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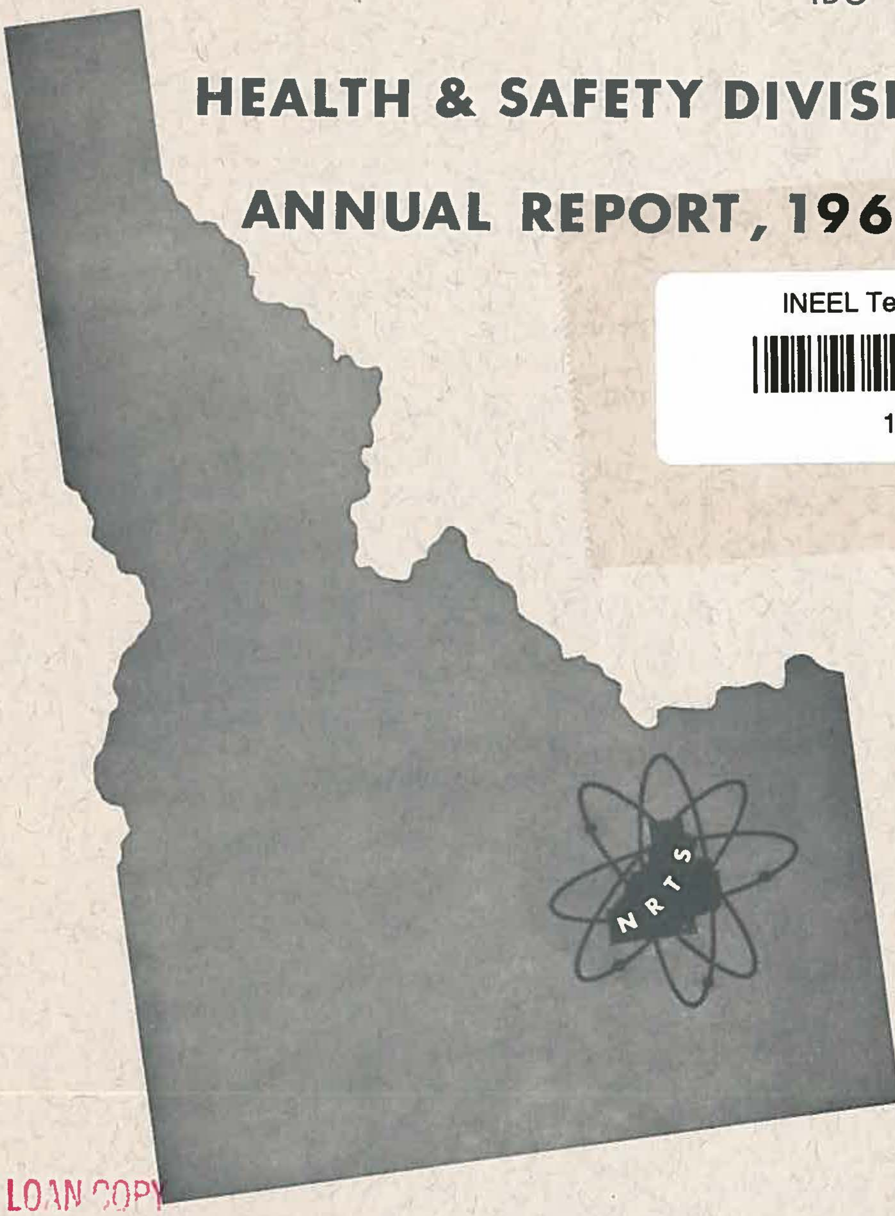
HEALTH & SAFETY DIVISION

ANNUAL REPORT, 1961



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HEALTH & SAFETY DIVISION
ANNUAL REPORT, 1961

John R. Horan
Director

Idaho Operations Office
U. S. ATOMIC ENERGY COMMISSION

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SUMMARY

Health Physics at SL-1. At the SL-1 accident early in 1961 health physicists encountered many "firsts" in health physics operations and management. Moreover, it enabled evaluation of how well the Health and Safety Division's preplanned program worked in a nuclear accident area. The experience of the rescue and cleanup crews working in a highly contaminated environment pointed out many valuable facts in health physics techniques and planning. There was opportunity to contrast remote and direct methods of performing operational and decontamination work.

Beyond the exposures received during the recovery of casualties, the nuclear status and cleanup operations were performed within the normal yearly operational exposure limits at the NRTS. Although a considerable quantity of finely divided radioactive debris was removed, there were no serious, and remarkably few, cases of personnel contamination.

Medical Services. In 1961 the Medical Services Branch's work was influenced by several factors which resulted in minor alterations in previous statistical trends. These factors include the expansion of the medical branch activities to provide physician services for Westinghouse Electric and General Electric facilities, the realization of IBM scheduling of physical and laboratory examinations, the decrease in the number of persons employed at General Electric and the general decrease in construction activity at the NRTS during the past year. The total number of CFA dispensary visits decreased about 2% compared to the previous year. The physical examination program expanded over 11%. A program to collect field samples for annual blood and urine screening tests on personnel in certain work locations was begun in the latter half of 1961. The laboratory work load increased 10% over the previous year.

The SL-1 reactor accident provided an unusual experience in the management of corpses contaminated with massive quantities of radioactive fission products. This experience has resulted in a number of major lessons which should be incorporated in the medical emergency plans, equipment and facilities in the atomic energy industry.

Personnel Metering. During 1961 the Personnel Metering Branch provided complete personnel metering service to 18 operating and construction contractors at 20 separate project areas. In addition, assistance was provided the contractors in performance of primary shield tests, steam generator case radioactivity measurements, high level calibrations and exposure determinations, and establishment of an average beta-gamma ratio for exposures in the SL-1 reactor building. Computer programs were compiled for interpretation of film badge results obtained during the SL-1 operation and for the reduction of analytical data for the Analysis Branch, and work was begun on a program for interpretation of telemetered data.

The radiation exposure experience at the NRTS during 1961 was the highest in its history due to the exposures received during the SL-1 operations. During the entire year approximately 1200 persons were utilized in the overall operation receiving average exposures of 2.02 rem beta and 1.12 rem gamma. A total of 35 persons exceeded the recommended Radiation Protection Guide for any quarter with 10 of these exceeding the annual Radiation Protection Guide. The highest individual exposure to penetrating whole body radiation during the year was 27.3 rem, while the highest accumulated skin dose was 88.1 rem. Eighty-one percent of all NRTS personnel received accumulated exposures to penetrating radiation of less than 500 mrem and only 0.41% received 5.0 rem or more including the SL-1 exposures. The average accumulated exposure to penetrating whole-body radiation for all NRTS personnel was 0.42 rem as compared to 0.29 rem in 1960.

Excluding the SL-1 exposures, the highest individual accumulated exposure to penetrating whole-body radiation for the year was 4.83 rem and the average for all NRTS personnel was 0.24 rem.

A total of 12,494 urinalysis results were recorded for 1961, of which only 4.0% were statistically significant. All were below 10% of the maximum permissible body burden for the isotope of interest except two. These two were between 10% and 20% and were the result of iodine-131 received during the SL-1 operation.

Analysis. The whole-body counting program and the application of high-speed electronic computers to automatic data handling showed the largest relative advancement of any activity. Both programs are in full stride and further advancement should be rapid. Investigation of the fluorometric determination of thorium was completed and application of the procedure to all ores of practical value and to air dusts and potable water was accomplished without separations of any kind. A laboratory and equipment for the geochemical studies of the Lost River Plain related to the waste management program at the NRTS were obtained and the first experimental plans initiated. Research in the development of new analytical procedures and in the chemistry of the transuranium elements was continued. Approximately 24,394 routine analyses of all types were completed.

Hazards Control. The Hazards Control Branch has the primary responsibility for the continued development and execution of an effective program encompassing the direct activities of IDO and the operational and construction contractor activities at the NRTS. To achieve an effective program, the branch has the specialized functions of safety engineering, fire engineering, fire department, industrial hygiene, and nuclear safety.

The Hazards Control Branch entered into the initial emergency response to the SL-1 accident and numerous aspects of assistance and collection of pertinent data in follow-up support. Safety and fire considerations were followed closely in subsequent work to recover the SL-1 reactor vessel and dismantling of the reactor building.

In development of assigned functions in disaster planning, attention has been concentrated on the type of disaster in which a centralized field control point would be established. Procedures and equipment have been re-evaluated from the SL-1 experience.

The SL-1 accident resulted in major increases in the overall NRTS severity rate and property damage statistics. Excluding this incident, all categories of injury and loss experience at the NRTS would have been significantly better than the average of all AEC activities.

The program for annual appraisals of operating contractors at the NRTS has proceeded satisfactorily. Continued progress in reaching "improved risk" standards was attained through design engineering on new projects and fire protection improvements in existing facilities. Research and testing of organic coolants, respirators, and in-plant filters has resulted in revised standards and controls significant to the operations. Extensive studies and reviews have been made for nuclear safety in the transport of fissionable materials.

Site Survey. The SL-1 accident had a major impact on the activities of the Site Survey Branch during the entire year. During the first few months, several of the branch programs had to be de-emphasized because of the higher priority of problems connected with the recovery operations. The contractor health physics appraisal program, which was initiated in the fall of 1960, was affected the most during that period. Another consequence was the increased emphasis on the importance of disaster planning. Not only did the accident provide an opportunity to evaluate the preparations to cope with a serious emergency, but many problems which had not been anticipated became apparent. In order to correct these deficiencies, much time and effort has been devoted to such things as emergency equipment procurement and modification, improved monitoring and personnel exposure control techniques, problems associated with high-level contamination of personnel, and contamination control methods.

Termination of the Aircraft Nuclear Propulsion program resulted in a reduction in special monitoring activities but had little effect on the routine monitoring program. The amount of radioactive material released to the atmosphere from the RaLa process at the ICPP again showed a decrease, and for this reason no longer requires close surveillance. The ICPP criticality of January 25 produced no significant health hazard either on- or off-site but provided an excellent training exercise.

Upon resumption of atmospheric testing of nuclear weapons by the USSR, the IDO fallout monitoring program was restablished. The highest concentration of airborne radioactive particulates measured in Idaho Falls was 31 pc/m^3 on November 13.

Following are the estimated amounts of radioactivity discharged to the environment from all NRTS facilities:

Liquid	4,000	curies
Solid	155,000	curies
Aerosol	338,000	curies

The increase in amount of solid waste, which is about 16 times the 1960 level, is attributed primarily to disposal of the GE-ANP in-pile loop from the ETR (about 100,000 curies). Elevated tritium concentrations were observed in several of the site production wells and many of the on-site observation wells. However, the maximum concentration measured in a production well was 6.2×10^{-5} $\mu c/cc$ which is 6.2% of the recommended drinking water Radioactivity Concentration Guide (RCG) for continuous exposure to the general population.

Significant changes in the solid waste disposal program included the establishment of a special burial ground to accommodate the dismantling of the SL-1 and establishment of a new acid disposal area outside of the NRTS burial ground.

Drilling of observation wells, geophysical logging, water quality, and hydrological investigations in the vicinity of MTR-ETR, ICPP, NRF and the burial ground continued during the year.

Ecology. The routine biological monitoring program consisted of quarterly collections of jackrabbits and vegetation samples from 33 stations in on-site, perimeter, and off-site areas. Milk was collected monthly from 12 perimeter farms. Jackrabbit thyroid iodine-131 and bone strontium-90 were used as biological indicators, of environmental contamination levels. The concentrations of strontium-90 in the bones of young-of-the-year rabbits was the best indicator of the strontium-90 contamination level in 1961.

The strontium-90 concentrations in the bones of perimeter and off-site jackrabbits in 1960 and 1961 were lower by a factor of two than in 1959. Perimeter and off-site levels followed the trend in fallout levels. The strontium-90 concentrations from stations around the Chemical Processing Plant were 5 to 30 times greater than the background strontium-90 levels in perimeter and off-site samples. The strontium-90 concentrations in the bones of cattle and five species of native animals were determined over a six-year period, 1956 to 1961. Except for the coyote, the strontium-90 concentrations were highest in all species in 1959. The trend of the strontium-90 levels followed the trend in fallout of strontium-90. Specie differences in strontium-90 concentrations were related to feeding habits and altitude of habitat.

Jackrabbit thyroid iodine-131 showed no contributions above background levels from NRTS operations to environmental iodine-131 in perimeter and off-site areas. Significant levels of iodine-131 were detected during and shortly after the Russian weapons tests and the SL-1 accident. Gross gamma activities on sagebrush and alfalfa indicated no perimeter or off-site contamination attributable to NRTS operations. Iodine-131 was detected in milk only during and shortly after the Russian weapons tests and the SL-1 accident.

Wild living jackrabbits were dosed with radiostrontium and radiocesium and elimination curves were plotted. Concentration ratios between food levels and rabbit tissue levels of radioactivity were determined for use in biological monitoring of low-level environmental contamination.

The food habits of the jackrabbit are being studied by the analyses of a reference collection of plants and the stomach contents of current and reference collections of rabbits. The identification and relative abundance of the different food plants were determined by microscopic examination. This study continues to develop the year-round relation between the plant material available and those selected for food by the jackrabbit.

