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RADIOLOGICAL AND MICROWAVE PROTECTION AT NRL

JANUARY 1981 - DECEMBER 1981

INTRODUCTION

This report summarizes the administrative, operational, research, and consultative activities of the Health Physics Staff, Code 6070, for the calendar year 1981.

The Staff has defined each of its major responsibilities and technical functions as programs or projects and periodically publishes the entire Program Summary-Progress Report. The last Program Summary-Progress Report was published in 1980 as NRL Memorandum Report 4523. The next one is scheduled for 1985. The index on page 7 of this report will identify specific Staff programs or projects by program number. The progress of each program or project during the last calendar year is included in the appropriately numbered paragraph.

RESPONSIBILITIES

Staff and Sections

The Naval Research Laboratory uses over 200 RF-producing devices and 900 sources of ionizing radiation which include radioisotopes in microcurie to kilocurie quantities; depleted, normal, and enriched uranium; plutonium; accelerators; a cyclotron; 126 x-ray machines; and a high level radiation facility in pursuing its research activities.

The Health Physics Staff is responsible for providing a Laboratory-wide safety program for the possession and use of all sources of ionizing and microwave radiation. The Staff performs the technical monitoring, professional evaluation, and regulatory control activities required to implement the program.

The Head of the Health Physics Staff has received the responsibility and authority from the Commanding Officer to halt any hazardous radiological or microwave experimentation or operation in the interest of health and safety. He must report all significant radiological or microwave incidents to the Commanding Officer and act as the Laboratory's principal representative and advisor on matters of radiological and microwave safety.

In order to perform the technical monitoring, professional evaluation, and regulatory functions associated with these programs, the Staff is organized as follows:

The Research and Technical Support Section, Code 6072, performs applied research, primarily, the development and calibration of radiation

Manuscript submitted March 1, 1982.

dosimetry systems required by the radiological safety program or by other Laboratory and Navy groups. In addition, the Section provides consultation and assistance on dosimetry problems to Staff, Laboratory, and other groups. The Section also maintains and calibrates the fixed field instrumentation used in the radiological safety program and sets standards for the calibration of portable radiation detection equipment. The Laboratory's ambient air monitoring station is operated and maintained by the Section.

The Survey and Analysis Section, Code 6073, is responsible for the radiation monitoring of radio frequency devices, particle accelerators, x-ray equipment, and areas where radioactive material is used or stored. It conducts programs for personnel monitoring, bioassay, radioassay, and radiological safety training. The receipt and shipment of radioactive material; radioactive waste disposal; and source storage, leak testing, and accountability are other major responsibilities of the Section.

Radiological Committee

The Radiological Committee plays an important role in Staff activities in that a subcommittee of research scientists reviews, on a day-to-day basis, the proposed procurement and use of sources of ionizing radiation. The full committee, composed of four civilian scientists, one Naval Officer, the Safety Officer, the Medical Officer, and the Head of the Health Physics Staff advises on radiological safety regarding pertinent regulations and instructions and is a reviewing committee for radiological incidents.

The current membership of the Radiological Committee is:

Dr. K. W. Marlow	Code 6610
Dr. C. H. Cheek	Code 4330
Dr. G. Cooperstein	Code 4773
Dr. J. D. Kurfess	Code 4510
Mr. H. E. Watson	Code 6394
Mr. H. C. Kennedy	Code 2010
Mr. J. N. Stone	Code 6070
CDR B. D. Uber	Code 2300
Medical Officer	Code 9005

Pertinent Regulations

- NRLINST 5400.14G, 8 December 1981, Part III. "Organizational Manual", - description of Code 6070, Health Physics Staff.

- NRLINST 5420.1P, 23 April 1980, "NRL Boards and Committees", Section 18, Radiological Committee - describes function and responsibilities.
- NRLINST 5101.2E, 4 January 1982, "Responsibilities for Nuclear Safety", - assigns responsibilities and defines nuclear safety program for NRL.
- NRLINST 5100.11C, 8 August 1978, "Radiological Safety Manual", - describes responsibilities and promulgates regulations for radiological protection and control.
- NRLINST 5100.14B, 28 July 1978, "Radiofrequency Safety Program", - protection program for use of non-ionizing radiation-emitting equipment.

ADMINISTRATIVE

Funding

		Overhead (14 People)	
FY 1981		FY 1982	
<u>(Expenditures)</u>		<u>(Budgeted)</u>	
Salaries/Wages	446.1K	Salaries/Wages	441.0K
• Overtime	0.0	Overtime	0.2
Materials/Supplies	62.7	Materials/Supplies	85.1
Travel	3.2	Travel	3.4
Depreciation	3.3	Depreciation	0.7
Tuition	1.3	Tuition	1.1
RCD Services	14.6	RCD Services	17.0
TID & Library Svcs.	2.8	TID & Library Svcs.	2.5
SYS Transfer-Debit	2.3	Communications	9.5
		Copy Machines	1.2
		Other Cont. Svcs.	11.0
TOTAL	536.3		
		TOTAL	572.7

Personnel Actions

Mrs. Gail F. Harmon was promoted to GS-6 Secretary (Typing) on January 11.

Mr. C. D. Forrest, a GS-8 Electronic Technician, transferred to the Washington Navy Yard effective February 7.

Mrs. Ellen Cox, a Clerk-Stenographer, was transferred to the Staff from the intermittent pool on February 19. She terminated this assignment on August 31.

Mr. K. J. King was promoted to GS-12, Health Physicist, on May 31.

Mr. S. G. Gorbics completed 25 years of NRL and federal employment on June 12, while Mr. T. L. Johnson qualified for 20-year awards on June 16.

