SLAC–295

# ANNUAL ENVIRONMENTAL MONITORING REPORT
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ENVIRONMENT AND SAFETY OFFICE
STANFORD LINEAR ACCELERATOR CENTER
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# I. Introduction

## A. General

The Stanford Linear Accelerator Center (SLAC) is a national facility operated by Stanford University under contract with the U. S. Department of Energy (DOE). It is located on the San Francisco Peninsula, about halfway between San Francisco and San Jose, California. The site area is in a belt of low, rolling foothills, lying between the alluvial plain bordering San Francisco Bay on the east and the Santa Cruz Mountains on the west. The whole accelerator site varies in elevation from 53 to 114 meters above sea level, whereas the alluvial plain to the east around the Bay lies less than 46 meters above sea level; the mountains to the west rise abruptly to over 610 meters. The SLAC site occupies 170 hectare of land owned by Stanford University and leased for fifty years in 1962 to the DOE (then AEC) for purposes of research in the basic properties of matter. The lands are part of Stanford's "academic reserve", and are located west of the University and the City of Palo Alto. The site is located in an unincorporated portion of San Mateo County. It is bordered on the north by Sand Hill Road, and on the south by the San Francisquito Creek. The accelerator is sited on a roughly 300 meter wide parcel, 3.2 kilometers long, running in an east-west direction. The width of the parcel expands to about 910 meters at the target (east) end to allow space for buildings and experimental facilities.

The SLAC staff currently numbers roughly 1,550 employees; there are about 1,200 full-time people, 200 part-time, and 150 visiting scientists. Approximately one quarter of the staff is professional, composed of physicists, engineers, programmers and other scientific related personnel. The balance of the staff composition is support personnel including technicians, crafts personnel, lab assistants, clerical and administrative employees.

## B. Accelerators in Perspective

Accelerators are simply tools of research enabling physicists to explore and understand the fundamental behavior of the subatomic environment. Some accelerators are linear, as is SLAC's; others are circular in geometry as are cyclotrons, synchrocyclotrons, betatrons, and synchrotrons. All conventional accelerators accelerate subatomic particles (electrons, protons, positrons, alpha particles) to a high energy and bombard a target nucleus. Physicists then study the effects of the collisions in an attempt to understand precisely what happens and thereby understand the nature of the atomic nucleus. Because of the very strong forces which bind the nucleus and its constituents together, physicists need greater and greater energies in order to delve constantly deeper. Consequently, accelerators have grown in size and complexity.

One of the important components of the U. S. high energy physics program is the 3.2 kilometer-long electron accelerator at the SLAC. This machine is capable of accelerating electrons to 30 billion electron volts (GeV) or positrons to 15 GeV. These particle beams are utilized by an array of experimental installations and two colliding beam storage rings.

The Positron Electron Project (PEP) storage ring is a special extension of the SLAC accelerator and poses no greater environmental problems than does the existing linac. The center-of-mass energy achieved by colliding beam particles together is vastly more efficient than having a single beam strike a stationary target. In a colliding-beam storage machine, the beam particles are truly "recycled", i.e., the same bunches of beam particles are brought into collision over and over again, rather than striking a target only once. For this reason, colliding-beam devices, in a fundamental way, produce very much less radiation and residual radioactivity than do conventional accelerators.

The PEP facility, completed in 1980, is a large storage ring housed in an underground tunnel at depths varying from six to thirty meters (m) and in which beams of electrons and their antimatter equivalent, positrons, circulate in opposite directions at energies up to 15 GeV. The underground ring has a diameter of about 700 m and is located at the eastern extremity of the SLAC site.

When particles of matter and antimatter meet head-on at high velocity, both are completely converted into energy. According to the formulations of Albert Einstein, energy can be transformed into matter and vice versa. In the electron-positron collisions some of the resulting energy is immediately transformed back into matter, producing a variety of particles of immense interest to physicists. Many of the design details of the PEP facility are based on the design and experience of a small existing storage ring at SLAC called the Stanford Positron Electron Asymmetric Ring (SPEAR). The SPEAR facility came into operation and began performing colliding-beam experiments in 1972. The SPEAR machine is about 1/8 the size and is capable of about 1/4 the energy of the PEP facility. Although the high energy physics usefulness of SPEAR will be fully exploited in the 1980's, its success has established the feasibility and served as a prototype for PEP. It also serves as a strong source of synchrotron light for the Stanford Synchrotron Radiation Laboratory (SSRL).

## C. Local Climate

The climate in the SLAC area is Mediterranean. Winters are warm and moist, and summers are mostly cool and dry. Long term weather data describing conditions in the area have been assembled from official and unofficial weather records at Palo Alto, 4.8 kilometers to the east. The SLAC site is 60 to 120 meters higher than the Palo Alto station and is free of the moderating influence of the city; temperatures therefore average about two degrees lower than those of Palo Alto. Daily mean temperatures are seldom below 0 degrees Centigrade or above 30 degrees Centigrade.