Jackrabbits were classified into three year-of-birth groups from their dry eye lens weights. The frequency distributions of the dry eye lens weights in milligram classes of the young-of-the-year and the older rabbits were distinct until March.

A previously tested systematic emergency monitoring program was operated over the first 10 days following the SL-1 accident. Deposition areas having iodine-131 concentrations above 100 micromicrocuries per gram of sagebrush were delimited and animal samples taken. Thyroid iodine-131 from sheep, jackrabbits, and deer mice taken during January from areas about four miles south of SL-1 were comparable at 0.1 microcurie per gram. Milk samples collected about eight miles south over the month of January showed that any iodine-131 present as a result of the SL-1 accident was well below recommended levels for non-occupational exposure.

Further control of noxious weeds in distributed areas was obtained by restricting the use of soil sterilizers and herbicides and reseeding with crested wheatgrass. Approximately 550 acres in areas along highways were reseeded.

Eighteen bobcats and 183 coyotes were killed on the NRTS through the predatory animal control program.

U. S. Weather Bureau. The meteorological support that is provided by the Weather Bureau for the various reactor operations is described. Several accidental releases are also discussed, principally with respect to the meteorological evaluation of radiation field data. Vegetation and air concentration measurements showed that a deposition velocity of 0.2 cm sec^{-1} for iodine-131 is appropriate over the NRTS during inversion hours. Some 20 releases of fluorescent tracer material over a densely sampled grid to two miles were carried out. The air concentration and deposition measurements from these diffusion studies are related to turbulence measurements made with high speed bivanes. A partially successful digitalization of the meteorological network at Central Facilities, with a readout on electric typewriter and punched paper tape, was made.

Instrument and Development. The activities of the Instrument and Development Branch resulted in an increase in many areas of service to the AEC and its operating contractors. The physical inventory under the custody of the branch increased 6% while the dollar value showed an increase of 49% to $1,150,000. This to a large extent was the result of the installation of a new and improved radiation monitoring telemetering system for the NRTS and the surrounding area of Southeastern Idaho.

Gamma calibration facilities were extended with the completion of an additional well utilizing motor drive and semi-automatic control. This new facility with its cesium-137 source now makes possible gamma calibrations to 1000 r/hr.

Tests on equipment and components were conducted for many of the branches of Health and Safety Division in the long range program, to continually upgrade the service capability of the branches and the division as well as the ability to cope with non-routine situations. Changes were made in the aerial survey analyzer to provide for more accurate logging of radiation data. The development section devoted its major efforts toward the design and fabrication of an improved automatic film reader and its associated equipment. Although the major fabrication work is completed, final check-out of the system is still in progress.

The radiation monitoring telemetering system was installed. Complete check-out and testing has been delayed due to strong radio frequency interference signals at the present repeater location.

Environmental Monitoring. The level of radioactivity during the first three quarters of 1961 at the NRTS remained well below Radioactivity Concentration Guide (RCG) values. Following the Russian atmospheric nuclear testing in September, radiation levels at the NRTS started to increase due to world-wide fallout, corroborating similar trends in other parts of the country. Iodine-131 was observed in the off-site milk samples due to the presence of this fallout. Detailed surveillance and analysis were undertaken for this particular isotope. During the fourth quarter individual samples of milk exceeded the RCG levels of 1×10^{-7} microcurie/milliliter, but the average for the year was below the RCG value.

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FIGURES

TABLES

NRTS NOMENCLATURE

AFSR	Argonne Fast Source Reactor
AMA	Assembly and Maintenance Area
A1W	Large Ship Reactor
AREA	Army Administration and Hot Cell Area
ARMF	Advanced Reactivity Measurement Facility
ATR	Advanced Test Reactor
BORAX V	Boiling Water Reactor No. 5
CFA	Central Facilities Area
EBOR	Experimental Beryllium Oxide Reactor
EBR-I, II	Experimental Breeder Reactor No. 1 and No. 2
ECF	Expended Core Facility
EOCR	Experimental Organic Cooled Reactor
ETR	Engineering Test Reactor
ETRC	Engineering Test Reactor Critical
FECF	Fuel Element Cutting Facility
FET	Flight Engine Test Facility
GCRE	Gas Cooled Reactor Experiment
ICPP	Idaho Chemical Processing Plant
IET	Initial Engine Test Facility
LPTF	Low Power Test Facility
ML-1	Mobile Low Power Reactor No. 1 (Army)
MTR	Materials Testing Reactor
NCR	Natural Circulation Reactor (S5G)
NRF	Naval Reactor Facility
OMRE	Organic Moderated Reactor Experiment

RMF	Reactivity Measurement Facility
SL-1	Stationary Low Power Reactor No. 1 (Army)
SPERT I, II, III, IV	Special Power Excursion Reactor Test No. 1, 2, 3, 4
STPF	Shield Test Pool Facility Reactor (SUSIE)
S1W	Submarine Thermal Reactor
TREAT	Transient Reactor Test Facility
WCF	Waste Calcination Facility
ZPR-III	Zero Power Reactor No. 3

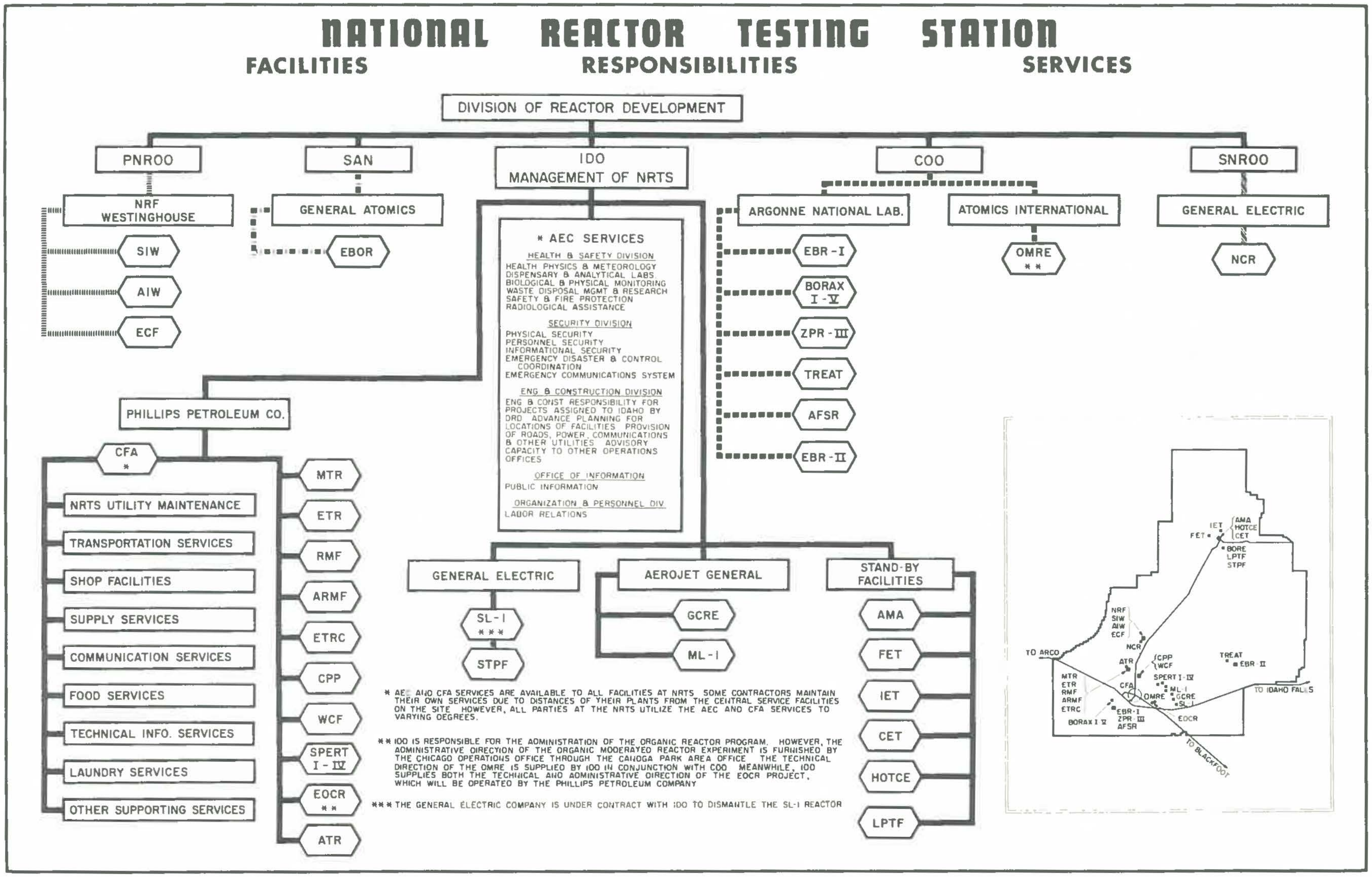


Fig. 1 NRTS organization chart.

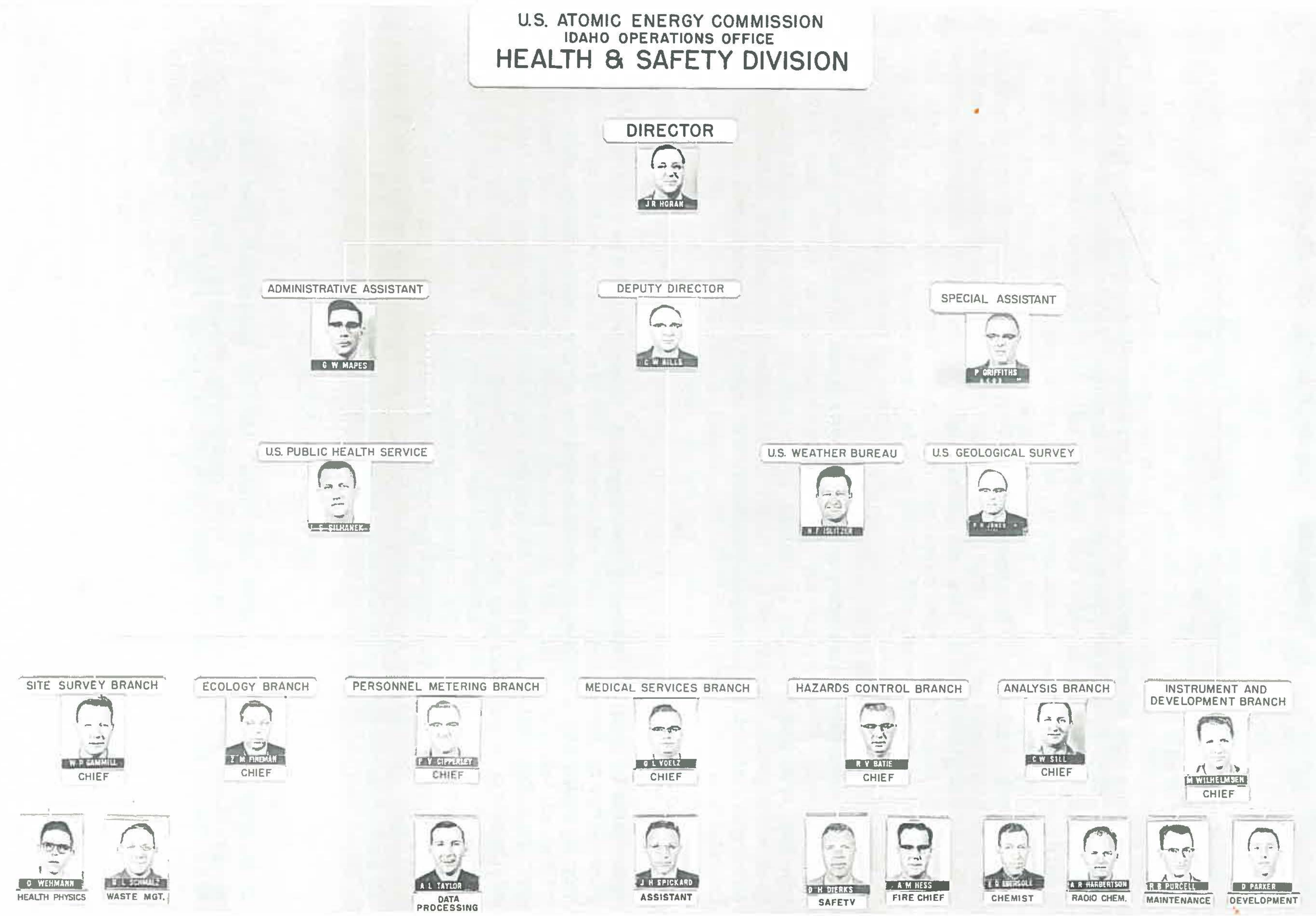


Fig. 2 Chart showing key personnel in Health & Safety division.