Miss Kimberly Lowry, a high school student participating in the American University Summer Research Participation Program at NRL, reported and was assigned to the Research and Technical Support Section on June 23. She completed this assignment on August 14.

Mr. R. N. Davis was promoted to GS-9, Health Physicist, effective December 15.

Publications and Presentations

T. L. Johnson, "Measurement of Radiation-Integration Dosimetry", presented to the American Board of Health Physics Certification Course at the Armed Forces Radiobiology Research Institute, Bethesda, Maryland, March 1981.

J. N. Stone, T. L. Johnson, and R. B. Luersen. "Radiological and Microwave Protection at NRL", October 1979 - December 1980", NRL Memorandum Report No. 4523, May 1981.

Steven G. Gorbics, Albert E. Nash, and Tommy L. Johnson, "Use of an Albedo Neutron Personnel Dosimeter for X- and γ -Ray Monitoring, Health Physics, Vol. 40, pp 811-821, June 1981.

T. L. Johnson and S. G. Gorbics, "An Iterative Perturbation Method for Unfolding Neutron Spectra from Bonner Sphere Data", presented at the Annual Health Physics Society meeting, Louisville, Kentucky, June 1981.

K. J. King, "Environmental Monitoring for Gamma Radiation at the Naval Research Laboratory - 1980", NRL Memorandum Report No. 4561, July 1981.

T. L. Johnson, "An Iterative Perturbation Method for the Solution of Simultaneous Equations", presented at the National Bureau of Standards, Gaithersburg, Maryland, August 1981.

Travel and Training

Mr. A. Stamulis attended the EPA National Symposium, "Monitoring Hazardous Organic Pollutants in Air" in Raleigh, North Carolina, from April 27 to May 2, 1981.

Mr. R. N. Davis completed a two-week training course "NEESA Radiation Safety Officer (RSO) Course", presented by the Naval Energy and Environmental Support Activity in Port Hueneme, California, on May 4-15, 1981.

Mr. T. L. Johnson attended the annual Health Physics Society meeting held on June 21-26, 1981, in Louisville, Kentucky.

Facilities and Equipment

Building 208 - Twelve office and ten laboratory modules on the west end, first floor of Building 208 are occupied by the Staff.

Building 83 - At this facility, the Staff utilizes a 150/300 KV x-ray calibration unit and three ^{60}Co source wells (125.8 Ci, 4.5 Ci, and 0.03 Ci) for radiac instrument calibration and dosimetry research irradiations. Additional office and laboratory space for the Research and Technical Support Section is located here, also.

Building 89 - The Material Science and Technology Division controls this building, but permits the Staff to utilize one hot cell for inspection and leak test of high level radiation sources and for storage of NRL radioisotopes not being used by the authorized custodian. The contaminated protective clothing laundry is located here, as are facilities for the shipment and receipt of radioactive material and rad waste processing and storage.

Organizational Chart

1981
HEALTH PHYSICS STAFF

HEAD

HEALTH PHYSICS STAFF (6070)

J. N. Stone (GM-14)

ADMINISTRATIVE SECTION (6071)

Secretary (Typing)

G. F. Harmon (GS-6)

RESEARCH & TECHNICAL
SUPPORT SECTION (6072)

Section Head

T. L. Johnson (GM-14)

Research Physicist

S. G. Gorbics (GS-13)
A. E. Nash (GS-12)

Chemical Engineer

A. Stamulis (GS-12)

SURVEY AND ANALYSIS
SECTION (6073)

Section Head

R. B. Luersen (GM-13)

Health Physicist

K. J. King (GS-12)
W. J. Powers (GS-12)
E. X. Rank (GS-12)
R. N. Davis (GS-9)
J. M. Averitt (GS-7)

Physical Science Technician

E. D. Snyder (GS-11)
P. J. Kasko (GS-9)

STAFF PROGRAMS AND PROJECTS

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- 2.2 Air Pollution Monitoring

- 3.1 Personnel Monitoring
 - 3.1.1 Personnel Accident Dosimetry
 - 3.1.2 Perimeter Radiation Monitoring
- 3.2 Accelerator Monitoring
- 3.3 Radioassay
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- 3.5 Radiac Instrumentation
- 3.6 Radiological Safety Training Program
- 3.7 Radiofrequency Radiation Monitoring
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- 3.9 Radioactive Material Receipt-Shipment
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- 3.11 Radioactive Decontamination
- 3.12 Radioactive Source Storage
- 3.13 Source Leak Testing
- 3.14 Source Accountability Program

Research and Technical Support Section (6072)

2.1 Research Projects

A. Determination of Scattered Neutron Spectra

In cooperation with the National Bureau of Standards, we began a project to determine the scattered neutron spectrum in concrete rooms. Knowledge of the scattered spectrum is important for personnel protection, for the prediction of induced activity, and for the proper calibration of radiation detection instruments, which, by necessity, are almost always calibrated in concrete rooms. Using "Bonner" spheres (a thermal neutron detector in the center of polyethylene spheres of various sizes), the scattered spectrum has been determined in four concrete rooms of various sizes. The spectra are unfolded from the Bonner sphere data using the iterative unfolding program YOGI developed at NRL. The general method of separating the source and scattered spectra is described in Health Physics (in press). A second publication in preparation compares the experimental NRL data with the NBS calculations. A third publication, describing the variation of the spectra with room shape and the position in the room, will be presented at the annual Health Physics Society meeting in Las Vegas in June 1982.