Rainfall averages about 560 millimeters per year. The distribution of precipitation is highly seasonal. About 75 percent of the precipitation, including most of the major storms, occur during the four month period December through March. Most winter storm periods are from two days to as much as a week in duration. The storm centers are usually characterized by relatively heavy rainfall and high winds. The combination of topography and air movement produces short fluctuations in intensity which can be best characterized as a series of storm cells following one another so as to produce the heavy precipitation for periods of five to fifteen minutes with lulls between.

### D. Site Geology

The entire SLAC site is underlain by sandstone and claystone. In general the bedrock on which the western half of the accelerator rests is of Eocene age (over 50 million years old) and that under the eastern half is of Miocene age (over ten million years old). On top of this bedrock at various places along the accelerator alignment are found alluvial deposits of sand and gravel generally of Pleistocene age (one million years old). At the surface is a soil overburden of unconsolidated earth materials averaging from 1 to 1.5 meters in depth.

### E. Site Water Usage

Use of water by SLAC is about equally divided between accelerator and equipment cooling, and domestic uses such as landscape irrigation, sanitary sewer, and drinking water. The "pre-PEP" (circa 1979) consumption amounted to about 340,000 cubic meters per year (930 cubic meters per day, on the average).

Since half of the water is necessary for machine cooling, the daily consumption of this component varies directly with the accelerator running schedule and hence also varies directly with electric power demand (the domestic water usage is relatively constant and is insensitive to the accelerator schedule). The relationship between power and water consumption can be appreciated if one considers that 85 percent of the power used in linac operation is finally dissipated by water evaporation in the ratio of about 630 kWh per cubic meter of water. SLAC now employs four cooling water towers comprising a total cooling capacity of 73 MW to dissipate the heat generated by the linear accelerator and other experimental apparatus.

Power consuming devices are directly cooled by a recycling closed-loop system of low conductivity water (LCW). The LCW is piped from the accelerator or other devices to be cooled, to the cooling towers where the heat is exchanged from the closed system to the domestic water in the towers. A portion of the tower water is ultimately evaporated into the atmosphere. Because of this constant evaporation during operation, the mineral content of the remaining water gradually increases and eventually must be discarded as "blowdown."

The SLAC domestic water is furnished via the Menlo Park Municipal Water Department (MPWD) whose source is the City of San Francisco-operated Hetch Hetchy aqueduct system from reservoirs in the Sierra Nevada. SLAC and its neighboring Sharon Heights development, including the shopping center, receive water service from a separate independent system (called "Zone 3") within the MPWD. This separate system taps the Hetch Hetchy aqueduct, and pumps water up to a 7600 cubic meter reservoir west on Sand Hill Road. The Zone 3 system was constructed in 1962 under special agreements among the City of Menlo Park, the developer of Sharon Heights, Stanford University, and DOE. The cost of construction including reservoir, pump station, and transmission lines were shared among the various parties; each party has a vested interest in, and is entitled to, certain capacity rights in accordance with these agreements.

During current operations roughly 45 percent of the water consumed by the laboratory is rejected by evaporation from the four cooling towers. The remaining 55 percent is disposed of as follows:

- 26 percent is runoff to the San Francisquito Creek via the storm drains;
- 20 percent is waste domestic and process water discharged via the sanitary sewers connected to the Menlo Park Sanitary District; and,
- 9 percent is absorbed into the ground from irrigation.

### F. Land Use

San Mateo County has the ultimate planning responsibility with respect to University lands which are within the county but not within an incorporated city. The San Mateo County General Plan is the primary land use regulatory tool with respect to such lands. Adherence will be made to all applicable federal, state, and local regulations including chemical and sanitary discharges which might adversely affect, directly or indirectly, the environmental quality.

The Board of Trustees of Stanford University has the responsibility to preserve and protect Stanford's land endowment for the use of present and future generations of students and faculty. While financial and political influences on land use policy are taken into account, the dominant and prevailing consideration is the appropriateness of those policies in the furtherance of the University's academic mission. Board policies are designed to encourage land uses consistent with the institutional characteristics and purposes of Stanford and to discourage those uses or claims which do not relate to or support the mainstream of the University. Certainly this project falls in the former category.

The purpose of the Stanford land endowment is to provide adequate land for facilities and space for the instructional and research activities of the University. The use of lands is planned in a manner consistent with the characteristics of Stanford as a residential teaching and research university, and provides flexibility for unanticipated changes in academic needs. Cooperation with adjoining communities is important, and the concerns of neighboring jurisdictions are considered in the planning process.

## G. Demography

Menlo Park is the closest incorporated city to SLAC. According to the 1980 census the City of Menlo Park has a land area of 43.8 km$^2$, a population of 26,369 and a population density of 602 persons per km$^2$. This population has decreased by 1.7 percent since the 1970 census.