I. INTRODUCTION

(John R. Horan - Director)

1. MAJOR ASPECTS OF HEALTH AND SAFETY PROGRAM

In 1961 the major impacts on the programs and activities of the Health and Safety Division resulted from the SL-1 reactor accident and the cancellation of the Aircraft Nuclear Propulsion program. Both events had a pronounced effect on the statistical summary for the year. A total of 4200 permanent personnel was employed at the end of the year at nine major operational areas and six construction sites. The replacement value of the facilities at the National Reactor Testing Station (NRTS) had increased to $364,000,000. During the performance of nine million man-hours of construction, development, testing, research and support activities there was a total of 18 lost time accidents which resulted in three fatalities and 15 disabling injuries. For the sixth consecutive year, radiation exposure was not a causative factor in any of the injuries experienced at the NRTS. The three fatalities ensuing the SL-1 accident were caused by blast.

The integrated total body exposure from penetrating radiation amounted to 2700 rem which is approximately an 18% increase over the previous year. Ten individuals involved in the early phase of the SL-1 accident exceeded the Radiation Protection Guide (RPG) value of 12-rem exposure for the year. The highest exposure was 27 rem. With but two exceptions, all internal exposures to radioactive materials were below 10% of the maximum permissible body burden for the isotope of interest. These two individuals received body burdens of 10% and 20% of iodine-131.

Under the radioactive waste management program, a total of 4000 curies of short to intermediate half-life materials was discharged as liquid waste to the soil; 10,000 cubic yards of intermediate to long half-life material were consigned to the national burial ground at the NRTS, and the atmosphere dissipated approximately 338,000 curies of short half-life aerosols. The controlled releases of radioactivity from the projects were accomplished with minimum risk to the environs. Environmental radioactivity levels were below the Radioactivity Concentration Guides (RCG) recommended by the Federal Radiation Council. There was no significant impact on the environment as a result of the SL-1 accident.

2. ACCIDENT CRITIQUE

At the very beginning of the year the Health and Safety Division was committed to the greatest challenge ever faced by the new health physics profession. The first major reactor accident in the 19-year history of the atomic energy industry resulted in the death of the entire three-man operating crew, and high-level radiation and contamination of the reactor building. To complicate matters, the accident occurred during one of the deepest and longest inversion periods recorded at the NRTS. Such factors as adverse weather temperatures, long working hours, highly contaminated bodies and unusual stresses contributed appreciably to the problems of the emergency teams.

Because of the international interest in the operational experiences of the Health and Safety organization during a limited disaster, it has been decided to document these experiences as the central theme throughout this annual report. In any situation involving loss of life, injury, or major property damage, it is always possible to indicate what could have been handled differently and possibly better. This is true of the SL-1 accident as it has been true of any other emergency. It is hoped that others will profit from the successes as well as the failures.

This accident served to emphasize the essential need for a trained emergency organization with adequate mobile support. There are five fundamental ingredients in effective control and recovery from any emergency:

(1) A sound plan

(2) Aggressive leadership

(3) Intensive training

(4) Adequate communications

(5) Efficient use of available resources.

The emergency plan must be current, simple and flexible. Since every emergency is unique there can be no single plan tailor-made for all occasions. There can be no perfect plan since there are limitations imposed by the lack of detailed information and communications in general. Also, one is working with the human equation with its biological and psychological parameters. For these reasons, emergency planning, similar to other health physics operations, will always be an art rather than a science.

The emergency control group will be called upon to make critical decisions under the fog of technical uncertainties and moral ambiguity. Information and facts must be collected, and reported rapidly and accurately to the control group for analysis. Evaluation must be made of field data so that actions will not be based on false assumptions or erroneous conclusions. The group must strive for confirming or corollary evidence, such as reports from two different sources or data arrived at by different techniques. Even then, false conclusions will be made, but the accuracy will be increased. Sound decisions must then be transformed into action by the teams in the field. Any emergency, particularly if life is at risk, demands the very best in group effort through leadership and teamwork.

Emergency team members must be trained to sharpen their observing and diagnostic skills. For speed, efficiency, and physchological reasons, planning and training must condition field personnel for initial response and actions which are highly automatic. Advantage must be taken of minor incidents to test the notification and response procedures. Afterwards, staff members should identify flaws, awkward, or unsuccessful portions of the plan and try new approaches or innovations to increase performance.

Since people learn best by doing, a period of seasoning is necessary to master any preplanned emergency operation. Team members must acquire maturity of judgment and confidence in their fellow members, their equipment, and the plan itself through dry runs and actual field experience. Training sessions should use tactical problems of hypothetical disasters which will tax the ability and equipment of emergency personnel. Problems should be centered around situations which could exist. As an example, preparedness and capability to handle all aspects of a maximum credible accident should be analyzed, ie, evacuation, rescue, decontamination, off-site notification, public relations, extent of land contamination, coordination with other agencies, manpower and equipment reserves, etc. Finally, previous accidents and disasters should be studied for basic patterns.

Communications includes all aspects of transferring information from one individual to another: radio, telephone, written messages, the use of pictures and models for briefing or debriefing, face to face reports, etc. Dr. Ralph G. Nichols, of the University of Minnesota, in a recent survey revealed that the average person recalls only half of what he has heard after a speaker has finished. Under stress or excitement, the figure is undoubtedly lower. Verbal instructions should be brief and exact. Important verbal communications should be repeated to the speaker to check the listener's understanding of the communication.

News about serious accidents should not be censored. The news media should be given straightforward and detailed stories. If this is not done the media probably will get incomplete facts in an improper perspective from other sources. Either way, the story will be told.

Essential personnel should not be used to the point of fatigue nor exposed to high radiation exposure. The future need and utilization of people should be considered. Some have rare skills which can be nullified by high exposures. Finally, time will never pass so rapidly as it will during the action phases of an emergency.

3. MAJOR ACCOMPLISHMENTS

The almost total involvement of the personnel and resources of the division in the many phases of field operations for many months following the SL-1 accident tends to overshadow the other major activities performed during the year. There is a continuing effort to upgrade the Health and Safety program to the highest standards of excellence and performance. During 1961 the following were among the more important accomplishments towards this goal:

(1) The development of an improved respirator program as the result of field and bench testing of various types of masks.

(2) The whole-body counting equipment was calibrated and placed in routine operation. During the first year, 870 counts were made on 250 people. This equipment offers a degree of sensitivity and accuracy unattainable by other techniques of internal dosimetry.

(3) The environmental monitoring program was bettered by new sampling and counting techniques. The locations of sampling stations were modified to provide greater coverage by utilizing population density and meteorological parameters.

(4) After several years of effort, the "improved risk" criteria for fire protection was achieved in existing IDO facilities.

(5) The appraisal of contractor health physics programs achieved operational status.

(6) All facilities and contractors at the NRTS are now provided with medical and fire protection coverage by IDO.

(7) A small computer was installed and integrated into the operational programs of the Personnel Metering, Analysis, and U. S. Weather Bureau groups for data reduction.

(8) Knowledge gained from research in radioactive waste management was factored into the design of liquid waste facilities for the EOCR and ATR installations. An intensive study of the chemistry, water quality, and geology of the MTR leaching pond was begun.

(9) The U. S. Weather Bureau initiated applied meteorological studies on deposition velocity and the inter-relationship of atmospheric discharges from multiple reactor facilities.

(10) During background studies of tritium in monitoring wells, prior to a tracer experiment, it was learned that significant quantities of tritium had been discharged to the environment. Full advantage of the situation is being taken by extending the underground water studies to a distance of five miles.

(11) The results of the extremely valuable applied research of the U. S. Geological Survey in geophysical logging at the NRTS were published in an interim report.

(12) The adaptation of a method of determining the age of jackrabbits from their dry eye lens weight makes possible a more accurate determination of current strontium-90 fallout.

II. HEALTH PHYSICS AT SL-1

(C. Wayne Bills - Deputy Director)

Normally, a discussion of in-plant health physics would not be included in the annual report of the IDO Health and Safety Division. Health physics at SL-1 is discussed here for the sake of continuity because there have been three responsible groups involved in 1961. IDO assumed Health Physics' responsibility shortly after the accident on January 3 and retained it until 8 a.m. January 13. Combustion Engineering, Inc. had the reponsibility until May 20 and the General Electric Co. had the responsibility from May 20 through the end of the year.

Preplanning went into effect within the first three minutes of the emergency action. The fact that the SL-1 alarm came from the reactor building initiated a preplanned request from the fire department for Phillips Petroleum Co.HP assistance since IDO does not have 24-hour health physics coverage on-site. A Phillips Petroleum health physicist from MTR arrived at the SL-1, approximately 10 miles away, only 15 minutes after the request had been initiated.

Although no fire was found at the SL-1, the initial emergency crews consisting of firemen and security forces, did detect radiation throughout the support facilities. They recognized the new emergency and took actions to minimize personnel exposures while reassessing the situation. When no personnel were found in the support area, it did not necessarily indicate that they were in the reactor building since this area was under administrative control (no guard at the gate). The personnel might have left the area to escape exposure prior to the arrival of the fire department.

When communication checks indicated that three people should still be in the area, a renewed search under Health Physics control was started. Penetrations were made into 25-, 200- and 500-r/hr zones with administrative checks being made at these levels to insure coordination of the search efforts.

No personnel had been found in areas explored within the range of the 500-r/hr Jordan Radectors.

Rapid response of Combustion Engineering, the Army Cadre and IDO Site Survey personnel to the SL-1 site placed additional knowledgeable personnel on the scene shortly after 10:15 p.m. Without adequate protective clothing, but equipped with self-contained breathing apparatus, the initial rescue team of five men (including two health physicists) made entry onto the reactor floor, found two men, and recovered the one man who showed signs of life. The man expired shortly after his removal from the building.

Four fresh men, again including health physicists, made an entry to find the third member of the crew. Finding him dead, the early rescue teams left the SL-1 area and proceeded to a decontamination area where film badges were collected to make an early assessment of their exposures. The exposures to penetrating radiations ranged from 7.4 to 27 r, with the exposure time in the reactor building being estimated at three minutes.

Through debriefings it was established that radiation fields greater than 1 r/hr were confined within approximately 100 feet of the reactor building.

Limited penetrations were made into this area the second day to close all doors and prevent freeze-up in the 10°-below-zero weather, to recover the nuclear accident dosimeter system, and to recover reactor logs and charts in the control room. These actions were under Health Physics control with protective clothing and exact preplanned objectives and actions.

Also requiring Health Physics surveillance was the handling and transport of the highly contaminated victim to the Chemical Processing Plant decontamination room. Removal of clothing was of no value in reducing the radiation levels because of fine fuel particles imbedded in the victim's skin. Use was made of coats fabricated from leaded cloth for some personnel in this operation, but quantitative data as to their effectiveness was not evaluated. In fact, the available coats upon delivery to the SL-1 area were contaminated and ready for decontamination in plastic bags with tags indicating up to 500 mr/hr. In contrast to the field being encountered in close proximity to the body, there was no hesitation in taking advantage of any protection they could provide. The local fields encountered were up to 400 r/hr in the close vicinity of wounded portions of the body.

Two-man teams, fully protected with anti-contamination clothing, assault masks on air packs, were used in the recovery and to assist in the recovery of the other two bodies. Health physics coverage was provided by a time and signal arrangement from the bottom of the reactor stairs where the HP was stationed in a 10- to 25-r/hr field. Administrative exposure limits of 10 r of penetrating radiation had now been established. The exposure time to crew members was approximately one minute with men receiving exposures ranging from 1.6 to 9 r during these operations.

One major effort requiring careful HP control was the removal of the I-beam above the freight doors in order to remove the small crane and allow access of the stretcher for recovering the third body, as reported in IDO-19301 [1]. The cutting of the I-beam required a welder to be at reactor floor level in a field of about 40 r/hr. The field was determined from a mock-up operation where the lead shielded box that was used to shield the welder was hung from the crane where the welder would be at work. Film badges exposed for 15 minutes showed 75- to 90-mr exposure within the box and about 8 r outside toward the reactor building wall. Actual entry time for the cutting operation was about one hour and the welder's whole-body exposure was 375 mr.

Of tremendous importance to the operations and to the HP work were the photos taken on the operating floor after the accident--operationally, because they assisted in planning the recovery of the third body and from the HP's standpoint, because they could be used in briefing entry teams. As always feared and as actually experienced in one case, a team member "froze" when confronted by the reality of the situation. Following this, photographs were used during briefings for conditioning purposes in addition to orientation. Another individual's reaction during a briefing session allowed him to be factored out prior to actual entry.

With recovery of the third body, personnel access to the reactor floor was discontinued late January 9 and prohibited until June 2, 1961.

The major problem then became the determination of the nuclear safety status of the reactor (Phase II). Neutron instrumentation was placed below the reactor building, tested, and set to alarm in event of further excursions. Remote viewing of the reactor head area, with a 16-mm movie camera, to determine access to the vessel was the first remote operation of Phase II.

The Health Physics role now became one of protecting remote crews from exposures beyond the administrative limit of 2.5 r/quarter set by IDO. Shielding was provided for the driver and equipment manipulator on the cherry-picker used for remote operation. Transient members of the operational crew were shielded behind a one-inch lead shadow shield which gave about a tenfold reduction in exposure. The general fields encountered by workers at the base of the reactor silo were from 1 to 10 r/hr during early operations in Phase II.

