsstrahlung to be a much larger problem on insertion device beamlines (especially for a straight section with poor vacuum), with their 6-7 meter straight sections, than on bendmagnet beamlines. Gas bremsstrahlung photons are produced with roughly the same angular divergence as the synchrotron beam. But, since they are of much higher energy, they cannot be reflected by mirrors or other optical elements in the path of the synchrotron beam. Instead, they interact with these components producing potential sources of scatter radiation.

As an example of the order of magnitude of gas bremsstrahlung dose rates consider an insertion device beamline and the storage ring operating at 1.9 GeV, 800 mA and 1 ntorr pressure. The dose rate 20 meters downstream of the source standing directly in the gas bremsstrahlung beam (neglecting the synchrotron beam) would be about 20 rads/hr. To attenuate this beam by a factor of ten requires about 2 inches of lead. If this gas bremsstrahlung beam were impinging on a thick optical element, the unshielded scatter dose rate at 1 meter to the side would be about 0.1 rad/hr (100 mrad/hr). To put this in perspective it would take about 15 minutes standing in the direct gas bremsstrahlung beam to reach the DOE annual limit for a radiation worker (5 rad), and about 50 hours to reach the same limit if standing 1 meter to the side. To reduce these levels to about 0.1 mrem/hour, we use 10 inches of lead to absorb direct bremsstrahlung radiation, and two inches of lead to absorb scattered bremsstrahlung radiation.

Synchrotron Radiation Hazards

Synchrotron radiation at the ALS can be produced by the storage ring bend magnets or by specially designed insertion devices such as wigglers or undulators. This radiation can be generally characterized as low energy (few hundreds of eV to few tens of keV) and extremely high intensity. The photon intensity at any energy from these different devices can vary by several orders of magnitude. Because of these unique spectral characteristics, the synchrotron shielding requirements can vary from beamline to beamline. In addition, a beamline may contain a number of filtering elements (e.g. Be windows) and/or optical elements (mirrors, monochrometers, etc.) greatly changing the shielding requirements along the length of a given beamline. Therefore, the shielding requirements can be roughly grouped by potential radiation hazard as follows: white (unreflected) wiggler, reflected wiggler and white bend magnet and white undulator, reflected bend magnet and reflected undulator, followed by monochromatic beamlines.

To give an idea of the potential level of hazard, consider an unshielded, white (unreflected), bend magnet beamline that accepts about 7 mradian of horizontal radiation and has a 2.5 mm Be vacuum window to absorb very low energy photons and to provide vacuum protection. The unshielded dose rate due to the synchrotron beam scattering off a piece of aluminum or lead at 30 cm to the side of the scatter point inside the required hutch or endstation is about 1000 rads/hr. The dose rate in the direct synchrotron beam is many orders of magnitude higher. This scattered dose rate drops to less than 0.1 mrad/hr (7 orders of magnitude) when shielded by just 1/8" steel (~3 mm).

Note that even the scattered synchrotron dose rate is several orders of magnitude higher than the direct gas bremsstrahlung beam, but not nearly as penetrating due to the differences in photon energy. This is why it is imperative that end stations, mirror tanks, and other sources of scattered synchrotron radiation be properly shielded and personnel access to these synchrotron beams, in particular white beams, be precluded.

IV. Description of Badging

History and Badging Requirement

The Berkeley Lab Advanced Light Source (ALS) is a state-of-the-art 3rd generation light source which has been operating for about 4 years. Much effort was involved in designing the radiation shielding to meet today's stringent standards and ALARA considerations. The overall design goal was to maintain dose rates to less than about 200 mrem per 2000 hr-year (0.1 mrem/hr) using conservative beam loss assumptions. Operating experience has taught us that actual sustained ambient radiation levels are much lower.

These levels are very consistent and predictable since the operation and delivery of beam to users is required to be extremely precise and predictable over long periods of time.