In 1974 a population estimate within 1.6 km of SLAC was determined by aerial photographs and type of structures revealed. The populated area surrounding SLAC is a mix of office, school, condominiums, apartments, single family housing and pasture. Occupancy factors of 1/10 - 1.0 were assumed depending on the type of structure. The populated area is about 1.5 km$^2$ or about 1000 people from the 1980 census population density. The total area including open lands is 8 km$^2$.[1]

# II. 1985 Summary

## A. Non-Radioactive

### 1. Waste solvent tank remedial action

A final report on the extent of groundwater contamination was submitted to the California Regional Water Quality Control Board, San Francisco Bay Region. The findings in this report were based on soil samplings fom borings and well logs, and on the groundwater analyses from seven monitoring wells. Four remedial alternatives were presented to the Board. The alternative with limited soil removal and groundwater extraction/treatment was accepted by the Board for initial action. Removal of contaminated soil and installation of the extraction well is expected to begin in May.

### 2. Underground storage tank program

The state of California, through the county agencies, has instituted a program to monitor and test all underground tanks containing hazardous materials. This program requires tank and pipe leak testing and a means of determining leaks, either through a monitoring system or inventory reconciliation. SLAC has tested each of its underground tanks and sent the required documentation to the county. Interim permits have been issued for each tank.

### 3. Construction discharge

Effluent containing concrete solds was discharged into the storm sewer system by a construction contractor. The California Department of Fish and Game worked with SLAC and the contractor to eliminate the silty discharge to San Francisquito Creek. Cleanup was completed to the Department's satisfaction.

## B. Radioactive

### 1. Neutron radiation

Neutron radiation dose near SLAC's boundaries was 6.7 mrem for 1985. The population dose for this period was estimated to be 0.48 man-rem. This integration was terminated at 730 meters from SLAC. The annual dose at this distance is $< 1$ mrem. The average annual dose in this population is 1.3 mrem. The number of people included in this area is 392 and their annual population dose from natural background radiation is estimated to be 39 man-rem.

### 2. Effluent monitoring

Effluent monitoring revealed that SLAC released 0.138 Ci of gaseous radioactivity. The standards would allow an airborne release of 560 Ci per year of $^{41}$Ar.

### C. SLAC Linear Collider Project (SLC)

A major new construction project was started in 1984. This project is described in DOE/E (No. 0154), Environmental Assessment, September 1982.

The project comprises two primary structures (see Fig. 2):

1. An underground tunnel system approximately 2.4 km in circumference constructed beneath existing facilities, and,
2. A research hall located midway around the tunnel near PEP's Region 2.

The new machine is designed to collide high energy beams of electrons and positrons (50 GeV each) provided by the 3.2 km long linear accelerator. It is expected to be operational late in 1986. It will not pose any greater environmental problem than that described for the existing research facilities.

## III. Environmental Program Information

### A. Environmental Monitoring Summary

### 1. General

Environmental monitoring is required by a variety of local, state and federal agencies. Samples of air and water effluents are analyzed for non-radioactive and radioactive elements and chemical compounds. Collected samples are analyzed by State of California certified laboratories. Some "in-house" analyses are performed for process control. In addition to liquid effluent monitoring, continuous air monitoring for radioactive gaseous emissions and external penetrating neutron radiation dose rate are performed.

2. Non-radioactive effluent – wastewater

Wastewater from SLAC is discharged in three ways:

- The sanitary sewer flows to a local treatment facility and eventual discharge to San Francisco Bay.
- Cooling tower blowdowns are discharged to natural open ditches. Eventual discharge is to San Francisquito Creek by surface flow or seepage.
- Storm sewer effluent is released to natural open ditches or the city/county storm sewer system. The ditches also carry the cooling tower blowdowns and any groundwater pumped from the linac or subsurface storage rings. The city/county storm sewer system empties into San Francisquito Creek.

Typical amounts are 42,000 $m^3$/year to the sanitary sewer; 150,000 $m^3$/year to the storm drains, and 150,000 $m^3$/year evaporated, for a total of 340,000 $m^3$/year. In addition, an average of 900,000 $m^3$/year falls as rain on the 170 hectare site, also flowing to the creek.

About 20 percent of SLAC's domestic water supply is released to the sanitary sewer; the remaining 80 percent leaves the site by evaporation or by storm drains and natural ditches to San Francisquito Creek. The sanitary sewer outlet at the northeast corner of the site carries sanitary wastes and treated plating shop effluents thru West Bay Sanitary District lines to the South Bay System Authority treatment plant (DOE Contract E(0403)-480).