There was extreme complexity in that all operations had to originate at ground level, then operate through the freight doors 20 feet above grade and finally, in cases of vessel penetrations, in 20 feet and back down through a six-inch open hole into the reactor head. These entries were time-consuming and the desired efficiency was seldom possible. In all operations from January 3 to May 21 approximately 775 men were badged at the SL-1 control point with a total exposure of about 540 r in penetrating radiation.

In May, following the determination that the reactor was dry and that it was therefore nuclearly safe if moderator remained absent, General Electric took over Phase III of the recovery effort. The General Electric effort was outlined to (a) make extensive surveys to determine the sources of radiation, (b) to decontaminate the reactor building to facilitate removal of the core, (c) to remove the vessel and core to the ANP hot shop, (d) examine the core, and (e) dismantle the building and restore the SL-1 area to habitable status.

When shielding of the open ports in the reactor vessel with bags of lead and steel shot failed to appreciably lower the radiation levels within the reactor building, it was recognized that a major decontamination job lay ahead. Remote operations, which were now well established, were used to make radiation and photographic surveys. By early June it was determined that the contamination created radiation levels of 50 to 250 r/hr on the reactor floor at this time, and there was a very general peaking toward the center of the building as expected.

The first Phase III direct entry of personnel onto the reactor floor was made June 2, 1961 to drain the 1000-gallon overhead water storage tank to further insure that moderator could not inadvertently get into the reactor vessel. The mission was a success although multiple entries of less than one minute were needed. In addition to the operational success, these entries gave much in the way of health physics information and experience for future entries. The dress was standard - consisting of cloth shoe covers, rubber booties, other shoe covers, two pair of coveralls, a surgeon's cap, full-face mask with activated carbon filters, and a full-head canvas hood, with all openings taped. One- and five-r range self-reading dosimeters and film badges were used. To conserve health physicists, the timing and recall alarms were at the foot of the stairs in a field of about 1 r/hr. To insure maximum operational attention, crews entering the floor did not carry portable radiation instruments except where this was the operational mission.

It soon became evident that the efficiency of direct operation far outshadowed remote techniques and the integrated personnel exposure was often in favor of the direct approach. For example, in February performance of a very complex remote television operation required 18 men to operate in fields of 0.25 to 5.0 r/hr from a few minutes up to two hours time, the total exposure being approximately 5.3 r. Later in June, four men and an HP performed a direct task of equal mechanical complexity working in fields from 40 to 100 r/hr for 1 to 1-1/2 minutes each. The total exposure for this operation was about 3.6 r.

The reduced requirement for coordination, mock-up training, briefing, debriefing and overall complexity favors the direct approach. In addition, the direct method provides much more flexibility, and extremely valuable information from direct observations. The health physics surveillance problem is greatly reduced by using fewer people even though the fields were much higher. The efficiency of briefings and dry-run practices are facilitated by using fewer people with definite tasks rather than larger numbers with multiple supporting roles. However, the risk to exposures in excess of the Federal Radiation Council guides is somewhat greater due to personnel errors within the short exposure times allowed. Phase III operations in 1961 which largely employed the direct approach resulted in 11 exposures beyond the administrative quarterly exposure of 3 r of γ or 10 r of $\beta + \gamma$. The highest γ exposure was 3.7 r and the highest $\beta + \gamma$ was 11.6 r.

After the contamination was determined to be general, plans were formulated for decontaminating the building to a point where the reactor could be moved. Early entries were made to remove major loose items that restricted removal of small debris on the floor (see Figure 3). These items included welding carts, ladders, chains, bell housings, etc. Radiation surveys showed the highest levels to be associated with the blotting paper that had been used pre-incident for contamination control and with the loose insulation from around the reactor vessel which had been scattered about. Large pieces were handpicked and placed in retrievable waste cans and the fines were vacuumed. All debris was later examined and classified by remote means in the hot shop.

Additional bags of steel and lead shot were laid over and near the reactor head where levels were up to 200 r/hr and the presence of the shield blocks obstructed rapid cleaning. Finally it was noted that there was a point of diminishing return from further cleaning of the reactor room due to hot spots overhead. It should be noted that waste cans and vacuum accumulations often became new concentrated sources. It was better to place the waste bucket near the door where it could be removed remotely and take debris to it, thus keeping the concentrated source away from the worker, instead of moving it around as work progressed.

The fan loft wall was cut open to allow decontamination of this area. The ventilation fan was removed through a hole cut in the fan loft ceiling as shown in Figure 4.

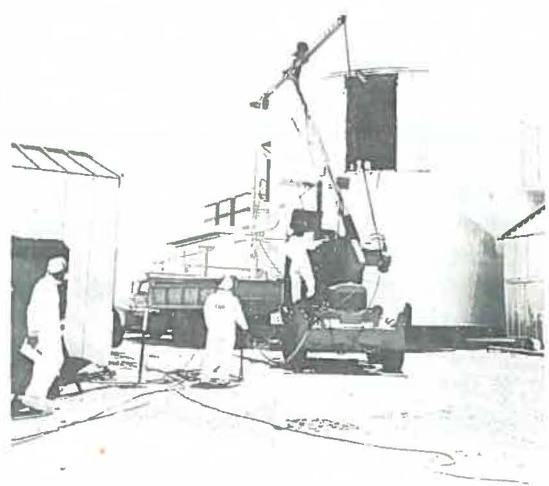


Fig. 3 Remote removal of radioactive debris from reactor floor of SL-1.

A technique was used of vacuuming the floor, then laying 1/4- to 1/2-inch-thick steel plate on the floor to further shield the worker since the preferential direction of exposure in the fan loft was from below. The fan loft appeared to contain a more finely divided contamination which began creeping through two pairs of cotton coveralls and caused some low-level contamination of the workers. Personnel began wearing disposable plastic pants and jackets in addition to the regular anti-c clothing, and again personnel contamination was under control. In fact, one of the outstanding features of the operation was the small number of workers who even experienced measurable contamination after entering the reactor building.

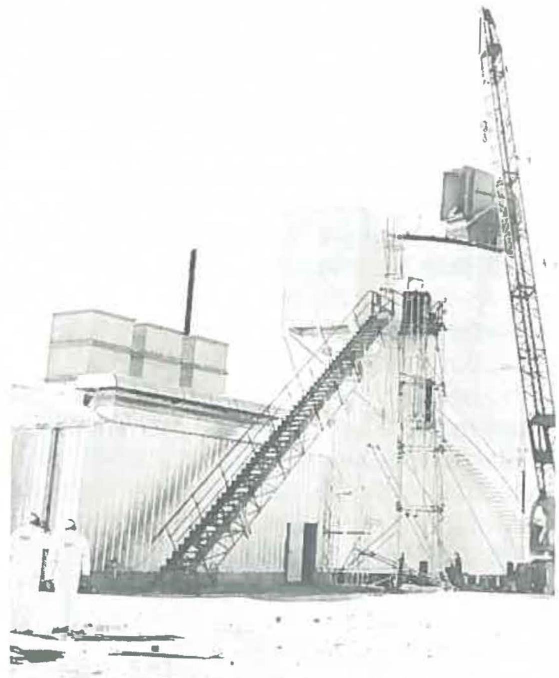


Fig. 4 Removal of partially decontaminated ventilation fan through hole cut in fan-loft ceiling. Stairway leads to area where first hole was cut into fan-loft wall.

Through all of this, the personnel metering was extremely complex. Monitoring was done by duplicate self-reading dosimeters and film badging. Although the initial entries on June 2 reflected a β-to-γ ratio of about 2:1, all subsequent operations showed a wide variation in this ratio. It soon became evident that the quarterly exposures would have to be controlled within the 10-r β plus γ exposure and not on penetrating exposure alone. Earlier it was noted that the exposures were directional with respect to the worker's assigned task as he was essentially working within the source. A practice of wearing a web belt with from 15 to 18 standard film badges was adopted. In this manner a good average β-to-γ ratio could be established. Generally the ratio was about 4:1, and penetrating exposures seldom exceeded 2 r per quarter for individuals doing recovery work.

Hot spots up to 150 r/hr were recorded in the fan loft area and generally were associated with equipment or porous material which retained the residue from evaporated contaminated water blown up through the holes in the reactor ceiling made by two or three shield plugs. A small amount of identifiable aluminum from fuel assemblies was found in the fan loft. As the high levels in the fan loft were reduced, largely by vacuuming techniques, the removal of the shield block became feasible since the 10-ton crane on the reactor floor could be returned to service. Decontamination continued on both levels with major reductions coming from removal of the fan and condensor units through the roof of the fan loft and further removal of loose material on the reactor floor immediately adjacent to the reactor head. Finally, the steel deck plates over the wire trench around the reactor were removed and final decontamination was done in hard-to-reach areas which still contained small local contamination reading up to 100 r/hr.

By early November the levels within the reactor room ranged from about 5 r/hr near the walls to 15 r/hr over the shielded head. The fan loft levels generally read less than 5 r/hr. Also, the β-to-γ ratio had been reduced considerably to about 2.5:1 except for work being done in a virgin area.

In contrast to the very short two- and five-minute exposure intervals used by workers during June and July, during September and October these were extended from 15 to 60 minutes depending upon the exact job location. Of interest is that the total accumulated time spent within the reactor building during June and July was only about 16 man-hours. Though slow, monstrous decontamination tasks were accomplished as reflected by the extended work time in later months.

Prior to final plans to dismantle the building sufficiently to remove the pressure vessel, it was necessary to determine more exactly the status of the vessel and core. Of major concern for many months were the exposures that might be involved in trying to free the vessel from its attached piping and its blanket of insulation. Photos were taken of the core and vessel interior to document more fully its condition prior to a trial lift to see if the vessel was firm. A major break in the recovery effort occurred when the vessel was found to have sheared itself free of attachments and was resting loose ready to be lifted for transport.

Final preparations for removal consisted of removing the fan loft ceiling, about half of the fan loft wall, and cutting a seven-foot-diameter hole in the ceiling above the reactor. Again, test runs of the lift were made with a sized and weighed mock-up vessel to reduce exposures and contamination spread, and to assure smooth operations. Contamination control was accomplished by withdrawing the vessel into a rubberized accordian-type plastic bag held tight at intervals by snug-fit elastic bands. In all, the bag was about 18 feet long and 4-1/2 feet in diameter and very effectively contained the debris attached to the sides of the vessel.

The entire low-boy truck and cask used for transport (see Figure 5) was plastic wrapped and taped to facilitate easy decontamination after the vessel was loaded. Another contamination control was a fresh surface of gravel that was laid over the road in the SL-1 fenced area just prior to positioning the truck and cask. Only a small amount of steam cleaning of the truck tire threads was necessary before transit to the Hot Shop began. Exterior radiation levels at the cask surface were about 35 to 40 mr/hr and increased to a maximum of about 60 mr/hr at nine feet from the cask due to shine from the partially shielded head area. Essentially, all of the 1700 pounds of lead and steel

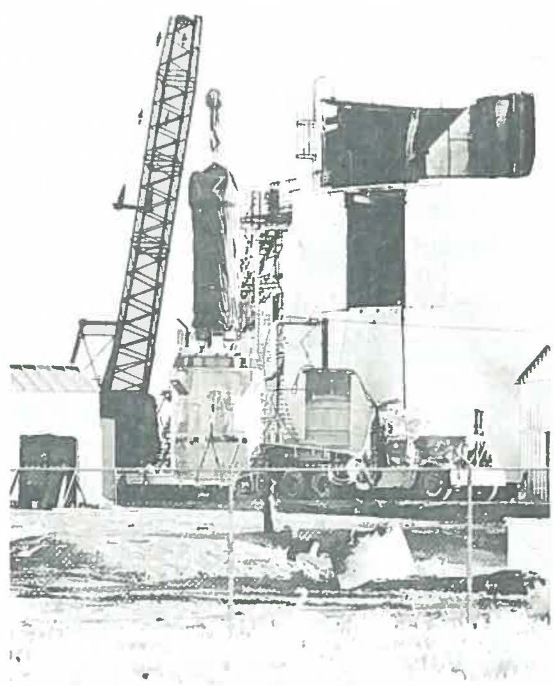


Fig. 5 SL-1 pressure vessel and core being moved into shielded cask for transport to Hot Shop.

shot packed around the nozzles for shielding during cleanup was transported with the vessel.

The cavity left by removing the vessel still read about 20 r/hr at reactor floor level and was later shielded by a large five-inch-thick lead plate during the dismantling operations on the remainder of the building. The entire fan loft had been removed at year's end.

Radiation exposure records show that the Phase III operation badged 656 different individuals between May 22 and December 15, 1961. The total accumulated exposure for this same period was 1744 r of β and 764 r of γ radiation. These values added to Phase I and II operations show that a total of 1200 persons received 2340 r of β and 1305 r of γ exposure which was attributable to the SL-1 recovery operations through December 15, 1961.