B. Computer Analysis of Thermoluminescence Glow-Curves

Since 1976, NRL has used a personnel dosimeter badge that requires only two LiF(TLD-600) detectors for the measurement of gamma rays, x rays, and neutrons. The neutron and gamma dose information is obtained by making two or more integrations during the readout of each detector. A problem with this system of glow-curve analysis is that differences in thermal contact between the detector and heating element cause shifts in the glow curves, resulting in errors in the integrations, the end points of which are determined by heating element temperature. In an attempt to solve this problem, Kimberly Lowry (a high school summer student) and Kirk King (Survey and Analysis Section), along with Steve Gorbics, have devised a prototype readout system in which the glow curves are digitized and analyzed by computer. The integration points are determined by analysis of the shape of the glow curve, thus reducing errors due to glow-curve shift in temperature. In addition, we have been able to reduce readout time from 30 sec to 15 sec with little loss of accuracy. Using a 30 sec readout, we have been able to determine the approximate exposure history of a detector by analyzing the glow curve shape using the iterative perturbation program, YOGI, originally devised for unfolding neutron spectra. Corrections for fading can then be made depending on the time of exposure and the type of radiation, fading being greater for neutrons than for gamma rays. These results will also be presented at the Health Physics Society annual meeting.

C. Shipboard Neutron Dosimetry and Spectrometry

In an extension of previous work, in which we have characterized approximately 50 neutron spectra produced by moderating Cf-252 fission or Am-Be neutron sources with steel and/or Lucite, lower energy spectra, such as those found on ships and submarines, have been generated.

We have accomplished this by moderating a Cf-252 source in a steel sphere 60 cm in diameter. The spectrum is further moderated by adding up to 10 cm of Lucite, and the thermal component is adjusted by adding sheets of cadmium. We plan to publish a compendium of neutron spectra suitable for calibrating all types of neutron dosimeters and instruments.

D. X-Ray Spectrometry

The feasibility of using YOGI, our iterative perturbation method of solving simultaneous equations, to determine pulsed x-ray spectra with thermoluminescent dosimeters and absorption filters has been investigated. Preliminary computer studies have been completed to determine optimum filter materials and thicknesses. Based on previous experimental results obtained several years ago, we will probably need to calculate, or have calculated, new response functions for the TLDs in various thickness filters. Preliminary data, obtained using an x-ray machine and currently available response functions, are encouraging, however.

E. YOGI Computer Program

Our iterative perturbation program YOGI, originally devised to unfold neutron spectra from Bonner sphere data, has been improved by adding an automatic search for "physically reasonable spectra". We plan to publish this version in an NRL report. As described in previous sections, we are also using the program for other purposes. The program is also in use at various other laboratories, and has even been used to replace more conventional linear programming methods for optimization of production processes.

2.2 Air Pollution Monitoring

The air monitoring station functioned normally throughout the year gathering data on the concentrations of ozone, sulphur dioxide, nitric oxide, nitrogen dioxide, other nitrogen oxides, methane, total hydrocarbons, and carbon monoxide. In addition, air temperature, relative humidity, and wind speed and direction were also measured. The data gathered was disseminated to various groups, including the Environmental Protection Agency.

The Chemistry Division used the air pollution data in their studies on weathering of charcoal filters. The ozone concentrations were used by the Optical Sciences Division in their studies on ultraviolet transmission in the atmosphere. The concentrations of the major air pollutants measured at the station during the past five years are summarized in Appendix A.

Survey and Analysis Section (6073)

3.1 Personnel Monitoring

The Personnel Monitoring Program is established for the purpose of evaluating radiation exposures to personnel working in a wide variety of

radiation environments at NRL. The program, also, provides important information for controlling exposures to radiation and the overall effectiveness of our radiological safety program.

The needs of the program are set forth in both federal and Navy regulations. Title 10, CFR, Part 20.202, and NAVMED P-5055, Radiation Health Protection Manual, require the Laboratory to provide personnel monitoring devices to individuals working with sources of ionizing radiation.

During 1981, the Staff used thermoluminescent dosimeters (TLD) for determining occupational radiation exposures to Laboratory personnel.

The TLDs are evaluated monthly for the Cyclotron, Linac, High Level Radiation Laboratory, and our own Staff. The rest of the dosimeters (about 330) are processed on a quarterly schedule. We maintain a shorter processing schedule for the aforementioned facilities because over 90% of our occupational exposures occur at them. A monthly determination permits management of each facility more latitude in adjusting work schedules and allows our Staff to change the amount of surveillance in order to keep exposures as low as possible.

The results of the personnel monitoring program for 1981 are as follows:

Employees receiving no measurable exposure	. . . . .	370
" " measurable exposure < 0.1 Rem	. . . . .	34
" " 0.1 to 0.25 Rem	. . . . .	12
" " 0.25 to 0.5 Rem	. . . . .	9
" " 0.5 to 0.75 Rem	. . . . .	2
" " measurable exposure > 0.75 Rem	. . . . .	0

During 1981, no employee exceeded the exposure limits of 1.25 Rem per quarter as described in 10 CFR, Part 20.101, and NAVMED P-5055, Ch. 4-3. All exposures greater than 0.005 Rem are considered measurable.

The Staff, once again, will participate in a test to evaluate dosimetry processors. This test, like the previous two, will be conducted by the University of Michigan to determine the impact of several significant changes made in the standard following completion of the first two tests.

3.1.1 Personnel Accident Dosimetry

The Personnel Accident Dosimetry Project provides an accident dosimeter for individuals who do not work with radioactive materials or who, in the course of their work, do not enter radiation areas. In the case of radiation workers, this project supplements the regular personnel monitoring program.