When the accelerator first began operation and a radiation badging policy was to be developed it was decided that, until we had the necessary dosimetry data to decide otherwise, we would badge the entire worker and experimental population. This would provide us with the best statistical data on stray radiation levels around the accelerator. Each person was issued a dosimetry badge that contained 4 TLD elements. Badges were processed on a monthly basis.

The badged population consisted of about 450 people. After three full years of operation, including the commissioning year where beam losses were the highest, the decision was made to remove the restriction that all workers and experimentalists must be issued personnel radiation dosimetry. The evidence was clear. Three years of badging the entire population (total of 65,000 TLD elements) failed to yield a single element exceeding 100 mrem in a year due to stray radiation fields at the ALS. In fact over 98% of the personnel badges have not exceeded 10 mrem per year above normal background using the LBL DOELAP accredited system and monthly changeout of the badges.

These results can be attributed to several factors:

Shielding was based on conservative beam loss assumptions.

No credit was taken in the design for self-shielding by the many accelerator beamline components, particularly the thick aluminum vacuum vessel and massive lattice magnets.

The linac walls are twice as thick as required (4-6' vs. 2-3') due to the availability of shield blocks from the decommissioning of the cyclotron originally at this site.

Locations of significant scatter radiation identified during the commissioning phase of a beamline are quickly retrofitted with local shielding to maintain low levels.

10 CFR 835 states: "For the purpose of monitoring individual exposures to external radiation, personnel dosimetry shall be provided to and used by . . . radiological workers who are, under typical conditions, are likely to receive . . . an effective dose equivalent to the whole body of 0.1 rem or more in a year."

10 CFR 20 Subpart F requires personal dosimetry for doses expected to be in excess of 10 percent of the 5 rem occupational exposure limit (five times the DOE limit).

Since, to date, we have not had a single person exceed 100 mrem in a year due to stray radiation under typical conditions at the ALS we do not meet the threshold for providing personnel dosimetry. Under abnormal or accident conditions one should rely on detailed measurements under appropriate conditions and time and motion studies to evaluate potential exposures. Personnel dosimetry can be misleading and non-conservative under these conditions. According to the DOE Radiological Control Manual, unnecessary issuance of dosimeters should be avoided.

V. Consensus Practices

Under the auspices of the Howard Hughes Medical Institute, a set of consensus guidelines for radiation protection practices for academic research institutions were developed. The Health Physics Journal published these guidelines in December 1996, Volume 71, Number 6. The guideline referring to personal monitoring criteria is as follows:

> Goals
>
> The goals of personal monitoring in a radiation program are (1) to verify the adequacy of radiation control procedures; (2) to help in eliminating unnecessary or unwarranted exposures: (3) to provide data for analysis of the distribution of doses among individuals and groups; and (4) to satisfy regulatory requirements.
>
> Guidelines
>
> Routine monitoring results rarely can be accepted as representative of true doses received by the monitored individuals without supplementary information and analysis by a radiation protection professional.
>
> To achieve the goals stated above, individual radiation users should be monitored for exposures to internal and/or external radiation sources unless they are unlikely to exceed 10% of an occupational dose limit. The likelihood of exceeding 10% of any dose limit may be inferred from monitoring data obtained from groups of workers in other comparable programs or by performing monitoring within defined groups or categories of radiation users . . .
>
> Monitoring of individuals who receive negligible doses is discouraged because it may lead to a false sense of protection against both biological and legal risks. In particular, external monitoring devices and data provide no protection to the individual but may actually increase legal liability to the institution unless there are adequate procedures that control the exchange and proper use of the devices and evaluation of the exposure conditions. Exposure conditions can be evaluated by monitoring of randomly selected individuals, by exposure rate measurements, and area monitoring . . .

The Federal occupational dose limit referred to above is 5 rem per year. According to 10 CFR 835.202, the occupational exposure limit to general employees resulting from DOE facilities is also 5 rem.