In summary it has been a great credit to Combustion Engineering and General Electric for their recovery performance within the normal operating exposure limits of the NRTS. Perhaps the outstanding HP benefit that has come out of the SL-1 recovery has been the confidence gained by the hundreds of workers who gained first-hand experience in how to work in high radiation fields and in areas of gross contamination. An AEC program which started by providing training for the Security and Fire Department personnel extended to volunteers from all administrative departments. These people felt that through their contribution of exposure time, they could gain a much closer appreciation of contractor problems where radiation and contamination were factors. Of credit too to the operating contractors on the SL-1 recovery is the fact that many people were performing strange jobs and there were no occupational injuries. This is attributed largely to briefing sessions which prepared personnel for their individual tasks. Indeed many of the participants had an active part in the safety program because, during debriefings, they were quick to report problem areas which aided the supervisors to amend their instructions. Often supervision and planning were handled by personnel conserving their own exposure for key operations, and much of the operation was dependent upon periodic photographic coverage and successful debriefing of the workers.

Photography played a paramount role in all operations to date. The need for qualified photographers in sufficient number to cover both operational and documentary activities, without abuse of individual exposure, needed continual planning. NRTS contractors provided photographic support and the Army Signal Corp and Army Pictorial Center gave added coverage.

The need of extended range instruments above 500 r/hr in sufficient number to make preliminary evaluations was an early observation in the SL-1 accident.

Preplanning should provide for both gamma and neutron detectors with remote read-out for initial remote and monitoring operations.

Additional HP training should be conducted for emergency groups like the Security and Fire Department personnel which are likely to handle the initial emergency response to potential radiation areas. Preplanning for handling, decontamination and subsequent action of highly contaminated personnel from nuclear accidents should receive high priority.

Additional SL-1 information can be found in three IDO reports[1,2,3]* regarding the reactor incident.

* Numbers in brackets refer to Section XIII, References.

III. MEDICAL SERVICES

(George L. Voelz, M. D.)

1. INTRODUCTION

The Medical Services Branch provides a centralized industrial medical department which may be utilized by the operating contractors at the NRTS. This service eliminates the necessity for each contractor to provide duplicate medical facilities staffed by part-time physicians. During 1961 the utilization of the AEC Medical Services Branch was increased when Westinghouse Electric and General Electric eliminated the services of part-time physicians at their NRTS dispensaries and arranged to use the Medical Services Branch for physical examinations, consultations and treatments. In-plant medical services are now provided to a total of six NRTS operating contractors; namely, Aerojet General Nucleonics, Argonne National Laboratory, Atomics International Division of North American Aviation, General Electric, Phillips Petroleum, and Westinghouse Electric. First aid and emergency medical care also are given to construction contractor personnel working at the NRTS.

The principal responsibilities of Medical Services in providing a comprehensive occupational medical program for the NRTS include:

(1) Performance of pre-employment physical examinations to promote proper job placement in accordance with the candidate's physical condition.

(2) Performance of periodic and termination physical examinations to ascertain the current health status of employees.

(3) Operation of dispensary service for evaluation and treatment of occupational injuries and illnesses, temporary treatment of minor non-occupational illnesses, and emergency medical care.

(4) Evaluation of plant health problems with recommendations for control and prevention of occupational health hazards in cooperation with the health physicists, industrial hygienists and safety engineers. Special medical evaluations are made for specific occupational exposures such as noise, ionizing radiation and toxic chemical exposures.

(5) Health counseling of employees and health education to employee groups.

1.1 Facilities

The AEC Central Facilities dispensary, which is the major medical facility at NRTS, is equipped to perform physical examinations and to evaluate and treat occupational injuries or minor non-occupational illnesses. The dispensary facilities include a clinical laboratory and a diagnostic X-ray department. The dispensary is equipped to provide diathermy and ultrasonic treatments as well as minor surgical repairs, primarily for skin wounds. A small room in the basement is available for emergency care of personnel who are radioactively contaminated. Ambulance service is available for emergency transportation from any of four AEC fire stations.

The medical facilities available at the NRTS are summarized in Figure 6.

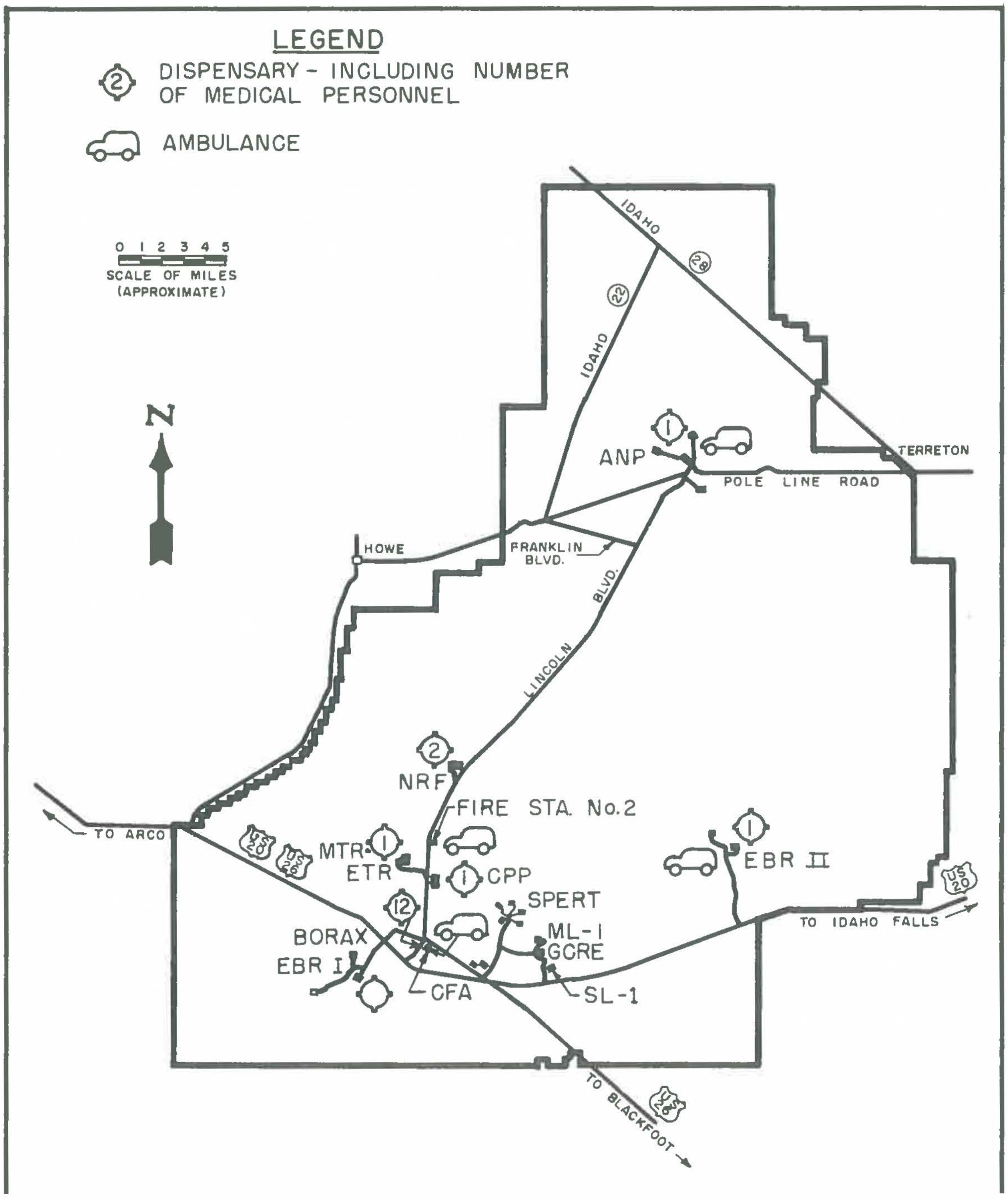


Fig. 6 Location of medical dispensaries, medical personnel and ambulances at NRTS (includes AEC and contractor facilities).

1.2 Personnel

Twelve full time AEC employees are assigned to the staff of the Medical Services Branch. The staff is composed of two physicians, a nurse supervisor, five nurses, a medical laboratory technician, an X-ray technician, and two clerk-typists. Four of the nurses work on rotating shifts to provide a nurse in attendance at the dispensary on night shifts, weekends, and holidays. One nurse spends part of her time visiting construction areas to provide close liaison with the first aid attendants and to perform medical follow-up visits (Figure 7). In addition, a part-time nurse is used in a relief role during absences of the regular nursing staff.

Fig. 7 Industrial nurse visiting worker in construction area.

In addition to these AEC personnel, the contractors staff their own dispensaries with registered nurses. Argonne National Laboratory has a nurse assigned to the EBR-II dispensary on week-day shifts, except for two half-days spent at the EBR-I trailer dispensary. Phillips Petroleum maintains a nurse at both the MTR-ETR and the CPP area dispensaries during the day shift. These Phillips dispensaries are visited for an hour on each night shift and on each weekend shift by the AEC nurse. Westinghouse Electric maintains a dispensary, including a clinical laboratory, staffed by two registered nurses in the NRF area. General Electric employs a registered nurse at its dispensary in the ANP area. The contractor nurses are administratively supervised by contractor health and safety directors; however, they are under the jurisdiction of the AEC physician professionally. They are guided by "Standard Procedures for NRTS Industrial Nurses", which is included in the IDO Medical Services Handbook.

2. MEDICAL SERVICES PROJECTS AND ACTIVITIES OF 1961

2.1 Medical Aspects of SL-1

The SL-1 reactor accident on January 3, 1961, involved medical personnel in two principal areas: (a) medical supervision of the recovery personnel and (b) management of the highly contaminated bodies of the three victims.

The medical supervision of recovery personnel was required to record any significant signs or symptoms occurring in the group. Since the highest whole-body gamma exposures were 27 r, no effects were anticipated. This proved to be the case. No significant psychological problems were noted despite the unusual stresses, long working hours and adverse weather conditions.

Blood counts were performed at weekly intervals for six weeks on individuals receiving more than 5 r gamma. In no instance, either individually or by group average, were any blood count changes noted which suggested a radiation effect. The results of urinalyses, direct thyroid counts and whole-body counts indicated that internal radioiostope deposition was detectable, but did not result in significant radiation exposures.

The early recovery parties had clothing and skin contamination ranging up to 50 r/hr which required prompt decontamination. This was accomplished by an initial shower at the facility nearest SL-1 after which they were transported to other areas, including a small decontamination room in the Central Facilities dispensary basement, where the final decontamination was performed. The majority of persons were decontaminated to background levels by use of detergents and water only; however, potassium permanganate solutions were used in a few instances, especially on the hands.

The decontamination facility at the Central Facilities dispensary is an unfinished 9- x 13-foot basement room that was modified only to the extent that it has an outside entrance, hand basin, a shower and containers for contaminated clothing. A stainless-steel table for injured persons was not used in the SL-1 accident. Through good traffic control, it was possible to decontaminate 30 persons in this minimal facility in the first several hours without spread of contamination to the dispensary proper.

The three victims killed by blast effects of the explosion had generalized radioactive contamination with gamma radiation levels ranging from 100 r/hr at the surface to over 500 r/hr at one foot. The successful management of this problem demonstrated conclusively that such bodies could be disrobed, transported, partially decontaminated and autopsied, with radiation exposures to health physics and medical personnel not in excess of 3.7 r gamma total to any individual. This work was done with only the standard tools available in an equipment decontamination room at the Chemical Processing Plant plus a few long-handled tools fabricated as needed by the local machine shop. It was readily apparent that management of a living patient with similarly contaminated physical injuries would provide much more difficult problems which require extensive preplanning, equipment preparation and personnel training to have even a reasonable chance for successful management.

The submersion of the bodies under melting ice in a sink for several days lowered surface contamination to levels which were not significantly improved by the later scrubbing with detergents, ethylenediamine tetraacetic acid (EDTA) and citric acid solutions. It was necessary to perform surgical debridements in those highly radioactive areas receiving blast damage from radioactive missiles in order to obtain effective decontamination. This work was performed at the time of autopsy by an eight-man team of physicians and health physicists from the Los Alamos Scientific Laboratory (see Figure 8). In addition to providing necessary decontamination of the bodies, the autopsies proved to be extremely valuable in providing positive identification of the victims and documentation

Fig. 8 Two doctors on the eight-man Los Alamos team outfitted in anti-contamination clothing and full-face respirators used in performing autopsies of SL-1 casualties.

of the blast effects on the bodies, which subsequently were used to establish the relative positions of the men on the reactor top at the time of the accident.

By use of lead shielding (1/8 to 3/4 in.) within standard caskets and vaults it was possible to reduce the exterior surface readings below 450 mr/hr in all areas except the bottoms of the caskets, which had somewhat higher readings. They were shipped to the cemeteries of the family's choice by military aircraft under escort.

Major planning lessons for the medical department as a result of the SL-1 accident may be summarized as follows:

(1) Transportation of highly contaminated victims (500 r/hr) can be done in conventional ambulances without excessive exposure of personnel; however, provision for a small amount of shielding for the driver, such as with a lead apron, should be made. Specifications on new ambulance purchases at AEC installations should be made with an eye toward the ease of decontamination of the back compartment.

(2) In addition to continuing an educational program for handling the radioactively contaminated patient in local hospitals, it is fully appreciated that preparations must also be made to handle high-level contamination within the plant confines. This includes the possible emergency use of surgical teams comprised of local physicians.