At present, all "permanent" Laboratory employees are receiving two teflon discs containing thermoluminescent phosphors in their security I.D. badge. The discs are wrapped in aluminum and positioned in the lower left-hand corner of the I.D. badge. When employees, who are issued this

dosimeter, complete their employment at the Laboratory, their security badges are returned to the Staff for filing. Should any of these employees, at a later date, claim that they received an exposure from radiation while working at NRL, we can pull their badge from the file and evaluate the discs.

3.1.2 Perimeter Radiation Monitoring

An NRL Memorandum Report, No. 4561, entitled "Environmental Monitoring for Gamma Radiation at the Naval Research Laboratory - 1980" was published this year. Data for the 1981 fence-line monitoring program will be tabulated and submitted for a memorandum report. One of the results of the 1981 study was a comparison between two different dosimeters. One, a $\text{CaSO}_4:\text{Dy}$ wafer currently being used in the program, was compared to the TLD dosimeter (LiF) being used in our personnel monitoring program. The results indicated that the TLD dosimeter outperforms the $\text{CaSO}_4:\text{Dy}$ wafer; thus, we will switch to the TLD (LiF) type dosimeter in 1982.

Air samples taken on the roof of Building 208 during 1981 showed some interesting isotopes. They were: ^{141}Ce , ^{144}Ce , ^{103}Rh , ^{106}Cs , ^{127}Zn , ^{95}Nb , ^{95}Nb , and ^7Be . With the exception of ^7Be , which is produced by the interaction of cosmic rays with atmospheric nuclei, all of these isotopes are the results of an atmospheric nuclear detonation in China around October of 1980. These samples were collected on 8" x 10" Whatman glass microfiber filters at an average air flow of 8.1×10^{15} cc/month. The highest concentration of any isotope detected was ^7Be at a level of 3.2×10^{-14} $\mu\text{Ci/cc}$ of air.

3.2 Accelerator Monitoring

Accelerator monitoring is the detection and measurement of specific radiation or group of radiations in and around the various accelerators at NRL. It involves the use of standard radiation detection equipment, which may be modified to make as convenient as possible the particular measurement required.

Although particle accelerators do not come directly under NRC regulatory control, the fact that NRL operates under a byproduct license necessitates a monitoring program. According to Title 10, CFR, Part 20.101, other sources of radiation in the licensee's possession must be considered in exposure limits governing radiation workers.

Personnel working with accelerators necessarily receive some exposure to radiation. Hopefully, the many radiation surveys and good operating practices will hold these exposures well below the approved limit. However, chances to receive larger amounts do exist and, thus, it is necessary to maintain an extensive monitoring program to prevent this possibility.

Idealistically, an effective program should provide the maximum amount of radiation safety while allowing the various facilities to function at their maximum capacities with a minimum amount of interference. During 1981, a rigorous health physics surveillance program was maintained at all of NRL's accelerators. The following summarizes some of the highlights at the various facilities:

A. Cyclotron

Routine surveillance at the Cyclotron indicated that activation of the machine components still present to operating personnel some unusually high radiation levels, while contamination levels are still quite low. Water leaks inside the accelerator continue to be the major problem for the operating staff. A typical example of this problem would be a succession of leaky coaxial beam extractors that required several pull backs of the RF resonate tank. Fortunately, the machine had received limited use prior to the start of these leaks and so activation and contamination levels were lower than normal. The coaxial itself was fairly active (≈ 300 mR/hr) and so working on it resulted in personnel doses of a few hundred mRem to two of the Cyclotron staff.

The NIH group has proposed making ^{18}F by an (α, np) reaction off the oxygen in water. This experiment has been reviewed and approved by the Radiological Committee. Currently, NIH is producing ^{13}F with a (d, α) reaction off of ^{20}Ne .

Working with the NIH staff has produced several improvements in the experiment over the past year. The radiation dose to the personnel doing the processing has been cut in half. A new carbon filter was installed on the fume hood used for the chemical separation of the ^{19}F by NIH personnel. This filter has cut the emissions from the process by a factor of 10 as measured in the exhaust air duct leading to the roof.

The Plasma Physics group has moved into the space vacated by the Manta people at the Cyclotron facility. Prior to moving their machines to this building, the Staff made several attempts to calculate the shielding requirements that would provide adequate shielding for operating personnel. Unfortunately, the proposed parameters and locations of the machines were changing faster than we could calculate; consequently, we produced a series of graphs that roughly gave the shielding needs for various combinations of machine parameters and placement. One of these machines, an inductive linac, is nearing completion and should be operational soon. A second machine, known as a "Racetrack" accelerator, is still in its final design stages; thus, shielding calculations have not started on this machine. Until the "Racetrack" is built, a Febetron (x-ray producing machine) is being used instead. Calculation and preliminary survey show that there is little radiation escaping from this machine. The area around the Febetron has been roped off and TLD survey badges have been placed around the machine.

Another machine, the Seven Ohm Line, was installed in an area outside Room 3 and is operational. The interlocks and shielding have been approved by the Radiological Committee. A preliminary survey indicated that some radiation was being scattered from the ceiling, but that the overall dose levels outside the shielding enclosure were very low. Because of the low dose rates, no additional shielding will be required for this machine.

During our conversations with the Plasma Physics groups, their people continue to talk about higher and higher energy machines so our

Staff is continuing to study the physics of shielding accelerators with energies greater than 100 MeV. Shielding calculations at these energies are complicated by the onset of pion production, with the resulting nuclear cascade.

B. Linac

The electron scatter experiment has been completed. The beam line, along with the experimental apparatus, has been removed from Room 103A. All of the equipment was smeared and checked for activation before removal. With the exception of some small residual activation of the target chamber and parts of the beam line, all of the equipment was free of activity. The activated parts were kept at the facility. Removing the beam line left a hole in the shielding wall between the accelerator room and the experimental room. This hole was plugged, and when the Linac was operated at a power level sufficient to produce high radiation levels, the integrity of the plug was found acceptable.