VI. New Personnel Monitoring Plan and Rationale

We have taken several steps in order to be conservative and further study radiation levels at the ALS. First, we have continued to provide personnel dosimetry to about 10% of the population (70 out of about 700). These individuals comprise that part of the workforce that we think have the greatest potential for any radiation exposure - no matter how small. They include: accelerator operators, beamline coordinators, mechanical and electrical technicians, etc. In addition a small number of beamline users are badged.

VII. New Area Monitoring Plan and Rationale

We have more than doubled the number of area monitors around the experimental area. We currently have about 2 in-close area monitors located on each beamline and about a two dozen area monitors located around the inside periphery of the building. The in-close monitors are exchanged monthly and the peripheral monitors are exchanged quarterly.

Since these area monitors are recording exposure 24 hours per day, 7 days per week we feel that information attained from them will provide the greatest sensitivity. These monitors are usually placed in locations that will give us the maximum integrated exposures based on radiation surveys.

Attached are the locations of the in-close and peripheral area monitors as well as the results of the in-close monitors over the last year since we removed the restriction on personnel dosimetry. As an example we will pick the area monitor labeled as ALS_ENV_14. This is located on beamline 5. This beamline provides for the transport of wiggler radiation for use in protein crystallography. Construction on the beamline outside the storage ring wall started about at the end of 1996. Scatter radiation from several components just inside the storage ring wall has resulted in what we consider significant levels. In ten months of taking data from December 1996- October of 1997, we have recorded about 106 mrem. See attached data (The "net" reading is obtained by subtracting the statistical average plus one standard deviation of the Dosimetry Department's control badges from the ALS area badges).

Note that the time interval for which this exposure has been summed over is about 7,200 hrs, i.e. 0.015 mrem/hr average. In spite of such low levels, efforts were recently completed which reduced the scatter dose rates in this area by about a factor of 2. These efforts continue.

In addition to the passive area monitors discussed above we are in the process of fully developing an active real-time area monitoring program. Since operation began we have had interlocked real-time monitoring which dumps the stored beam if a predetermined threshold has been exceeded. These were primarily intended for use during electron beam injection into the storage ring and were positioned around the ring before any synchrotron beamlines had been constructed. The injection process has now been well characterized. In addition to these interlocked monitors, we will install active monitors in the white light section of each beamline and in new beamlines as they are developed. These monitors will have remote readout to the control room and will alarm in the control room at preset levels. In addition, we will log the data from these monitors.