(3) Special medical decontamination facilities would appear to be feasible only in a few of the larger AEC installations, but plans should be formulated for initial decontamination of the massively contaminated patient at all reactor locations in a separate building in the vicinity. These plans should include preparation of shower facilities, hose connections, storage for highly contaminated clothes and a controlled traffic pattern. Such decontamination areas may well be designed as part of a hallway or vestibule normally used for other purposes similar to the safety showers used in industry.

(4) Equipment which may be useful to decontaminate personnel in these areas should include scissors or knifes for clothing removal, hoses, nozzles, long handled brushes similar to a car-wash brush, detergent solutions and hair clippers. A belt or sling to hold an injured patient in a vertical position for more rapid decontamination also may be worthwhile.

(5) In large plants where more costly facilities are possible, the planning should be toward making a versatile decontamination facility. On the basis of the SL-1 experience, a large unpartitioned decontamination room is preferred which will permit vehicles to drive into the room to facilitate unloading, reduce contamination of adjacent areas, and allow mechanical handling of heavy casks or shields. There should be adjacent rooms available for use as an emergency surgery and a change room. The equipment available should include a large sink, decontamination table,

movable shields with arm ports and viewing window, shielded storage for clothes and equipment, and a mechanical crane or a remotely controlled, movable device of some type.

(6) As important as, or even more important than, adequate facilities is the need to educate, train and practice all emergency personnel (health physicists, nurses, firemen, security guards, etc) in the problems of decontaminating the massively contaminated persons in emergencies. The training should include decontamination procedures for management of the seriously injured with high levels of contamination.

A paper on the medical aspects of the SL-1 accident is being prepared for publication in cooperation with the Los Alamos personnel who participated in the autopsy and decontamination of the victims. This report will describe in more detail the medical experience and recommendations resulting from the SL-1 accident.

2.2 Microfilm Program for Inactive Medical Records

During 1961, initial steps were undertaken to microfilm the medical records which have been removed from the active files. These records currently are being stored until it is apparent that no further scientific or legal purpose is served by their preservation. This requirement will extend for many years, probably until after the predicted average life expectancy of these individuals has been reached. Therefore, it was considered desirable to reduce these records on microfilm for storage and yet preserve them in a fashion which would provide a convenient recall on demand.

All the inactive medical records at the Central Facilities were microfilmed with a 24:1 reduction in size. The films were mounted in plastic 3- x 5-inch jackets which would hold up to 36 record pages each. The jackets are labeled by individual name and filed. Over 4000 inactive records have been filmed and mounted in this fashion.

The reader-printer device shown in Figure 9 was purchased to enable the user to read the record directly or to receive a prompt print-out of the page. When an individual's record is reactivated, the microfilmed portion remains in the file until a specific need arises to reproduce a particular page.

After some experience is gained in the use of this system it is anticipated that portions of the active records also can be processed as the need for additional filing space arises.

Fig. 9 The reader-printer device enlarges microfilmed records for direct reading or print-out. The file cabinet will store approximately 10,000 medical records.

2.3 Medical Record Research

Throughout the atomic energy installations, interest has been high on the interpretation of peripheral blood counts. In some studies, such as a study of U. S. uranium miners, the ordinary blood counts have demonstrated significant statistical changes at relatively low radiation exposure levels. Since many other factors are known to affect blood counts in various manners, there also is need for further study of these changes in the normal working population.

With these considerations in mind, a blood count questionnaire was devised to provide information on some of these factors. Each person receiving a routine blood count at the dispensary is asked to complete the questionnaire to provide information which may be analyzed in the future. Information will be available to study the influences of such factors as age, sex, occupation, time of sampling, sampling technique, seasonal variations, effects of various clinical flu and cold symptoms, effect of other infections, drug effects and variations in consecutive individual samples. The blood counts on any occupational radiation exposure groups or exposure levels also can be studied. The questionnaire results will be transferred to IBM cards so that when sufficient numbers are available a statistical analysis can be undertaken.

This study also will be of interest because both red and white blood counts are being made on automatic blood cell counting equipment. It will provide an opportunity to examine the normal blood count variations seen with such equipment used in a routine industrial-type dispensary.

During 1961 the study of slit lamp eye examinations in nuclear reactor workers has been continued by reviewing the examinations performed this year and coding them on IBM cards. It is anticipated that within another year or so a sufficient number of new examinations will be available to augment the paper published in 1960.

2.4 Industrial Medical Consultations

The branch chief attended a 2-day working conference called by the U. S. Army Surgeon General's Office to formulate recommendations for handling military reactor accidents. He participated as a member of the group assigned to recommend emergency radiation protection standards. Other groups studied the problems of control and reduction of exposure during reactor emergencies, follow-up action for exposed personnel and handling of injured and dead.

Medical consultation was provided to the IDO office of counsel during a preliminary hearing of a workmen's compensation case involving an AEC-IDO contractor. The claim involved damages for cataracts alledgedly due to radiation exposure. The case is being continued for future hearings.

As part of the daily dispensary medical work, a number of potential or existing health problems in the plants were discovered or examined. These are investigated by the industrial hygienist and the medical department for recommendations regarding future control. During 1961 medical examinations and recommendations were provided for such problems as organic coolant (terphenyl) exposures, coal tar pitch fume, oxides of nitrogen, lead peroxide and benzene exposures.

The branch is frequently consulted for presentations at plant safety meetings. Talks on such topics as occupational hazards, toxicology, radiobiology and first aid are considered an important part of the employee training required for a good preventive medical program.

2.5 Medical Services Branch Training

An Armed Forces Medical Symposium at Sandia Base, Albuquerque, N. M. was attended by the assistant branch chief. The course presented material on nuclear weapons hazards and nuclear medicine which will be of value to the Radiological Assistance Medical Team. He also attended the Northwest Health Mobilization Training Course sponsored by the USPHS at Sun Valley, Idaho.

The branch chief attended a one-week "Management Institute" sponsored by the American Society for Public Adminstrators at Boulder, Colorado.

A weekly staff meeting is held for the Medical Services Branch personnel and contractor nurses. Typical subjects considered at these meetings during the past year included a review on artificial resuscitation, types of respiratory protective equipment, closed chest cardiac massage, plutonium hazards, ice water treatment of burns, industrial dermatitis, treatment of dermatitis, obesity, the inflamed eye, intramuscular injections, anaphylaxis, medicolegal aspects of occupational medicine, practical applications of psychiatry, psychological techniques in handling stress, carbon monoxide poisoning and fallout.

2.6 Hospital Planning for Handling Radioactively Contaminated Patients

In past years surveys of the Idaho Falls hospitals had been made to formulate a plan for the best method to handle radioactively contaminated patients in their facility and avoid contamination of the rest of the hospital. During 1961, the Lost River hospital at Arco, Idaho, also was surveyed for this purpose. A plan was completed and forwarded to the hospital. The plans of a new hospital construction project in Idaho Falls were reviewed during 1961 to incorporate certain ideas which would be useful as a decontamination facility in emergencies.

Two meetings with Idaho Falls physicians were conducted for the purpose of familiarizing them with the problems one can anticipate when attending radioactively contaminated patients.

Preliminary plans are being made with the state hospital association, insurance carriers and the Idaho Department of Labor to have a one-day seminar in 1962 to instruct hospital administrators, supervisory and nursing personnel throughout Southeastern Idaho on radiological safety and procedures in the hospital. The help of the local chapter of the Health Physics Society and AEC Medical Service personnel has been requested in the presentation of the course.

3. 1961 MEDICAL SERVICES STATISTICAL REPORT

3.1 Dispensary Visits

In 1961 there were 5408 personnel visits for treatment or consultations at the CFA dispensary. An additional 3914 visits were made for physical examinations, laboratory or X-ray examinations, innoculations and sample collections. The 9322 total visits represent a decrease of 2% from 1960. This decrease was due almost exclusively to the decline in construction activity at the NRTS which resulted in only 55% of the 1960 treatment visits for construction contractors.

The distribution of the treatment visits are tabulated in Table I. Comparison of the number of treatments at the CFA dispensary for the years 1958-1961

Table I

1961 CFA DISPENSARY TREATMENT VISITS

Company	Occupational	Non-Occupational	Total	%
Phillips	631	2506	3137	57.7
AEC	111	928	1039	19.2
Construction Contractors & Others	317	237	554	10.1
Argonne	65	128	193	3.7
Atomics International	65	81	146	2.8
Other Federal Employees[a]	46	93	139	2.6
Westinghouse	71	48	119	2.2
Aerojet	12	30	42	0.9
Combustion Engineers	1	33	34	0.7
General Electric	3	2	5	0.1
Totals	1322 (24.4%)	4086 (75.6%)	5408	100.0

(a) Includes all Federal employees except AEC, ie, U. S. Weather Bureau, U. S. Geological Survey, U. S. Public Health Service, U. S. Navy, U. S. Army, etc.

is shown in Figure 10. It is to be noted that three treatment visits out of four are for non-occupational conditions. Although this figure is comparable with other industrial experience, the geographical isolation of the NRTS promotes somewhat greater emphasis of treatment for minor non-occupational conditions since visits to a family physician result in the probable loss of at least one-half man-day of work.

The number of treatments and total visits to the contractor dispensaries are tabulated in Table II.

The total number of treatments in all NRTS dispensaries during 1961 was

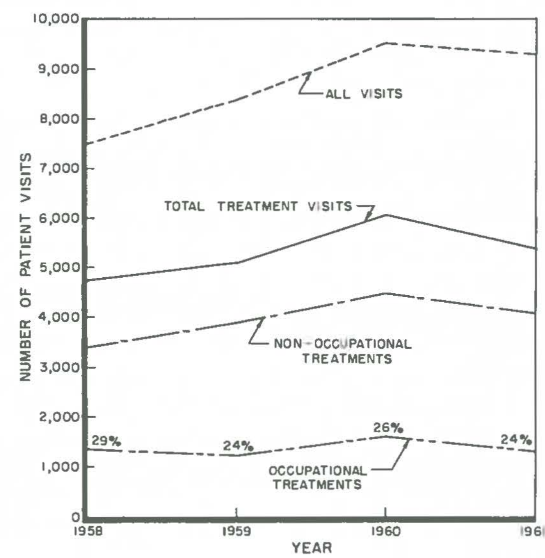


Fig. 10 CFA dispensary visits, 1958-1961.

Table II

1961 NRTS CONTRACTOR DISPENSARY TREATMENT VISITS

Dispensaries	Occupational	Non-Occupational	Total
CPP (Phillips)	245	1,304	1,549
MTR-ETR (Phillips)	985	5,762	6,747
EBR-I & EBR-II (Argonne)	230	1,142	1,372
NRF (Westinghouse)	1,796	10,715	12,511
General Electric	166	2,320	2,486
First aid stations	300	462	762
Totals	3,722 (15%)	21,705 (85%)	25,427

30,835. In addition, 13,664 patient visits were made for the purpose of physical examinations, immunizations, and laboratory sample collections. The grand total for all dispensary visits was 44,499.

An analysis of 2299 occupational injuries occurring at NRTS during 1961 is tabulated in Table III. The data indicate that 68% of injuries were lacerations, abrasions and contusions of the skin, of which the majority occur on the extremities. The incidence of eye injuries, particularly foreign bodies, constitutes 10% of all cases. A 14% decrease in eye injury frequency from 1960 appears to be due to the decline of construction work. Sprains or strains and burns are the other frequent classes of injury. It is to be noted that more than 95% of the occupational cases resulted from physical injuries. These are minor injuries for the most part and the totals reflect the relative emphasis on reporting minor injuries.

3.2 Physical Examinations

A total of 1307 personnel received physical examinations in 1961, an increase of 11.3% over 1960. Table IV identifies the number of examinations done for the various contractors. The growth of the physical examination program is illustrated in Figure 11.

The physical examination scheduling system instituted last year has greatly improved the distribution of medical examinations. The emphasis is for more-frequent examinations on the older employees and for those working in radiation areas.

Table V compares percentages of more common diagnoses on physical examination during the past three years. Table VI itemizes the most common new diagnoses of which 56% were asymptomatic.

3.3 X-ray and Laboratory Work

X-ray examinations were made on 1690 persons during 1961. This was a 12.8% reduction from the previous year. A portion of this decrease was due to a

Table III

ANALYSIS OF 2299 OCCUPATIONAL INJURIES AT THE NRTS

	Extremities	Trunk	Head	Eyes	Total	%
Skin wounds	1423	35	94	13	1565	68
Foreign bodies	81	0	6	149	236	10
Strains & sprains	61	93	0	0	154	7
Burns	153	6	16	6	181	8
Flash burns	—	—	—	19	19	1
Dermatitis (Conjunctivitis)	9	5	2	37	53	2
Blisters	35	0	4	0	39	2
Fractures	10	2	0	0	12	
Hernias	—	3	—	—	3	1
Electrical shock	1	3	0	0	4	
Fume exposure	—	3	—	—	3	
Miscellaneous(a)	7	2	21	0	30	1
Total	1780 (77%)	152 (7%)	143 (6%)	224 (10%)	2299	100

(a) Includes headaches, concussion, temporary hearing loss, consultations, infections, neuritis, etc.