Wastewater discharged through the storm drain system includes a combination of water run-off and miscellaneous sources, such as once-through cooling water and pumped groundwater from sumps in the storage rings. Rainwater run-off from the Campus Area drains into the city storm sewer system. Run-off from the rest of SLAC is collected and discharged with the cooling tower blowdowns to two oil-water separators. The separators collect oil run-off from parking lot areas prior to discharge to the drainage ditches and San Francisquito Creek. Groundwater from the last third of the linac drains into this storm drain system as well.

The National Pollutant Discharge Elimination System (NPDES) permit covering the cooling tower blowdowns was renewed this year by the Regional Water Quality Control Board, San Francisco Bay Region. Samples from cooling tower blowdowns are collected twice a week, analyzed and reported to the Board. A quarterly toxicity bioassay is now required by this permit. Table III-1 shows the type and frequency of sampling required by the NPDES permit. Table III-2 summarizes the NPDES discharge for the calendar year.

There is a sanitary sewer sampling station that can be operated close to Sand Hill Road, northeast of PEP Interaction Region 12 (IR-12). Most of SLAC's sanitary sewage flows through this point. The West Bay System District has a flow measuring system at this connection. The total sewer discharge standards are listed in Table III-3. This station is out of service due to SLC construction.

The South Bayside System Authority (SBSA) monitors the treatment facility effluent and the total sewer discharge for compliance with the pretreatment standards and the total sewer discharge limits. Standards for the treatment facility are shown in Table III-4.

## Table III-1

## NPDES Sampling Requirements

| Sampling Stations | E-001, E-002, E-003 | | | C-R,C-1(2) | Limit |
|---|---|---|---|---|---|
| Type sample | Obs | Cont | Grab | Grab | |
| Flow rate (gal/day) | | M | | | |
| Settleable matter (ml/l/hr) | | | M(1) | | 0.1 |
| Oil and grease (mg/l) | | | W | | 5 |
| Total phosphate (mg/l) | | | 2/W | W(1) | <20 |
| Total suspended solids (mg/l) | | | W | W(1) | |
| Total dissolved solids (mg/l) | | | W | W(1) | |
| pH (units) | | | M | | 6.5-8.5 |
| Temperature (C) | | | M | M(1) | |
| Toxicity % survival | | | Q(1) | | 90 |
| All applicable standard observations | M | | | | |
| Cooling water chemicals (type and lbs/mo added) | M | | | | |

Type of Sample

Obs = observation
Cont = continuous sample
Grab = grab sample

Frequency of Sampling

W = once each week
M = once each month
Q = once each quarter
2/W = twice a week

(1) To be sampled on days coincident with effluent sampling.

(2) San Francisquito Creek upstream and downstream of discharge points.

Table III-2

1985 Summary of NPDES Monitoring Results

| Parameter | Value | E-1 | E-2 | E-3 |
|---|---|---|---|---|
| Daily flowrate (gal/day) | Minimum | 0 | 0 | 0 |
|  | Maximum | 24500 | 21900 | 69500 |
| Monthly flowrate (gal/mo) | Minimum | 200 | 100 | 2000 |
|  | Maximum | 208300 | 444600 | 864770 |
| Settleable matter: (ml/l/hr) |  | Range <0.1 |  |  |
| Oil and grease (mg/l) |  | Range <1 to 5.8 (1) |  |  |
| Total phosphate (mg/l) |  | Range 1.43 to 14.6 |  |  |
| Total suspended solids (mg/l) 30-day avg |  | Range 1.0 to 8.65 |  |  |
| Total dissolved solids (mg/l) 30-day avg |  | Range 120 to 445 |  |  |
| Toxicity (% survival) |  | 100 (2) |  |  |
| pH |  | Range 6.5 to 8 |  |  |

(1) Oil and grease values over 5 mg/l are normally seen at the beginning and during the rainy season as storm drains pick up oil and grease from vehicle parking areas.

(2) Toxicity tests on E-001, E-002, and E-003 samples were run in June and October of 1985.

Table III-3

Sanitary Sewer Standards

| Species | mg/l |
|---|---|
| Arsenic | 0.1 |
| Cadmium | 0.2 |
| Chromium (total) | 0.5 |
| Copper | 2.0 |
| Cyanide (total) | 1.0 |
| Lead | 1.0 |
| Mercury | 0.01 |
| Nickel | 1.0 |
| Silver | 0.2 |
| Sulfides dissolved | 0.1 |
| Zinc | 3.0 |
| Oil or grease, animal or vegetable origin | 300 |
| Oil or grease, mineral or petroleum origin | 100 |
| Chlorinated hydrocarbons | 0.02 |
| Phenolic compounds | 1.0 |
| Temperature | < 65°C |
| pH | > 6.0 |

Table III-4

Standards for Treatment Facility

| Species | Daily max. mg/l | Avg. last 4 samples mg/l |
|---|---|---|
| Arsenic | 0.1 | 0.1 |
| Cadmium | 1.2 | 0.7 |
| Chromium (total) | 7.0 | 4.0 |
| Copper | 4.5 | 2.7 |
| Cyanide (total) | 5.0 | 2.7 |
| Lead | 0.6 | 0.4 |
| Mercury | 0.01 | 0.01 |
| Nickel | 4.1 | 2.6 |
| Silver | 1.2 | 0.7 |
| Zinc | 4.2 | 2.6 |
| Dissolved sulfides | 0.1 | 0.1 |

There is a second sewer connection serving PEP IR-4, 6 and 8. This connection carries only small amounts of ordinary human wastes; no cooling or process water is discharged through this line. There is no monitoring of this sewer connection.