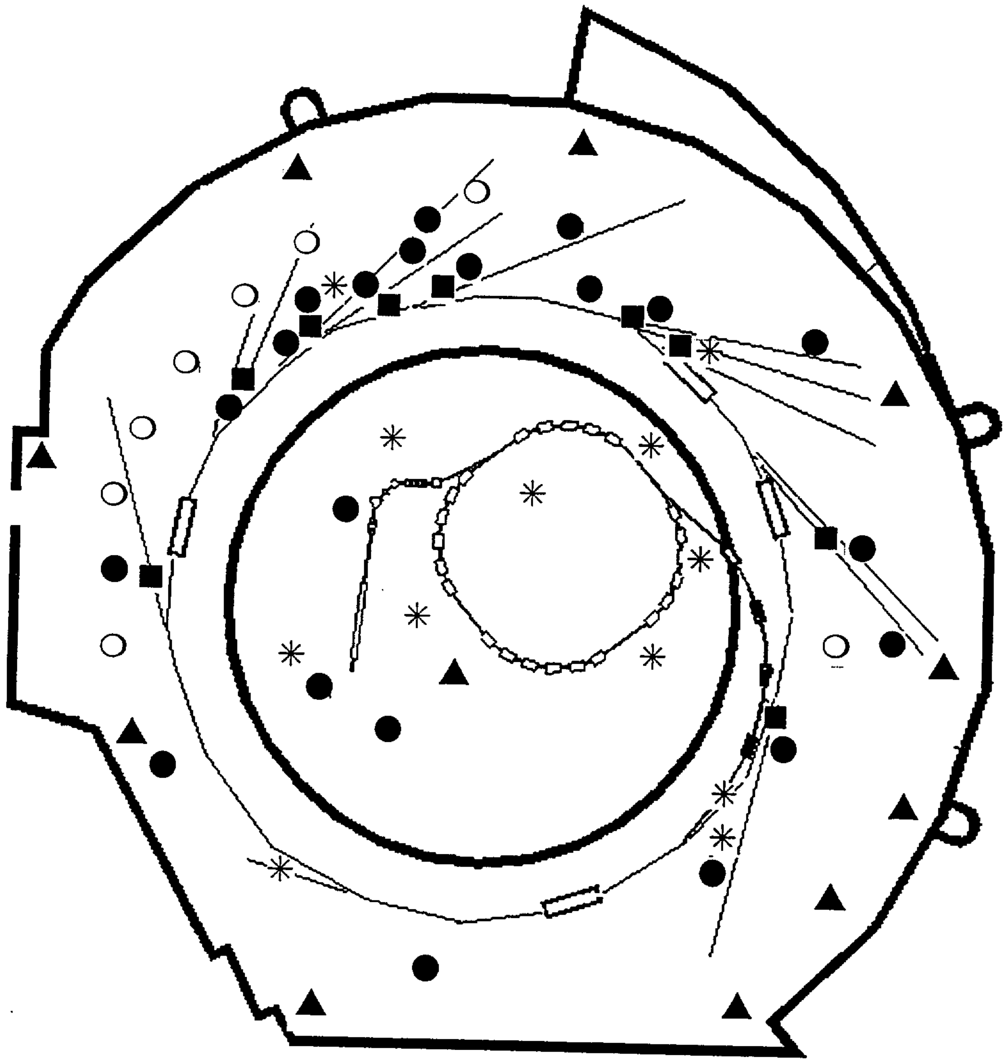
The "in close" monitors have a threshold of less than a few mrem and are changed out monthly. The "peripheral" monitors have a threshold of 10-15 mrem and are changed out quarterly. These, combined with the approximately 70 personnel badges (changed out quarterly), the interlocked real time monitors around the shield walls, and the proposed real time beamline monitors provide us with a very complete characterization of the stray radiation fields at then ALS, both in time and location.

VIII. Conclusion

In summary, we are adhering to Federal, DOE, and consensus standards by not requiring personnel dosimeters. In addition, our dosimetry program is in the true interest of maintaining personnel exposures ALARA.

* This work was supported by the Director, Office of Energy Research, Office of Basic Energy Sciences, Materials Sciences Division of the US Department of Energy, under Contract No. DE-AC03-76SF00098.

ALS Radiation Monitors



Monitors/Time

- ■ Active Beamline Monitors - 3 min.
- ● In-close Monitors - 1 month
- ○ Peripheral (Mezzanine) - 3 months
- ▲ Peripheral (floor) - 3 months
- ✳ RSS Monitors < 1 min.