A minor incident occurred at the Linac during the year. During an irradiation of high explosives, the type of explosive was changed from a very stable type to an unstable one. Unfortunately, nobody mentioned this to the Linac operator, and the resulting explosion blew large chunks out of the back of the machine. One of the chunks came out of the water-cooled window which was being used at the time, so the Linac promptly filled up with water. The machine was down for several weeks while the operation staff dried it out. We took water samples and conducted smear surveys at the time, but no contamination was found.

C. Waldorf

The Waldorf Site has been closed. All of our equipment has been removed after it was smeared and found to be free of contamination. General lab equipment, such as work benches and lockers, were smeared and left in place for the persons who take over the facility. The neutron generator was dismantled and disposed of as contaminated waste.

In all, very little contamination was found. Even cutting up the generator did not cause any great concentration of tritium in air. The maximum concentration measured was about 10^{-3} $\mu\text{Ci/cc}$, and that was for only a brief period while the target was removed and placed in a tin can. The small amount of contamination that was found on the floor and on a couple of tables was cleaned up, and the site was left free of contamination.

3.3 Radioassay

The radioassay program is designed to furnish, for the Staff, the amount of radioactive material and/or contamination in any sample submitted for analysis. The program is capable of performing both qualitative and quantitative analyses on all samples.

The need and significance of the program is generated by Title 10, CFR Part 20. In general, the regulations require all licensees to determine the radioactive content of all gases, liquids, and solids prior to discharging them to the environment.

For this year's radioassay program, we spent a great portion of our time adapting our DEC-10 computer program to our own computer, writing new computer programs, determining efficiencies for various samples, comparing different sample counting configurations, evaluating the response of various detectors, and updating our counting equipment. Following is a brief summary of these efforts:

A. Computer Programs

Some of the new computer programs will allow us to calculate the tolerance limits for the counting equipment reliability testing; compute the least-square fit of a set of data points to a hyperbola, parabola, and straight line; and to determine the amount of fading that takes place in a dosimeter exposed to gamma and/or neutron radiation.

B. Standards

New radioactive standards were prepared and used to determine new efficiencies for sample configurations with different detectors. These new efficiencies were placed in the various computer programs for use in determining sample activities.

C. Equipment

A new lithium drifted germanium (GeLi) detector was received, installed, and calibrated. In addition, a new linear amplifier and high voltage power supply were purchased and installed. The old GeLi detector has been installed in a new lead shield and will be used to count environmental samples, and as a backup detector to our primary system. Also, two new gas flow proportional counters were received and tested during this year. These new counters allowed us to replace equipment that was over twenty years old.

3.4 Bioassay

The bioassay program is basically the examination of some part of the body or its products.

The need for the bioassay program is generated by Title 10, CFR Part 20.108. In general, this regulation requires all licensees to determine the extent of an individual's exposure to concentrations of radioactive material. It further directs the licensee to make available to the individual appropriate bioassay service.

During the year, 33 individuals were sent to the National Institutes of Health in Bethesda, Maryland, for whole body counts. The results of these counts indicated that all individuals were well below the maximum permissible body burdens for all radionuclides.

A urinalysis was conducted whenever an individual was working with radioactive materials that were easily taken up by the body, or in an area where airborne concentrations were likely. The selection of individuals for urinalysis is determined by the Staff's health physicists. The levels of internal radiation detected in all urine samples during 1981 were below the maximum permissible body burdens.

3.5 Radiac Instrumentation

The instrumentation provided by this program is used to measure the absorbed dose and exposure rates of the various types of ionizing radiation in an area that may be occupied. In addition to providing instruments, this program assures that the various instruments are in proper working condition and are calibrated. Also, this program makes every attempt to anticipate the instrument needs of the Staff before the need materializes.

During 1981, all portable instruments were serviced and calibrated every nine weeks. The fixed monitors located throughout NRL were calibrated every three months.

3.6 Radiological Training

This program is designed to provide adequate training in Radiological Safety to: (1) all personnel involved in emergency response at NRL; (2) scientists and technicians at NRL whose duties involve the handling or use of radioactive sources; and (3) outside activities as requested, and as time permits.

During 1981, routine indoctrination for all new employees was performed on a monthly basis. Radiation safety classes were held for the operators of the Linac and Cyclotron. The classes dealt with the biological effects of radiation and transportation of radioactive materials. A training session was also given to the Beam Dynamics (Code 4740) group. The session was given in two parts; the first detailed the NRL radiation safety regulations, while the second dealt with the biological effects of radiation.

Several radiation safety lectures were given to the incoming summer employees working around accelerators.

3.7 Radio Frequency Radiation Monitoring

This program evaluates and controls personnel exposure hazards associated with the operation, modification, or repair of radio frequency (RF)-emitting equipment.

Experiments have shown that short exposures to RF and microwave radiation at certain power levels will cause significant damage in human tissue. To assure that these hazards are acknowledged, the Navy has established RF safety procedures and exposure limits designed to prevent hazardous exposures at any power level and/or time interval. This program assures that NRL's RF and microwave equipment is operated in accordance with Navy regulations.

Several comprehensive microwave and RF surveys were performed on a wide variety of equipment this year. Some of the equipment surveyed included the flat plate antenna located on the roof of Building 2 at CBD; several "J" and "I" band radar units, plus a tracker radar; and a step frequency unit located in the vans at Building 2, CBD. At the main site, a survey was made on an "X" band radar used in a microwave-pumped laser

located in Building 101. In Building 210, the Advanced Electronic Warfare System was evaluated for RF leakage. At Pomonkey, Maryland, the Traveling Wave Tube Amplifier system was surveyed for excessive power densities.