3. Non-radioactive effluent-airborne

Monitoring for non-radioactive airborne effluents is not required. SLAC has been issued permits from the Bay Area Air Quality Management District (BAAQMD) for boilers, paint spray booths, sandblasting booths, degreasers and other miscellaneous point sources of particulates, organics, nitrogen oxides, sulphur dioxide and carbon monoxide. This agency has not required air monitoring.

4. Radioactive effluent-airborne

Airborne radionuclides are produced in the air volume surrounding major electron beam absorbers such as beam dumps, collimators and targets. The degree of activation is dependent upon the beam power absorbed and the composition of the parent elements. The composition of air is well known, consisting of nitrogen, oxygen and trace quantities of carbon dioxide and argon. Induced radioactivity produced at high energies are short-lived such as oxygen-15 and carbon-11, having halflives of 2 minutes and 20 minutes respectively. Nitrogen-13, having a halflife of 10 minutes, is also produced but in much lower concentrations. As a consequence of water cooling and concrete shielding, both containing large quantities of hydrogen, the thermal neutron reaction with stable argon produces argon-41, which has a half-life of 1.8 hours.

We have not detected any other radionuclides including particulates in the airborne effluent exhausted from SLAC.

The accelerator, PEP, SPEAR and experimental areas are designed to transport (not absorb) high energy electrons and positrons. Radioactive gas concentrations are therefore not produced in measurable quantities. The Beam Switch Yard (BSY) represents the only portion of SLAC designed to absorb high energy particles and is the only source of detectable gaseous radioactive emissions. The

BSY is not vented continuously. It is vented only for emergencies and at the end of each experimental cycle for brief periods of one hour or less.

The Concentration Guides (CG's) for airborne radioactivity appear in Ref. 2. They were derived from dose standards which require that no individual in the general population be exposed to greater than 100 mrem in one year.

Airborne radioactivity produced as the result of operations is short-lived; i.e., the half-lives range from 2.1 minutes to 1.8 hours, and are in gaseous (not particulate) form. These isotopes include the following:

Table III-5

Radioactive Gases Released to Atmosphere

| Isotope | Half-Life | $\mu$Ci/cm$^3$ |
|---|---|---|
| 150 | 2.1 minutes | $1 \times 10^{-8}$ (*) |
| 13N | 9.9 minutes | $1 \times 10^{-8}$ (*) |
| 11C | 20.5 minutes | $1 \times 10^{-8}$ (*) |
| 41Ar | 1.8 hours | $1 \times 10^{-8}$ |

(*) Calculated from Ref. 3, assuming total submersion.

Since we do not routinely release airborne radioactivity while the beam is on, and require a waiting period before turning on the exhaustors, the only radioisotope released is Argon-41. By far the greater proportion of exposure an individual may receive, under any circumstances, from the radioelements listed in Table III-5 is from whole body immersion. Thus, for an individual to receive a whole body dose of 100 mrem annually requires a continuous exposure to a large cloud whose average concentration equals $1 \times 10^{-8}$ $\mu$Ci/cm$^3$ (Ci/m$^3$) for an entire year.

The BSY areas are vented by a total of 5 fans: the discharge point is just slightly above roof elevation. The total exhaust rate for the accelerator is 60 m$^3$/min, and for the BSY 40 m$^3$/min. Venting of PEP and its Interaction Regions (IR's) is accomplished by a total of 14 exhaust fans which vent just above grade level, with a total exhaust rate of 50m$^3$/min. PEP is the only facility that is vented while the beam is on.

Each BSY ventilation fan is provided with a radioactive gas detector. A Geiger-Mueller (GM) detector, power supply, rate meter, strip chart recorder and air pump are interlocked with the ventilation fan so that they operate only when the machine is vented.

The gas monitors for the BSY collect particulate samples during venting and have revealed negative results; during this monitoring period particulate radioactivity above background was not detected.

5. Radioactive effluent – wastewater

Wastewater containing radioactivity is not routinely released from the site. The only possible source of liquid radioactive effluent is from primary cooling water system in the BSY. In the event of leaks from the systems, water is collected in stainless steel lined sumps sized to contain the entire water volume. When necessary the contents of the sumps are pumped to a mobile holding tank. The tank is then moved to the nearest sanitary sewer inlet and drained into the sewer after a sample is removed for analysis.