Low Dose 802 Algorithm

Date: 10/7/97 13:11
97100604
Dose Calc Performed By: GEJ

Location Description	ID#	Issue	Return	Dose (mrad)	Net (mrad)
ALSENV# 01	S97340	9/2/97	10/6/97	9.86	5.10
ALSENV# 02	S97341	9/2/97	10/6/97	7.16	2.40
ALSENV# 03	S97342	9/2/97	10/6/97	5.62	0.86
ALSENV# 04	S97343	9/2/97	10/6/97	5.04	0.00
ALSENV# 05	S97344	9/2/97	10/6/97	4.17	0.00
ALSENV# 06	S97345	9/2/97	10/6/97	4.64	0.00
ALSENV# 07	S97346	9/2/97	10/6/97	3.95	0.00
ALSENV# 08	S97347	9/2/97	10/6/97	4.40	0.00
ALSENV# 09	S97348	9/2/97	10/6/97	4.36	0.00
ALSENV# 10	S97349	9/2/97	10/6/97	5.83	1.07
ALSENV# 11	S97350	9/2/97	10/6/97	4.93	0.00
ALSENV# 12	S97351	9/2/97	10/6/97	7.09	2.33
ALSENV# 13	S97352	9/2/97	10/6/97	4.85	0.00
ALSENV# 14	S97353	9/2/97	10/6/97	5.62	0.86
ALSENV# 15	S97354	9/2/97	10/6/97	5.36	0.60
ALSENV# 16	S97355	9/2/97	10/6/97	17.26	12.50
ALSENV# 17	S97356	9/2/97	10/6/97	6.59	1.83
ALSENV# 18	S97357	9/2/97	10/6/97	16.94	12.18
ALSENV# 19	S97358	9/2/97	10/6/97	8.54	3.78
ALSENV# 20	S97359	9/2/97	10/6/97	4.62	0.00
ALSENV# 21	S97360	9/2/97	10/6/97	5.00	0.00
ALSENV# 22	S97361	9/2/97	10/6/97	13.03	8.27
ALSENV# 23	S97362	9/2/97	10/6/97	26.28	21.52
CONTROL	S97363	9/2/97	10/6/97	4.64	0.00
CONTROL	S97364	9/2/97	10/6/97	4.93	0.00
CONTROL	S97365	9/2/97	10/6/97	4.61	0.00
CONTROL	S97366	9/2/97	10/6/97	4.72	0.00
CONTROL	S97367	9/2/97	10/6/97	4.91	0.00
unused	S97585	10/1/97	10/6/97	1.06	#N/A

Low Dose 802 Algorithm

Date: 9/22/97 17:16
97092202
Dose Calc Performed By: GEJ

Location Description	ID#	Issue	Return	Dose (mrad)	Net (mrad)
ALS ENV#01	S97280	8/6/97	9/2/97	10.75	4.57
ALS ENV#02	S97281	8/6/97	9/2/97	10.38	4.20
ALS ENV#03	S97282	8/6/97	9/2/97	6.11	0.00
ALS ENV#04	S97283	8/6/97	9/2/97	5.81	0.00
ALS ENV#05	S97284	8/6/97	9/2/97	5.01	0.00
ALS ENV#06	S97285	8/6/97	9/2/97	5.45	0.00
ALS ENV#07	S97286	8/6/97	9/2/97	4.95	0.00
ALS ENV#08	S97287	8/6/97	9/2/97	5.25	0.00
ALS ENV#09	S97288	8/6/97	9/2/97	5.39	0.00
ALS ENV#10	S97289	8/6/97	9/2/97	6.47	0.00
ALS ENV#11	S97290	8/6/97	9/2/97	5.63	0.00
ALS ENV#12	S97291	8/6/97	9/2/97	8.25	2.07
ALS ENV#13	S97292	8/6/97	9/2/97	6.06	0.00
ALS ENV#14	S97293	8/6/97	9/2/97	7.19	0.00
ALS ENV#15	S97294	8/6/97	9/2/97	6.21	0.00
ALS ENV#16	S97295	8/6/97	9/2/97	14.18	8.00
ALS ENV#17	S97296	8/6/97	9/2/97	6.86	0.00
ALS ENV#18	S97297	8/6/97	9/2/97	14.06	7.88
ALS ENV#19	S97298	8/6/97	9/2/97	8.49	2.31
ALS ENV#20	S97299	8/6/97	9/2/97	5.94	0.00
ALS ENV#21	S97300	8/6/97	9/2/97	7.46	0.00
CONTROL	S97304	8/6/97	9/2/97	5.96	0.00
CONTROL	S97302	8/6/97	9/2/97	5.80	0.00
CONTROL	S97301	8/6/97	9/2/97	6.37	0.00
CONTROL	S97303	8/6/97	9/2/97	5.97	0.00
CONTROL	S97301	8/6/97	9/2/97	6.84	0.00