Table IV

1961 PHYSICAL EXAMINATIONS

	Pre-Placement	Periodic	Termination	Total	%
Phillips	36	420	134	590	46
Argonne	104	147	45	296	22
AEC	40	124	31	195	15
Westinghouse	40	36	13	89	7
Atomics International	32	22	—	54	4
General Electric	—	50	—	50	4
Combustion Engineers	—	4	27	31	2
Others	1	—	1	2	0
Total	253	803	251	1307	100

decrease in personnel at the NRTS, and part is due to some relaxation in the requirement for chest X-rays when personnel terminate their employment.

There was a 10.5% increase in laboratory studies performed in 1961 compared to last year. A summary of laboratory procedures performed in 1961 is tabulated on Table VII. During the latter half of 1961, the technician began collecting blood and urine samples at some of the plant areas in conjunction with the annual laboratory work done on all persons working in radiation areas. This was done to reduce the time lost from work for such sample collections. A total of 268 individuals had laboratory work done in this manner.

The patient visits for laboratory and X-ray work for the past six years are portrayed in Figure 12.

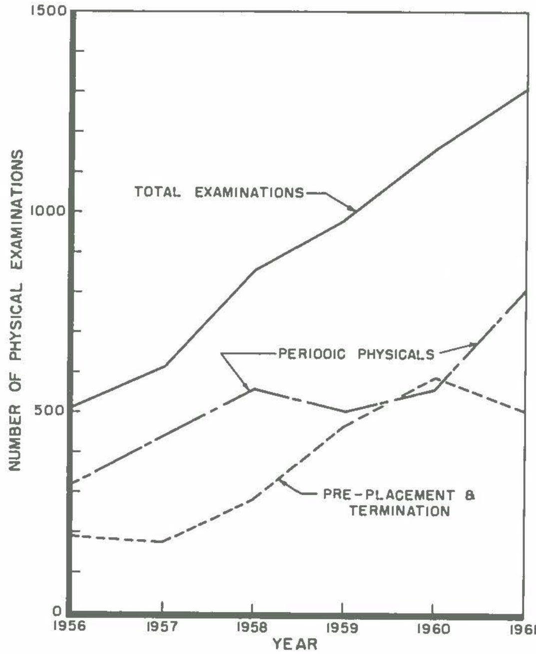


Fig. 11 Physical examinations performed by Medical Services branch, 1956-1961.

Table V

MOST COMMON DIAGNOSES ON PHYSICAL EXAMINATIONS

	Exams Evaluated (%)		
Diagnosis	1961(a)	1960(b)	1959(c)
Normal	25.7	27	26
Vision correction required	23.8	22.0	18.2
Overweight	18.5	13.0	9.9
Hay fever	9.7	6.1	4.9
Defective color vision	4.9	2.6	3.3
Drug sensitivity	4.7	2.7	2.7
Hearing loss	4.6	2.7	4.0
Hypertension	2.8	2.8	2.0
Prostate disease	2.8	1.8	2.5
Peptic ulcer or recurrent gastritis	2.1	1.6	2.4
Recurrent back strains	1.9	2.1	1.6

(a) 939 exams evaluated.

(b) 1157 exams evaluated.

(c) 975 exams evaluated.

Table VI

MOST FREQUENT NEW DIAGNOSES

Diagnosis[a]	No.[b]	%
Prostatitis	17	1.8
Hypertension	8	.85
Hemorrhoids	5	.54
Inguinal hernia	4	.43
Dermatitis	3	.32
Testicular mass	3	.32
Organic heart disease	2	.21
Diabetes	2	.21
Anemia	2	.21

(a) Acute respiratory disorders not included.

(b) Out of 939 exams.

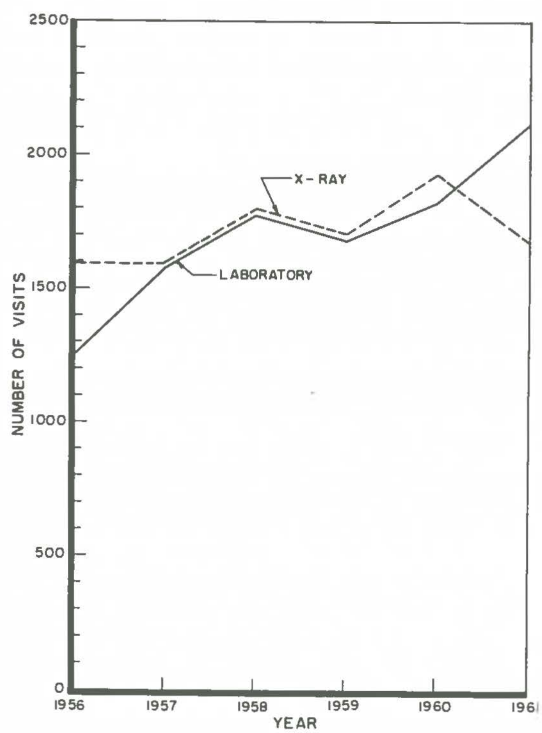


Fig. 12 Patient visits for X-ray and laboratory examinations at CFA dispensary, 1956-1961.

Table VII

1961 LABORATORY PROCEDURES

Hemoglobin	1,678
Hematocrit	345
White blood count	1,985
Red blood count	1,621
Differential cell count[a]	1,985
Urinalysis	1,855
Serology	515
Electrocardiograms	228
Miscellaneous[b]	21
Timed vital capacity	25
Total	10,258

(a) In some cases, slides are only prepared and stored without counting.

(b) Includes glucose tolerance, uric acid, blood sugar, and sedimentation rate tests.

4. FUTURE PROJECTS

4.1 Emergency Planning and Facilities

Work will continue in order to incorporate the lessons of the SL-1 accident into the available medical emergency plans. The initial efforts have been designed toward procuring essential emergency equipment and supplies. It will be necessary to place greater emphasis on instructing emergency personnel in standard techniques for decontamination of injured persons in the next year.

Some preliminary planning has been done for establishing a medical decontamination center adjacent to the CFA dispensary. It is planned to submit a proposal for such a facility in the 1964 budget. In addition to the decontamination center, allowances will be made to incorporate additional dispensary space to correct present deficiencies and to meet anticipated future needs.

4.2 Research Programs

Although the efforts of the branch personnel and the medical facilities are directed almost wholly toward the promotion of preventive industrial health procedures, there has been a continued interest in secondary research problems. In addition to continuing the eye examination program for detection of early radiation effects and the blood count statistical study, it is hoped that an additional program on developing a simplified platelet-counting technique can be started during the next year.

There is a need to study economical, screening-type personnel monitors for rapid detection of internal gamma-ray-emitting isotopes in persons at a fraction (10 to 25%) of permissible body burdens. The availability of such a device for incorporation with physical examinations would have a number of advantages for routine counting even though the sensitivity and versatility would be relatively limited when compared with more elaborate whole-body counters. Although there is no proposed program of this type at present, the Medical Services Branch maintains an interest in the potentials of this subject.

5. TALKS

The following papers were presented by Dr. John H. Spickard during 1961:

(1) "Medical Aspects of the SL-1 Accident", Pacific Northwest Section of American Industrial Hygiene Association, Idaho Falls, Idaho.

(2) "Common First Aid Problems", Idaho Falls Chapter of Safety Engineers Society, Idaho Falls, Idaho.

The following talks were given by Dr. George L. Voelz during 1961:

(1) "Acute Biological Effects of Radiation"	State University of South Dakota Medical School facility, students and local medical society. This talk was arranged

	and sponsored by the Medical Education for National Defense (MEND) program.
(2) "Medical Aspects of the SL-1 Accident"	AEC Bio-Medical Program Director's Meeting, Berkley, California.
	University of Cincinnati Medical School Radioisotopes Department lecture.
	Kettering Laboratory, Industrial Medicine Seminar, Cincinnati, Ohio.
	Central Chapter of the Society of Nuclear Medicine, Chicago, Illinois.
	Idaho Falls LDS Medical Staff, Idaho Falls, Idaho.
	Upper Snake River Medical Society, St. Anthony, Idaho.
	Annual AEC-AEC Contractor Health Personnel Meeting, Oak Ridge, Tennessee.
(3) "Reactor Accidents"	USPHS Conference for the Medical Liaison Officer's Network, Las Vegas, Nevada.
(4) "Medical Supervision of Workers Potentially Exposed to Radiation"	American Industrial Health Conference, Los Angeles, California.
(5) "Biological Effects of Radiation"	Annual Navy Reserve Nuclear Sciences Seminar, Idaho Falls, Idaho.
	Air Force Reserve, Pocatello, Idaho.
	Southeastern Idaho Medical Society, Pocatello, Idaho.

6. PUBLICATIONS

(1) "Medical Supervision of Workers Who May Be Exposed to Radiation", George L. Voelz, M. D. Journal of Occupational Medicine, Vol. 4, p 212, April 1962.

(2) "Industrial Nursing in the Nuclear Reactor Industry", George L. Voelz, M. D., American Association of Industrial Nurses Journal, Vol 9, p 18, November 1961.

IV. PERSONNEL METERING
(F. V. Cipperley - Branch Chief)

1. SCOPE

As a service organization, the Personnel Metering Branch provided personnel metering coverage to 18 operating and construction contractors at 20 separate project areas during 1961. In addition to the normal services furnished, assistance was provided the contractors in performance of various special tests, special procedures were developed for the SL-1 operation, and new computer programs devised for reduction of data accumulated by all branches of the division.

2. SUMMARY OF MAJOR PROGRAMS

2.1 SL-1 Operation

As a result of the SL-1 accident the task of radiation exposure determination and accumulation constituted one of the major programs of the branch during 1961.

Approximately 63 persons were involved in the exploratory and rescue phase of the operation on January 3 and 4. The highest estimated exposures for this group were 120 rem of beta and 27 rem of gamma. These original estimates were arrived at by the simple method of evaluating the density on the film behind the cadmium filter as penetrating gamma, subtracting this density from the total density found on the film in the open window area, and evaluating the remaining density in the open window area as beta. This method tends to produce an erroneously high beta value but was accepted to provide a quick gross estimate of the exposures received. Later re-evaluation, using the energy determination procedure, reduced this beta exposure to 65 rem.

Approximately 310 persons were involved in the recovery phase of the operation and received average exposures of 0.47 rem beta and 0.45 rem gamma. Ten persons were authorized up to 10 rem during this phase. The personnel neutron threshold detectors, described in the 1960 annual report [4], which were incorporated in the film badges of these persons were counted with negative results.

The task of radiation exposure determination and the type of reporting service furnished during the emergency would have been impossible without the use of multiple filter badges, the wide range of the Dupont-558 film packets (0.01 to 1000 r) and the automatic data processing capabilities.

An extremely difficult energy dependance problem was encountered in the film dosimetry due to mixed energy beta and gamma radiation with maximums of 2.5 and 1.6 Mev respectively and dose rates as high as 1000 r/hr. How this problem was solved is explained in the section on Special Activities.

During the period January 5 through February 15, complete updated exposure lists were furnished the control group each morning at 8 a.m. covering all exposures received at SL-1 through 9 p.m. the preceding day. These lists showed the exposure received on each entry into the SL-1 as well as the accumulated total for each individual as of that date and proved invaluable for exposure control and work assignment purposes. These lists (example in Table VIII) were continued on a weekly basis for the balance of the year.

General Electric took over the contract for cleanup and dismantling of the SL-1 on May 22 and utilized approximately 660 persons during the rest of the year. The average exposure for this period was 2.6 rem beta and 1.1 rem gamma. The recommended Radiation Protection Guide of 10-rem skin dose with not more than three rem of penetrating radiation in any quarter, or 30-rem skin dose in a year, applied to this phase of the operation. The high beta-to-gamma ratio during the initial clean-up, and in certain locations after the removal of the reactor vessel, caused the skin dose to be the limiting factor in almost all cases. Where the beta-to-gamma ratio could not actually be determined, a 4:1 ratio was applied based on results obtained from experiments.

2.2 Automatic Data Processing Improvements

An IBM 1620 computer with paper tape reader punch was added to the automatic data processing equipment in March of 1961 and a card reader punch was added in September. This provided the input and output capability of cards, tape, typewriter or any combination of the three. This computer proved invaluable in the exposure evaluation, and type and energy determination of the large number of films necessitated by the SL-1 dismantling operation. The computer is shown in Figure 13.

In addition to the regular film badge evaluation program referred to in the 1960 report, the following programs have been compiled and are currently in use:

Statistics - Sigma I. General Fortran program to accept data and calculate mean, variance, standard deviation, and relative standard deviation of any list of numbers. Used for analysis of various experimental data.

Statistics - Sigma II. Fortran program to accept data in special form from output of mutlichannel analyzer, perform analysis of individual channel values, differential values, or numerical integration. Output is mean of quantity involved, variance, standard deviation, and relative standard deviation.

Whole-Body Counter Program - I. A Fortran program solving a set of simultaneous equations involving relative photo peak heights to determine body content of several radioisotopes, from multichannel analyzer data, from the whole-body counter.