As discussed in Section III A-2-4, the only source of induced radioactivity is where the electron/positron beam is absorbed. Since water is composed of hydrogen and oxygen, the only radioisotopes produced are the short-lived oxygen-15 and carbon-11, beryllium-7 (54d) and tritium (12.3y). Oxygen-15 and Carbon-11 are too short-lived to present an environmental problem and the beryllium-7 is removed by the resin beds required to maintain the electrical conductivity of the water at a low level. Therefore, tritium is the only radioactive element present in the water that is of environmental importance.

Water that leaks from these systems is disposed of via the sanitary sewer. The concentration of tritium released is less than the Concentration Guides as specified by DOE Order 5480.11, Requirements for Radiation Protection, without using the sewer effluent for dilution. SLAC is also bound by the provision in a contract for service, with the West Bay Sanitary District and DOE Contract E(04-3)-480.

6. Penetrating radiation monitoring

Six Peripheral Monitoring Stations (PMS) provide continuously-recorded data from radiation monitors located near SLAC boundaries. Their positions are located in Fig. 3.

The measured annual dose to the general population coming from accelerator operations is almost entirely from fast neutrons and is characterized as skyshine from SLAC's research area. Estimates of individual and general population whole body doses can be calculated from the PMS data, based on estimates of distance and population density near SLAC. PMS-1 is located at the most sensitive location. Historically this station has always been used to calculate population dose since it records the maximum dose near our site boundary.

From demographic information and the measured radiation dose near the site boundary, we can estimate both the average individual dose and the population dose from SLAC operations. From 1974 data, we used a population of 2040 persons who are included in the pool exposed to 1 mrem or more for any calendar year. A shift in the experimental program to low intensity experiments, including storage ring experiments, is the primary reason for the decrease in site boundary measurements, calculated population dose, and population number.

Radiation information is obtained with a GM tube for the ionizing component, and a paraffin-moderated $BF_3$ neutron detector calibrated with a Pu-Be neutron source. The resultant sensitivities are such that a gamma exposure of 1 mR from a radioactive $^{60}Co$ source would be recorded as $10^4$ counts on the GM tube channel, and a neutron dose-equivalent of 1 mrem would be recorded as $10^5$ counts on the $BF_3$ channel.

The hourly printout cycle of the Sodeco register is programmed by two clock motors with cam actuated switches and associated electronic circuitry. This programmer automatically interrupts data acquisition, generates a print command, resets the digits in parallel, and reverts to the normal condition of serial counting of incoming data pulses. Dead time per printout cycle is less than 20 seconds per hour, so that the related corrections would be negligible and are not made.

## B. Environmental Permits, Orders and Notices

### 1. Permits

In addition to DOE Orders, the following regulatory permits or contracts have been issued to SLAC:

California Regional Water Quality Control Board
San Francisco Bay Region
NPDES permit: CA0028398

Bay Area Air Quality Management District
Plant No. 556

West Bay Sanitary District
Contract with district to treat sanitary sewer wastes
DOE Contract E(04-3)-480
MPSD Resolution 779

## C. Environmental Activities

### 1. Waste solvent tank remedial action

Three additional monitoring wells and more soil borings were taken in May 1985 to provide information on the extent of groundwater and soil contamination from the removed solvent tank. A final report incorporating data from this study and the previous one was sent August 1985 to the Regional Water Quality Control Board. As required under the wastewater discharge permit issued for the contaminated groundwater, a report was prepared by SLAC personnel outlining four remedial alternatives. The alternative recommended by SLAC was approved for the initial action. This alternative involves limited soil removal and groundwater extraction/treatment to levels agreed upon by SLAC and Board. Removal of contaminated soil and the installation of the extraction well is expected to begin in May 1986.

### 2. Underground storage tank program

On January 1, 1985, all owners of underground tanks were required to register with the State Water Resources Control Board. By July 1, 1985, owner and operators of underground storage tanks were required to have tested the tank and associated piping for leaks, and to have initiated a monitoring system or inventory reconciliation for leak detection. The counties were delegated the authority to enforce the underground storage tank regulations.

SLAC complied with the state registration and the underground tank testing. Seven underground tanks, containing gasoline or diesel fuel, were leak tested onsite; associated underground piping for one tank was not checked due to problems in the testing method and the piping setup. Documentation was sent to San Mateo County of the tank test results, along with the plans for an inventory reconciliation program. San Mateo issued the required permits for operation of the underground tanks at the end of 1985.

### 3. Silty discharge from construction

In April 1985, a silty discharge from a storm drain flowing into San Francisquito Creek was discovered and reported to the California DEpartment of Fish and Game. The discharge was traced back to concrete operations associated with major new construction at SLAC. Although the contractor had been ordered to discharge the silty material into the sanitary sewer last year, the line was rerouted without SLAC's knowledge sometime in early 1985.