Low Dose 802 Algorithm

Date: 8/22/97 12:52
97082202
Dose Calc Performed By: GEJ

Location Description	ID#	Issue	Return	Dose (mrad)	Net (mrad)
ALS ENV 01	S97132	5/5/97	8/15/97	24.08	11.45
ALS ENV 02	S97133	5/5/97	8/15/97	17.77	5.14
ALS ENV 03	S97134	5/5/97	8/15/97	14.86	2.23
ALS ENV 04	S97135	5/5/97	8/15/97	14.69	2.06
ALS ENV 05	S97136	5/5/97	8/15/97	11.82	0.00
ALS ENV 06	S97137	5/5/97	8/15/97	13.07	0.00
ALS ENV 07	S97138	5/5/97	8/15/97	11.47	0.00
ALS ENV 08	S97139	5/5/97	8/15/97	11.83	0.00
ALS ENV 09	S97140	5/5/97	8/15/97	12.71	0.00
ALS ENV 10	S97141	5/5/97	8/15/97	14.69	2.06
ALS ENV 11	S97142	5/5/97	8/15/97	13.15	0.00
ALS ENV 12	S97143	5/5/97	8/15/97	19.29	6.65
ALS ENV 13	S97144	5/5/97	8/15/97	12.53	0.00
ALS ENV 14	S97145	5/5/97	8/15/97	19.94	7.31
ALS ENV 15	S97146	5/5/97	8/15/97	15.98	3.35
ALS ENV 16	S97147	5/5/97	8/15/97	32.61	19.98
ALS ENV 17	S97148	5/5/97	8/15/97	16.35	3.71
ALS ENV 18	S97149	5/5/97	8/15/97	39.76	27.13
ALS ENV 19	S97150	5/5/97	8/15/97	21.88	9.25
ALS ENV 20	S97151	5/5/97	8/15/97	12.64	0.00
ALS ENV 21	S97152	5/5/97	8/15/97	12.67	0.00
CONTROL	S97156	5/5/97	8/15/97	13.00	0.00
CONTROL	S97153	5/5/97	8/15/97	12.43	0.00
CONTROL	S97156	5/5/97	8/15/97	12.99	0.00
CONTROL	S97154	5/5/97	8/15/97	12.29	0.00
CONTROL	S97154	5/5/97	8/15/97	12.37	0.00

Low Dose 802 Algorithm

Date: 6/27/97 11:49
97062702
Dose Calc Performed By: GEJ

Location Description	ID#	Issue	Return	Dose (mrad)	Net (mrad)
ALS ENV 01	S97120	4/1/97	6/16/97	23.82	13.39
ALS ENV 02	S97119	4/1/97	6/16/97	13.15	2.72
ALS ENV 03	S97118	4/1/97	6/16/97	10.44	0.00
ALS ENV 04	S97117	4/1/97	6/16/97	10.26	0.00
ALS ENV 05	S97116	4/1/97	6/16/97	8.96	0.00
ALS ENV 06	S97115	4/1/97	6/16/97	10.15	0.00
ALS ENV 07	S97114	4/1/97	6/16/97	8.59	0.00
ALS ENV 08	S97113	4/1/97	6/16/97	9.01	0.00
ALS ENV 09	S97112	4/1/97	6/16/97	9.85	0.00
ALS ENV 10	S97111	4/1/97	6/16/97	11.34	0.91
ALS ENV 11	S97110	4/1/97	6/16/97	11.60	1.17
ALS ENV 12	S97109	4/1/97	6/16/97	12.98	2.55
ALS ENV 13	S97108	4/1/97	6/16/97	10.05	0.00
ALS ENV 14	S97107	4/1/97	6/16/97	27.81	17.38
ALS ENV 15	S97106	4/1/97	6/16/97	12.05	1.62
ALS ENV 16	S97105	4/1/97	6/16/97	24.89	14.45
ALS ENV 17	S97104	4/1/97	6/16/97	12.77	2.34
ALS ENV 18	S97103	4/1/97	6/16/97	16.43	6.00
ALS ENV 19	S97102	4/1/97	6/16/97	12.81	2.38
ALS ENV 20	S97101	4/1/97	6/16/97	9.70	0.00
ALS ENV 21	S97100	4/1/97	6/16/97	10.08	0.00
CONTROL	S97097	4/1/97	6/16/97	10.21	0.00
CONTROL	S97098	4/1/97	6/16/97	10.43	0.00
CONTROL	S97099	4/1/97	6/16/97	10.67	0.00
CONTROL	S97123	4/1/97	6/16/97	10.63	0.00
CONTROL	S97124	4/1/97	6/16/97	10.19	0.00