In all of the surveys conducted, no power density levels above the limit of 10 mW/cm² were detected.

During 1981, all microwave ovens were surveyed quarterly in accordance with NRLINST 5100.14B. None of the ovens exceeded the acceptable limit of 5 mW/cm² at any given point 5 cm or more from any external surface of the oven.

3.8 Radiological Monitoring

Radiological monitoring is the means by which radiation and/or contamination hazards associated with the production and use of radioactive material, or the operation of ionizing radiation-producing equipment, are detected, evaluated, and controlled. Progress summary details for this program are contained in the following three projects.

3.8.1 X-Ray Monitoring

The X-Ray Monitoring Project evaluates and controls the radiation hazards associated with the operation of x-ray equipment by means of routine and special surveys.

Thirty-two routine surveys of diffraction units, electron microscopes, irradiators, pulsed x-ray sources, and spectrometers found no hazardous radiation levels in occupied areas.

Surveys continued on the Pulserad machine in Building 101. At this facility, an electron beam is injected into air, producing significant amounts of low energy x-rays. Concrete walls have been added to some areas of this facility, but radiation levels are not significant in occupied areas, and rooms next to the machine are evacuated for each shot; hence, distance, rather than shielding, is used to prevent personnel exposure.

Surveys also continued on the Autoaccelerator machine in Building 71E as they attempt to reach higher voltages. Problems with the Max generator and switches have prevented going higher than 3 mV on the generator with a maximum of 5 Mev electron energy being achieved. Integrated exposures inside the shielded machine room were above 1 R, but the exposures on either side were negligible — 5 mR in the control room, and about 30 mR in the corridor/storage area.

Gamble II is being readied for high intensity bremsstrahlung producing shots in late January 1982. This will be the first extensive x-ray producing series of shots since the shielding was modified and the room enlarged. The operators were asked to add lead shielding in several locations where present shielding is inadequate, such as around the ventilation ducts. Surveys will be made to assure that the revised shielding is adequate for the high intensity shots.

3.8.2 High Level Radiation Laboratory Monitoring

HLRL monitoring assures that the radiation and contamination hazards associated with the handling and testing of large quantities of radioactive material at that facility receive comprehensive radiological safety evaluation and control.

During the year, much of the work at this facility was directed toward completing NRC contracts and moving equipment from NRL to new NRC contractors. In concert with this work, we were disposing of excess or "junked" equipment by either decontaminating it or preparing it for disposal as radwaste. It appears that much of the equipment, which has never been used in the cells, can be deconned and disposed of normally, rather than as radwaste.

The back room was also cleaned up, the floor washed, and waste packed in drums. Air samples were taken during the cleaning and waste packing operations. Air activity was found to be less than the 40 hour maximum permissible concentration (MPC) for workers, even during the waste packing. Personnel involved wore coveralls, gloves, and boots at all times and, during waste packing, also used a supplied air hood for breathing.

In addition to the back room, Cells 2 and 3 were cleaned up after extensive maintenance operations were completed in them. Air samples were taken in the cells during this work and the maximum activity found was 8.3×10^{-10} $\mu\text{Ci/cc}$. The maximum individual isotopic concentrations were $^{54}\text{Mn} - 4 \times 10^{-10}$ and $^{60}\text{Co} - 1.5 \times 10^{-10}$ $\mu\text{Ci/cc}$. These values are at least a factor of 10 below the MPC values for a 40-hour work week. Coveralls, gloves, boots, and hood-supplied breathing air were also used in this operation.

Filters were changed in the absolute filter bank. Air activity in the housing was less than 10^{-12} $\mu\text{Ci/cc}$, and workers wore the usual protective clothing to avoid possible contamination. Air activity in the exhaust varied from 1 to 8×10^{-14} $\mu\text{Ci/cc}$ before the filter change, and dropped to less than 5×10^{-15} $\mu\text{Ci/cc}$ afterward. Several weeks after changing the filters, the air activity concentrations were back to 10^{-14} $\mu\text{Ci/cc}$. The detectable isotopes in these samples were ^{54}Mn , ^{60}Co , and ^{137}Cs .

3.8.3 General Area Monitoring

General area monitoring provides radiological services to facilities having Van de Graaff accelerators operating at voltages of less than 5 MeV, areas using large quantities of radioactive materials on an infrequent or inherently safe basis, and/or areas in which a number of sources with limited activities are used or stored.

Of the 115 Requests for Radiological Safety Review that were received and processed, 64 requested changes in source custodian/location, 30 requested the purchase of new sources/equipment, 16 were for irradiation services, and 5 were for the disposal of unwanted material.

The completion of 527 routine area smear and radiation surveys found no uncontrolled hazards to personnel. A total of 41 water and 212 air samples, taken in conjunction with the surveys, supported these findings.

The 200 Curie ^{60}Co irradiator was installed in Room 125 of Building 75. Surveys were made with the source in its operating position and, as expected, additional shielding was required on the far wall that was in line with the beam. After hanging lead sheets on the wall, the radiation levels in the room behind the wall were reduced to less than 2 mR/hr. Backscatter, at the doorway, from the far wall was less than 10 mR/hr, which is acceptable for a limited access radiation area. Additional surveys still need to be run to determine what the backscatter will be from various objects placed in the beam for irradiation. We do not expect any problems from the backscatter radiation.

3.9 Radioactive Material Receipt-Shipment

The movement of radioactive material is authorized and controlled to assure that shipments are packaged and labelled properly; the receipts are monitored, tagged, and delivered promptly; and that intra-laboratory transfers are accomplished safely.