The contractor was ordered by the state Fish and Game to clean up an area, about 100 yards long, where the storm drain came to the surface prior to discharge into the creek. The contractor removed the silt by damming the outflow and vacuuming up the silt. Some removal was done by flushing the storm drain and collecting the silt at the dammed outflow. Cleanup was completed to the California Fish and Game Department's specifications.

## D. Radioactive Effluent Monitoring Summary

### 1. Liquid

As stated in Section III-A-5, water containing radioactivity is not routinely released from the site. However, water from the BSY sumps must be pumped occasionally because of the accumulation of water from small leaks or drainage due to modification or repair of the cooling systems. Samples from these sumps are collected and sent to a certified analytical laboratory for analysis. The water is pumped to a holding or transfer tank and released to the sanitary sewer. There were no releases during 1985. Because of heavy construction the sewer sampling station has been out of service. This station will be reestablished late in 1986.

### 2. Airborne

During 1985 0.138 curies of radioactive gas were released from the BSY. The offsite average concentration for the year was $< 2 \times 10^{-12}$ Ci/m$^3$ which is 0.02 percent of the technical standard.

## E. Dose Assessment from Neutron Monitoring

Four PM stations have been out of service for the entire year because of heavy construction. PMS 1 and 5 have been operational. Also, the gamma sensor at PMS-1 has been modified to test a neutron counter that may permit a more precise evaluation of neutron dose from SLAC skyshine. This unit is being tested under actual environmental conditions.

## F. Ground Water Monitoring

### 1. Non-radioactive

There are presently no local, state or federal regulations requiring ground water monitoring at SLAC for non-radioactive compounds or elements.

Table III-6

Annual Penetrating Radiation Dose Measured

Near SLAC Boundaries for 1985

| PMS | Gamma (mrem) | | | Neutron (mrem) | | |
|---|---|---|---|---|---|---|
| No. | Total | Background | Net | Total | Background | Net |
| 1 | OS | OS | | 19.7 | 13 | 6.7 |
| 2 | OS | OS | | OS | OS | |
| 3 | OS | OS | | OS | OS | |
| 4 | OS | OS | | OS | OS | |
| 5 | 75.3 | 70.0 | (a) | 15 | 12 | 3.0 |
| 6 | OS | OS | | OS | OS | |

(a) Within normal fluctuation of background radiation.
OS = Out of service.

### 2. Radioactive

SLAC instituted a ground water monitoring program in 1965. Some of the wells used to define geological formations for construction purposes were used to sample well water to document a background level. Since that time, many of these wells have been abandoned. We have maintained three wells near major beam absorbers to document that induced radioactivity or leakage of radioactive water is not a problem. Because of construction samples were not analyzed during 1985. We will resume samples and analysis about September, 1986.

# APPENDIX A

## Atmospheric Dispersion Model

In 1966, an independent evaluation of meterological regimes at SLAC was performed.[4] From this study, an empirical mathematical model was developed. The model that is used predicts the centerline concentration very well, but overestimates the total dosage values.

$$\frac{\chi P}{Q} = \frac{G}{u} \left(\frac{X}{X_0}\right)^{-1.75+[b(1-c)/u]}$$

where

$\chi P$ = centerline concentration (Ci/m$^3$)

$Q$ = source strength (Ci/s)

$G$ = 8 m$^{-2}$

$u$ = mean wind speed (m/s)

$X$ = distance from source (m)

$X_0$ = 2 m

$C$ = fraction of sky covered by low clouds

$b$ = 0.5 m/s day; $b = -1.2$ m/s night

Figure 4 summarizes peak concentration per unit source strength as a function of wind speed and atmospheric stability at a fixed distance of 400 meters (roughly the distance from the source to SLAC's boundaries). To characterize atmospheric stability, the degree of cloud cover is indicated for day and night time regimes. This method is based upon Pasquill's data for cloud expansion for various stability categories.

For a wind speed of 2 m/s atmospheric dilution factors – for determining centerline concentrations – range between $2 \times 10^{-5}$ and $1.5 \times 10^{-3}$ sec/m$^3$. For purposes of estimating radiation dose at the site boundary, neutral conditions are assumed, and a generally conservative dilution factor of $4.5 \times 10^{-4}$ sec/m$^3$ is used to calculate average concentration at the site boundary (see Fig. 4, curve 1.0).

# APPENDIX B

## Model For Potential Dose Assessment

According to Department of Energy orders, an assessment of whole body man-rem dose to the general population near SLAC is required where appropriate. Our site boundary dose due to accelerator operation has generally been less than 10 mrem per year from penetrating radiation. We have estimated the population size to include individual annual doses down to 1 mrem, which corresponds to a distance of approximately 1.6 km from a central point representative of the source of neutrons. The 1 mrem value is approximately one percent of the total natural background dose, and one percent of the technical standards for the general population (DOE Order 5480.11).