Low Dose 802 Algorithm

Date: 4/8/97 18:43
Filename: 97040703
Dose Calc Performed By: GEJ

Location Description	ID#	Issue	Return	Dose (mrad)	Net (mrad)
ALS_ENV_1	S97078	3/3/97	4/4/97	19.20	15.07
ALS_ENV_2	S97079	3/3/97	4/4/97	7.44	3.31
ALS_ENV_3	S97080	3/3/97	4/4/97	4.34	0.00
ALS_ENV_4	S97081	3/3/97	4/4/97	4.23	0.00
ALS_ENV_5	S97082	3/3/97	4/4/97	3.82	0.00
ALS_ENV_6	S97083	3/3/97	4/4/97	3.98	0.00
ALS_ENV_7	S97084	3/3/97	4/4/97	3.86	0.00
ALS_ENV_8	S97085	3/3/97	4/4/97	4.12	0.00
ALS_ENV_9	S97086	3/3/97	4/4/97	4.47	0.00
ALS_ENV_10	S97087	3/3/97	4/4/97	5.20	1.07
ALS_ENV_11	S97088	3/3/97	4/4/97	4.46	0.00
ALS_ENV_12	S97089	3/3/97	4/4/97	5.58	1.45
ALS_ENV_13	S97090	3/3/97	4/4/97	4.35	0.00
ALS_ENV_14	S97091	3/3/97	4/4/97	26.27	22.14
ALS_ENV_15	S97092	3/3/97	4/4/97	4.32	0.00
ALS_ENV_16	S97063	3/3/97	4/4/97	17.59	13.46
ALS_ENV_17	S97064	3/3/97	4/4/97	5.99	1.86
ALS_ENV_18	S97065	3/3/97	4/4/97	6.92	2.79
ALS_ENV_19	S97066	3/3/97	4/4/97	8.28	4.15
ALS_ENV_20	S97067	3/3/97	4/4/97	4.30	0.00
ALS_ENV_21	S97068	3/3/97	4/4/97	4.74	0.61
CONTROL	S97069	3/3/97	4/4/97	4.20	0.00
CONTROL	S97070	3/3/97	4/4/97	4.08	0.00

Low Dose 802 Algorithm

Date: 4/1/97 13:22

Dose Calc Performed By: GEJ

Location Description	ID#	Issue	Return	Dose (mrad)	Net (mrad)
ALS ENV 1	S97021	2/4/97	3/6/97	13.74	7.47
ALS ENV 2	S97022	2/4/97	3/6/97	9.07	2.80
ALS ENV 3	S97023	2/4/97	3/6/97	7.42	1.15
ALS ENV 4	S97024	2/4/97	3/6/97	7.20	0.93
ALS ENV 5	S97025	2/4/97	3/6/97	7.91	1.64
ALS ENV 6	S97026	2/4/97	3/6/97	7.19	0.92
ALS ENV 7	S97027	2/4/97	3/6/97	7.49	1.22
ALS ENV 8	S97028	2/4/97	3/6/97	7.12	0.85
ALS ENV 9	S97029	2/4/97	3/6/97	8.36	2.09
ALS ENV 10	S97030	2/4/97	3/6/97	8.05	1.78
ALS ENV 11	S97031	2/4/97	3/6/97	9.57	3.30
ALS ENV 12	S97032	2/4/97	3/6/97	8.56	2.29
ALS ENV 13	S97033	2/4/97	3/6/97	7.34	1.07
ALS ENV 14	S97034	2/4/97	3/6/97	30.48	24.21
ALS ENV 15	S97035	2/4/97	2/28/97	4.18	0.88
CONTROL	S97036	2/4/97	3/6/97	6.59	0.00
CONTROL	S97037	2/4/97	3/6/97	6.25	0.00