Forty incoming shipments, totalling 764.4 Curies of various isotopes, and 90 outgoing shipments, totalling 77.3 Curies of various isotopes and 1.2 kg of depleted uranium, were handled without problems.

3.10 Radioactive Waste Disposal

This program provides for the collection, packaging, and disposal of solid waste and the controlled release of liquid waste to the sanitary sewer.

Thirty-two 55-gallon drums of low level radioactive waste were shipped to the state of Washington disposal site operated by U. S. Ecology. A total of 2.2 Curies was involved.

A total of 5000 gallons of liquid radioactive waste, containing 1055 microcuries, was released to the sanitary sewer from the hot cells at Building 71M. The concentration of isotopes in the released water was about 8×10^{-5} $\mu\text{Ci/cc}$ with the principle isotopes being ^{54}Mn and ^{60}Co . In addition, 600 gallons of liquid waste, containing one microcurie, were released from the hold-up tanks at Building 89 to the sanitary sewer.

3.11 Radioactive Decontamination

This program provides for the control and removal of contamination created by the use of radioactive materials at the Laboratory.

During the year, decontamination efforts were limited to those normally required by routine operations.

3.12 Radioactive Source Storage and Leak Testing

3.13

These programs assure that sealed sources held under USNRC licenses are leak tested, as required, and that unused radioactive materials are stored safely.

Completion of 237 source leak tests found none to be leaking.

There were 124 sources in storage at the end of the year. All of these sources are stored in Building 89.

3.14 Source Accountability

Source accountability is maintained by means of quarterly inventories conducted by source custodians and cognizant health physicists utilizing computer-produced listings of source location and description.

Quarterly source inventories were completed, as scheduled, and all sources were located.

At the end of the year, 120 custodians held 866 sources — 523 on Material License No. 8-1393-2, and 168 on Source Material License No. SMB-448. Also among their totals were 46 radium sources and 126 radiation-producing machines.

Appendix A

SUMMARY OF NRL AIR QUALITY DATA (1975 - 1981)

A. Stamulis

The NRL air monitoring station has been in continuous operation since January 1975. The housing, instruments in use, and method of analysis have been reported in NRL memorandum reports (1,2). The data gathered has been reported in yearly summaries for the calendar years 1975 - 1979 (3-7). Additional reports on various air quality topics have also been published (8-12).

The concentrations of the pollutants ozone, sulphur dioxide, non-methane hydrocarbons, and carbon monoxide for the years 1975 - 1981 are summarized in Tables 1 - 4. The concentrations of nitric oxide and nitrogen dioxides for the years 1979 - 1981 are summarized in Tables 5 and 6.

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TABLE 1
MONTHLY AND YEARLY AVERAGES OF OZONE (O₃) IN ppmv

Month	Year							Combined Monthly Average
	1975	1976	1977	1978	1979	1980	1981	
Jan	0.023	0.013	0.007	0.013	0.006	0.013	0.012	0.012
Feb	0.025	0.012	0.010	--	0.009	0.016	0.015	0.015
Mar	0.039	0.014	0.012	--	0.006	0.030	0.025	0.021
Apr	0.053	0.010	0.013	0.034	0.032	0.033	0.035	0.030
May	0.071	0.005	0.015	0.027	0.027	0.023	0.036	0.033
Jun	0.032	0.012	0.020	0.052	0.032	0.030	0.038	0.031
Jul	0.016	0.040	0.040	0.035	0.024	0.041	0.042	0.035
Aug	0.022	--	--	0.038	0.034	0.045	0.032	0.034
Sep	0.015	0.013	--	0.030	0.023	0.035	0.025	0.024
Oct	0.015	0.008	--	0.055	0.016	0.021	0.017	0.022
Nov	0.010	0.010	0.013	0.012	0.017	0.024	0.037	0.018
Dec	0.009	0.006	0.012	0.012	0.013	0.008	0.007	0.009
Yearly Average	0.026	0.013	0.014	0.031	0.021	0.031	0.026	

Combined Yearly Average (1975 - 1981) = 0.023

peak season - spring-summer
 peak month - July
 peak time of day - 2 p.m. - 3 p.m.
 prevailing wind direction(s) - NNW, SW, SSW
 yearly trend - increasing

TABLE 2
MONTHLY AND YEARLY AVERAGES OF SULFUR DIOXIDE (SO₂) IN ppmv

Month	Year							Combined Monthly Average
	1975	1976	1977	1978	1979	1980	1981	
Jan	0.044	0.042	0.052	0.028	0.028	0.030	0.045	0.038
Feb	0.047	0.038	0.029	--	0.019	0.030	0.017	0.030
Mar	0.042	0.027	0.023	--	0.026	0.034	0.013	0.028
Apr	0.024	0.024	0.023	0.016	0.017	0.026	0.009	0.020
May	0.021	0.017	0.020	0.013	0.015	0.019	0.006	0.016
Jun	0.028	0.015	0.020	0.014	0.013	0.018	0.006	0.016
Jul	0.030	0.026	0.023	0.014	0.013	0.018	0.012	0.019
Aug	--	0.026	--	0.015	0.012	0.016	0.012	0.016
Sep	--	0.035	--	0.024	0.013	0.013	0.013	0.020
Oct	0.024	0.019	--	0.029	0.015	0.014	0.012	0.019
Nov	0.025	0.035	0.015	0.029	0.018	0.016	0.014	0.022
Dec	0.034	0.036	0.022	0.091	0.022	0.039	0.019	0.038
Yearly Average	0.033	0.027	0.024	0.030	0.018	0.028	0.013	
Combined yearly average (1975-1981) = 0.025								

peak season - winter
 peak month - Dec-Jan
 peak time of day - 9 a.m. - 10 a.m.
 11 p.m. - mdn.
 prevailing wind direction - W
 yearly trend - decreasing