There are three major pathways leading to human exposure from ionizing radiation: (1) airborne, (2) food chain, and (3) direct exposure to penetrating radiation. Of the three major pathways listed above, only direct exposure to penetrating radiation is of any measurable significance from SLAC operations. The source of this exposure is from neutrons resulting from the absorption of high energy electrons and photons in the experimental areas creating energetic particles, some of which escape from the heavily shielded enclosures.

In order to make an accurate and realistic assessment of radiation exposure to the public at low doses, it is necessary that exposure from the natural radiation environment be known. This is true because the instruments used respond to natural radiation sources as well as man-made sources, and the portion due to natural radiation must be subtracted from the total measurement. The population exposure assessments appearing in this document are, in all cases, overstatements of the true impact. Hence, the resulting values are representative of an upper limit of the possible range.

While the annual neutron dose from accelerator operations at the site boundary has generally been measurable, it has always amounted to less than 10 percent of the total annual individual dose from natural background radiation. According to an EPA report, the average dose from cosmic, terrestrial, and internal radiation in California is 125 mrem. For purposes of comparison, we have rounded this number to 100 mrem.[5]

Another quantity of interest is the population dose in units of man-rem. This is simply the product of average individual dose and the total population exposed. For example, if there are 1000 people exposed to an average annual background dose of 0.1 rem (100 mrem), then the population dose is $0.1 \times 1000$, or 100 man-rem from natural background radiation. The annual variation of exposure to natural background radiation may vary by ±20 percent, largely caused by the difference of naturally occurring uranium, thorium, and potassium present in the ground and in building materials where people live and work.

There are two major problems associated with this dose assessment that affect overall accuracy of the measurement. First the conversion of neutron flux to dose requires that the spectrum of neutrons at the measurement point be known because the quality factor QF is a function of neutron energy. Because of the very low neutron fluences at the SLAC boundary and beyond it is impossible to measure the energy spectrum. Therefore we have selected a QF of 10 as a conservative choice. We feel that this choice leads to an overestimate of the neutron dose-equivalent by a factor of approximately 2. Until a useful experiment can be performed, with neutron yields of sufficient intensity, the quality factor cannot be determined with any better precision.

A second problem is the behavior of neutrons at large distances. Most of the high energy accelerator laboratories have made measurements. They are unique to each facility because of design differences, type of machine, and surrounding topography. Here, again, we have chosen a conservative formula for calculating the dose at distances other than the point of measurement. Lindenbaum[6] gave a method for evaluating skyshine neutrons which was later verified by Ladu et al.[7] using Monte Carlo techniques. Lindenbaum approximated the falloff by $\frac{e^{-R/\lambda}}{R}$ where $R$ is distance in meters from the source and $\lambda = 250$ meters. This equation fits the SLAC data fairly well, and is the one used to predict doses beyond our measuring station (Fig. 5). We feel that the methods used and reported in this document may overestimate the true population dose by at least an additional factor of 2.

The population activity close to SLAC, i.e., within 1.6 km, is a mixture of commerce and residential dwellings. The occupancy factor – the proportion of time throughout the year that these structures are occupied – is assumed to be 1/4 for business activities, and 1.0 for private dwellings. The number of people is estimated for each type of structure, multiplied by the occupancy factor, and summed to estimate the total population that might be continuously present.

According to the 1980 census the city of Menlo Park has an average population density of 602 persons per square kilometer ($km^2$). The populated area impacted by this source term is 1.5 $km^2$. Therefore the population total is 920 people. Previous estimates have resulted in a larger number by a factor of 2 which is a function of the analytical model used. For purposes of estimating the population dose we have rounded the calculated number to 1000 people.

# APPENDIX C

## Calibration and Quality Assurance Procedures

The natural background radiation provides continuous verification that the monitoring equipment is connected and functioning properly. During accelerator downtime and any interrupted operation background radiation provides a calibration base-line as well.

A regular calibration procedure was initiated in 1984 using two small radioactive sources. The sources are placed at a measured distance to produce a known dose equivalent rate. The equipment is kept in normal operation during these checks. The printer is marked so the calibration data is not confused with normal measurements. This procedure will be repeated twice each year and following equipment repair or maintenance. Also, response to natural background radiation provides proof that the instruments are operating properly.

### Airborne Radioactive Monitoring Equipment

Dose-equivalent from gaseous radioactivity reaching the site boundary, if large enough, would be detected by the PMS, which has its own quality assurance procedures.

The separate radioactive gas monitors for each ventilation fan are inspected and calibrated at the beginning of each accelerator cycle. They are calibrated with a small radioactive source. During operation, the natural background radiation response assures that they are operating properly.

All water samples are analyzed by certified analytical laboratories which have their own documented quality assurance procedures.

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