Low Dose 802 Algorithm

Date: 2/26/97
Filename: '97021314
Dose Calc Performed By: KDD

Location Description	ID#	Issue	Return	Dose(mRad)	Net(mRad)
AREA #1	S96620	12/5/96	2/7/97	14.6	8.4
AREA #2	S96595	12/5/96	2/7/97	10.4	4.1
AREA #3	S96599	12/5/96	2/7/97	8.6	2.3
AREA #4	S96602	12/5/96	2/7/97	8.2	2
AREA #5	S96603	12/5/96	2/7/97	7.8	1.5
AREA #6	S96604	12/5/96	2/7/97	8.4	2.1
AREA #7	S96612	12/5/96	2/7/97	7.6	1.4
AREA #8	S96597	12/5/96	2/7/97	8.1	1.8
AREA #9	S96610	12/5/96	2/7/97	9.8	3.6
AREA #10	S96618	12/5/96	2/7/97	10.3	4.1
AREA #11	S96596	12/5/96	2/7/97	11.9	5.7
AREA #12	S96619	12/5/96	2/7/97	11.5	5.3
AREA #13	S96607	12/5/96	2/7/97	8.8	2.6
AREA #14	S96608	12/5/96	2/7/97	40.9	34.6
AREA #15	S96606	12/5/96	2/7/97	8.8	2.5

Low Dose 802 Algorithm

Date: 12/17/96 14:26
Filename: 96121302
Dose Calc Performed By: GEJ

Location Description	ID#	Issue	Return	Dose (mrad)	Net (mrad)
AREA #1	S96542	11/1/96	12/9/96	9.98	4.34
AREA #2	S96543	11/1/96	12/9/96	6.84	1.20
AREA #3	S96544	11/1/96	12/9/96	5.56	0.00
AREA #4	S96545	11/1/96	12/9/96	5.39	0.00
AREA #5	S96546	11/1/96	12/9/96	5.00	0.00
AREA #6	S96547	11/1/96	12/9/96	5.46	0.00
AREA #7	S96548	11/1/96	12/9/96	4.96	0.00
AREA #8	S96549	11/1/96	12/9/96	5.63	0.00
AREA #9	S96550	11/1/96	12/9/96	5.90	0.00
AREA #10	S96551	11/1/96	12/9/96	6.20	0.56
AREA #11	S96552	11/1/96	12/9/96	7.92	2.29
AREA #12	S96553	11/1/96	12/9/96	6.81	1.17
AREA #13	S96554	11/1/96	12/9/96	5.42	0.00
AREA #14	S96555	11/1/96	12/9/96	15.54	9.91
AREA #15	S96556	11/1/96	12/9/96	5.91	0.00
CONTROL	S96564	11/1/96	12/13/96	5.64	0.00
1 mR	S96557	11/1/96	12/13/96	6.42	0.78
1.5mR	S96558	11/1/96	12/13/96	6.55	0.91
2.5mR	S96559	11/1/96	12/13/96	7.70	2.06
5 mR	S96560	11/1/96	12/13/96	9.72	4.08
10 mR	S96561	11/1/96	12/13/96	14.37	8.74
15 mR	S96563	11/1/96	12/13/96	19.86	14.22
20 mR	S96562	11/1/96	12/13/96	24.54	18.90