TABLE 3
MONTHLY AND YEARLY AVERAGES OF NON-METHANE
HYDROCARBONS (RHC) IN ppmv

Month	Year							Combined Monthly Average
	1975	1976	1977	1978	1979	1980	1981	
Jan	1.01	0.11	0.28	0.04	0.06	--	0.37	0.31
Feb	0.68	0.09	0.42	--	0.04	0.24	0.42	0.32
Mar	0.19	0.05	0.24	--	1.02	0.44	0.30	0.37
Apr	0.64	0.20	0.40	0.02	0.95	0.14	0.34	0.38
May	--	0.25	0.22	0.10	0.12	0.66	0.30	0.28
Jun	8.51	0.49	0.93	0.05	0.28	0.30	0.15	1.53
Jul	6.24	0.53	0.09	0.07	2.53	0.32	0.15	1.42
Aug	2.37	0.47	--	0.06	0.32	0.30	0.14	0.59
Sep	5.16	0.29	--	0.02	0.26	0.28	--	1.20
Oct	1.51	--	--	0.09	0.32	0.35	0.19	0.49
Nov	0.16	0.12	0.04	0.28	0.44	0.28	0.18	0.21
Dec	0.09	0.49	0.06	0.89	0.23	0.48	0.47	0.39
Yearly Average	3.00	0.29	0.25	0.12	0.55	0.33	0.21	

Combined yearly average (1975 - 1981) = 0.68

peak season	-	summer
peak month	-	June-July
peak time of day	-	7 a.m. - 8 a.m. 11 p.m. - mdn
prevailing wind direction	-	NNE, S, SW
yearly trend	-	decreasing

TABLE 4
MONTHLY AND YEARLY AVERAGES OF CARBON MONOXIDE (CO) IN ppmv

Month	Year							Combined Monthly Average
	1975	1976	1977	1978	1979	1980	1981	
Jan	1.93	1.58	1.92	1.45	1.42	2.97	1.32	1.80
Feb	1.50	1.32	1.22	1.10	1.67	--	1.46	1.38
Mar	1.31	0.98	3.77	--	1.80	1.33	1.16	1.73
Apr	0.87	0.68	0.63	1.10	1.75	1.30	1.06	1.06
May	--	0.54	0.32	1.24	1.08	1.45	1.15	0.96
Jun	1.15	0.33	0.98	1.06	0.98	0.79	1.10	0.91
Jul	1.20	1.23	0.95	1.06	1.59	0.77	1.12	1.13
Aug	1.69	1.81	--	1.25	0.96	0.87	1.13	1.29
Sep	0.72	1.92	--	1.14	1.26	0.93	1.50	1.25
Oct	0.89	1.65	--	1.56	1.63	1.02	1.21	1.33
Nov	1.52	2.67	1.17	2.25	--	1.12	1.18	1.65
Dec	1.58	1.79	1.62	1.52	1.99	--	0.97	1.58
Yearly Average	1.20	1.42	1.33	1.39	1.47	1.26	1.20	
Combined yearly average (1975 - 1981) = 1.32								

peak season - winter
 peak month - January
 peak time of day - 8 a.m. - 9 p.m.
 11 p.m. - mdn
 prevailing wind direction - NNE
 yearly trend - no change

TABLE 5
 MONTHLY AND YEARLY AVERAGES OF
 NITRIC OXIDE (NO) IN ppmv

Month	Year			Combined Monthly Average
	1979	1980	1981	
Jan	0.025	0.035	0.029	0.030
Feb	0.028	0.034	0.038	0.033
Mar	0.031	0.017	0.013	0.020
Apr	0.008	0.014	0.012	0.011
May	0.009	0.016	0.012	0.012
Jun	--	0.009	0.007	0.008
Jul	0.008	0.009	0.009	0.009
Aug	0.013	0.005	0.012	0.010
Sep	0.024	0.013	0.015	0.017
Oct	0.034	0.023	0.031	0.029
Nov	0.054	0.026	0.028	0.036
Dec	--	0.028	0.033	0.031
Yearly Average	0.023	0.020	0.021	
Combined yearly average (1979 - 1981) = 0.021				

peak season - winter
 peak month - November
 peak time of day - 7 a.m. - 8 a.m.
 11 p.m. - mdn
 prevailing wind direction - NNE, S
 yearly trend - no change

TABLE 6
MONTHLY AND YEARLY AVERAGES OF
NITROGEN DIOXIDE (NO₂) IN ppmv

Month	Year			Combined Monthly Average
	1979	1980	1981	
Jan	0.024	0.020	0.029	0.024
Feb	0.028	0.023	0.020	0.027
Mar	0.026	0.018	0.027	0.024
Apr	0.021	0.021	0.021	0.021
May	0.010	0.023	0.025	0.019
Jun	--	0.023	0.019	0.021
Jul	0.035	0.030	0.026	0.030
Aug	0.019	0.020	0.025	0.021
Sep	0.022	0.023	0.023	0.023
Oct	0.023	0.029	0.025	0.026
Nov	0.033	0.022	0.025	0.027
Dec	--	0.024	0.022	0.023
Yearly Average	0.024	0.023	0.025	
Combined yearly average (1979 - 1981) = 0.024				

peak season	-	summer
peak month	-	July
peak time of day	-	7 a.m. - 10 a.m. 7 p.m. - 8 p.m. 11 p.m. - mdn.
prevailing wind direction	-	NNW, NNE, NE
yearly trend	-	no change