Whole-Body Counter Program - II. Similar to WBC-I under differing geometry conditions dependent upon

Fig. 13 Computer room.

Table VIII

RADIATION EXPOSURES CHARGEABLE TO SL-I ACCIDENT

Name	Date	Contr.	Area	Badge No.	mr Values Beta	mr Values Gamma	Temporary Film No.
Doe, John	1-9-61	1	3	661127			
	1-5-61	1	16	661127		120	29171
					*	120*	
Doe, Harry		71	22	064764			
	1-6-61	71	16	064764		30	26592
	1-12-61	71	16	064764			29234
					*	30*	
Doe, Jack	1-27-61	67	16	160107		400	38267
	1-28-61	67	16	160107		520	38293
	2-3-61	67	16	160107			40685
	2-4-61	67	16	160107		190	33514
	2-7-61	67	16	160107	50	380	39415
					50*	1490*	
Doe, Tom		2	5	032062			
	1-7-61	2	16	032062		55	22644
	1-9-61	2	16	032062			29218
	1-10-61	2	16	032062		40	28366
	1-12-61	2	16	032062		40	32816
	1-23-61	2	16	032062		30	20505
	1-25-61	2	16	032062		40	29860
	1-26-61	2	16	032062		35	41001
	1-26-61	2	16	032062		25	37654
	1-27-61	2	16	032062		40	38266
	1-28-61	2	16	032062		65	40960
					*	370*	
Doe, Bill	1-6-61	71	22	040132			
	1-6-61	71	16	040132	110	40	26632
					110*	40*	

* Indicates total

orientation of the subject and utilizing specific calibrations for specific conditions.

Calculation of Body Burden - I. Fortran program operating under same general approach as WBC-I and II except much more flexible. Embodies selection of constants from tabulated data in memory, and solution of a set of simultaneous equations by matrix inversion. Input data is multichannel analyzer output.

Frequency Distribution of Film Badge Results. Fortran program to select the correct frequency interval for beta, gamma plus neutron and total exposure, and to accumulate the number of exposures within each category. Used for monthly, quarterly and annual reports.

SL-1 Film Badge Program. Fortran program for exposure determination on belt badges worn during SL-1 operation. Output is calculated beta and gamma exposure and the residual soft gamma energies, in a form utilized for further computer processing.

SL-1 Belt Badge Program. Fortran program to determine exposure to regular body badge, calculate average beta and average gamma from belt badges, and determine beta-to-gamma ratio. Applies this ratio to either the regular body badge gamma or average belt badge gamma, whichever is higher, and assigns beta and gamma exposure for individual entry into SL-1. Also calculates mean, variance, standard deviation, high, low, average and difference of film badge exposures.

Carbon Cartridge Program. Fortran program for calculating air concentration values and maximum iodine-131 dose to the thyroid. The input is data from carbon cartridges used in conjunction with hi-volume air samplers for environmental monitoring.

2.3 Visitor Procedure

The visitor badge procedure, discussed in the 1960 annual report [4], eliminating X-ray operation, specially numbered badges and specific servicing schedules, has proven quite satisfactory. An estimated 50% saving in time has been achieved through use of this procedure, as well as the ability to accumulate all exposures for transient personnel.

3. SPECIAL ACTIVITIES

3.1 SL-1 Recovery Operations

The rescue and recovery operation following the SL-1 accident was the largest contributor to special activities for the year. Exposure evaluations, radiation level determinations, special calibrations, special film processing, and the determination of a beta-gamma ratio fully occupied several weeks following the accident. Special one-time reports on various aspects of the operation, as well as the daily reports of accumulated exposures, also represented a sizable load.

The film results of the initial rescue personnel were determined through evaluation of densities in the open window area and behind the cadmium filter without regard to energies, as stated previously. All subsequent determinations were made using the energy determination procedures. At that time all calculations were done manually, as the computer had not yet been received. Exposures received up to 9 p.m. one day were evaluated and the results available for preparation of the updated exposure report by 8 a.m. the following morning. After installation of the computer this phase of the work was much faster and easier.

The radiation levels within the SL-1, which ranged from approximately 1000 r/hr above the reactor vessel to approximately 400 r/hr on the periphery of the operating floor, were determined by use of specially processed badge film, chemical dosimeters and high-range instruments.

To aid in the film evaluation, quantities of film packets and badges were exposed to 5000 r and 10,000 r gamma by the National Bureau of Standards for use as calibration films. Also, films were exposed to 5000 r and 15,000 r, as measured by Fricke dosimeters and E. G. & G. chemical dosimeters, at the MTR gamma facility for the same purpose. During one of the recovery operations, badges were positioned above the reactor vessel for approximately 10 hours and the films were then processed with the special calibrations. These films were first evaluated by densitometric methods and were determined to exceed the upper limits of the system. They were then evaluated by Mr. W. V. Baumgartner of General Electric at Hanford using the radio-fluorometric method. With this method the quantity of reduced metallic silver contained in the film emulsion is determined by exciting the silver with X-ray and measuring the fluorescence produced. The amount of fluorescence is then compared with that produced by calibration standards. This method allows exposure determinations much higher than densitometric methods which rely on the absorption of light. Eleven of the twelve films indicated estimated exposures of 10,000 r and the final film was estimated at approximately 12,000 r. This indicated a radiation level of approximately 1000 r/hr above the reactor. The personnel threshold neutron detectors in these badges were processed with no indication of neutron activity being detected.

At the start of the cleanup phase of the operation, the General Electric health physicist was faced with a difficult problem. The indicated variation in the beta-to-gamma ratios was so great that work time limits were practically impossible to set with any degree of confidence that the total exposure received would approximate the calculated exposure. To complicate matters further, the film densities produced in the open window area at the exposure levels being experienced approached saturation on the sensitive film and were barely above threshold levels on the insensitive film. This resulted in three densities on the filtered areas of the sensitive film and one unreliable density on the open window area of the insensitive film, with no capability of correlating the four densities. This of course negated the energy determination procedure for differentiating beta and soft gamma radiation by the use of multiple filters.

To fully appreciate the problem being faced, picture debris and material emitting beta and gamma radiation with an energy spectrum of 0 to 2.5 and 1.6 Mev, respectively, covering the entire inside of a large steel can approximately 12 feet high and 38 feet in diameter. Several attempts were made using various filter materials and phantoms to determine an average beta-to-gamma ratio, with very little success. Apparently the ratio indicated on any given entry was determined by the material or item the man was working with, and his orientation relative to the multiple sources within the reactor building.

Finally it was decided to try to overcome orientation and other problems by using a large number of badges in different body positions for each person entering the reactor building. A supply of army-type web belts with roller buckles which could be adjusted to fit any size waist were obtained. These were equipped with a maximum of 18 badges each to form a complete circle around the wearer. Two or three large men used all 18 badges but in most cases 12 to 15 were sufficient. Badge number one was positioned just to the left of the belt buckle in all cases, with the highest numbered badge positioned just to the right of the buckle. During the experimental period, two belts were mounted on fiberboard cartons and taken into the reactor building. These were left long enough to produce reliable densities behind all four filters on the insensitive film. This then allowed application of the energy determination procedure to the evaluation of the insensitive film densities.

Each person entering the reactor building wore one of these belts with from 1 to 18 badges. Each person also wore a regular film badge in the normal location on the chest (Figure 14) which was designated as badge number 19 in all cases.

After each person left the building, his badge films were processed and, fortunately, in almost all cases a sufficient number were capable of evaluation to provide a beta-gamma ratio for that particular entry. This ratio was then applied to either the gamma exposure as shown by the film badge in the normal chest location or the average gamma exposure as shown by the belt badges, whichever was higher. From the results of the two test belts exposed to the higher exposure level and averages of a large number of the other belts, an average beta-to-gamma ratio of 4:1 was established for cases where energy determinations could not be made. These cases occurred occasionally due to the fact that empirical data for energies of 25 Kev through 1.3 Mev from cobalt-60 only were available for use in the energy determination procedure with no density ratio figures to apply for energies from 0.0 to 25 Kev. Table IX is an example of a series of belt badge results.

Fig. 14 SL-1 badge belt and regular body badge.

3.2 Generator Case Activity Tests

A complete series of tests was performed for Westinghouse at the NRF area to determine the distribution and magnitude of residual radioactivity in steam generator cases. This entailed fabrication of special light-tight film holders shaped to fit the generator cases, cutting and loading of Kodak type KK radiographic film and special calibrations.

3.3 Primary Shield Tests

Primary shield tests were performed for Aerojet General Nucleonics at the GCRE area to determine its efficiency. Regular film badges were water-proofed and used underwater for these tests. Determinations were performed for gamma and fast neutrons.

3.4 On-the-Job Training

A number of persons were provided training in personnel metering techniques and procedures during the year. They included Dr. Argeo Benco, Dr. Massimo Giubileo and Mr. Claude Pelletier of the Euratom group, Ispra, Italy; Dr. Francis Duhamel, Mr. Michel Gras and Mr. Charles LeMorvan of Paris, France; and Mr. Henry Gjrup and Dr. Roberto Kayser of Riso, Denmark.

AEC Fellows Arden Bicker, John Zinbrick, Alfred Western, Myrl Wilson, John Kendig, Robert Landolt and Jacqueline Power spent a week each with the group as part of the NRTS Applied Health Physics Training Program.

Four personnel metering clerks were provided instruction in the operation of the IBM 1620 computer and one new clerk received on-the-job training. Twenty-six seminars were held covering personnel metering techniques.

3.5 Non-Routine Processing

In addition to regular activities, the branch processed various non-routine items used by the Site Survey Branch, contractors and other groups in fallout studies, special tests, etc. Table X lists a comparison of these items processed in 1960 and 1961.

Table IX

SL-I BELT BADGE RESULTS

	mr Values		
Badge No.	Beta	Gamma	Total
1	3630	1265	4895
2	No Determination Made		
3	5280	1215	6495
4	Saturated Open Window	1565	—
5	Saturated Open Window	1150	—
6	5570	1110	6680
7	5600	1150	6750
8	5365	1160	6525
9	5400	1140	6540
10	5530	1200	6730
11	4035	1160	5195
12	3645	1130	4775
13	3480	1120	4600
14	3535	1180	4715
19	Saturated Open Window	1285	(reg. body badge)
Belt Badge Averages			
11 out of 14	4643	1196	5839

Beta-gamma ratio = 3.88

Exposure Determination

3.88 x 1285 = 4990	1285	6275

Belt average beta-gamma ratio (3.88) times regular body badge gamma (1285).

Table X

NON-ROUTINE FILM PROCESSED 1960 - 1961

Year	5 x 7 Film	14 x 17 Film	Beta-Gamma Film	Neutron Film	Ring Film	Wrist Badges
1960	31	179	7,381	77,850	1082	61
1961	—	174	12,257	83,183	862	2

4. ROUTINE ACTIVITIES

The radiation exposure experience at the NRTS during 1961 was the highest in its history. The effects of the exposures received at the SL-1 area were felt by most of the contractors due to the cooperation of their personnel. Volunteers from the general NRTS area were utilized in the various phases of the operation. The highest individual accumulated exposure to penetrating whole-body radiation during the year was 27.3 rem while the highest accumulated skin dose was 88.1 rem. Eighty-one percent of all NRTS personnel received an accumulated exposure to penetrating radiation of less than 500 mr and only 0.41% received 5.0 rem or more. The average accumulated exposure to penetrating whole-body radiation for all NRTS personnel, including exposures received at the SL-1 area, was 0.42 rem as compared to 0.29 rem in 1960.

Table XI presents a frequency distribution of exposures received by IDO personnel. These results are for AEC and contractor personnel engaged only on contracts administered by IDO, and do not include visitors or personnel employed on contracts administered by other Operations offices.

A total of 20,660 visitors was badged during 1961 with over 98% receiving statistical zero exposures. All others were well below the recommended Radiation Protection Guide for any period.

A comparison of the number of routine personnel metering badges processed for 1960 and 1961 is shown in Table XII.

Table XIII presents the radioactivity results of urinalyses performed in 1961 and a comparison of totals for 1960 and 1961. Ninety-six percent of the samples yielded insignificant results and only two were 10% or above of the permissible body burden for the isotope of interest. One of these was 10% and the other approximately 20% as a result of iodine-131 inhalation received during the SL-1 operation.

Table XI

WHOLE-BODY PENETRATING RADIATION EXPOSURES RECEIVED BY ALL IDO PERSONNEL IN 1961

Exposure Level (rem)	Average Exposure (rem)	Group A	Group B	Group C	Group D	Group E	Group F	Group G	Total	%
0 - 0.5	0.07	1101	233	1417	34	66	36	48	2935	72.02
0.5 - 1	0.73	201	34	64	2	1	10	21	333	8.17
1 - 2	1.43	167	88	49	8	0	34	35	381	9.35
2 - 3	2.45	84	49	20	4	0	44	13	214	5.25
3 - 4	3.42	63	40	1	3	0	31	6	144	3.53
4 - 5	4.38	27	11	0	0	0	7	2	47	1.15
5 - 12	6.73	3	0	0	0	0	8	1	12	0.29
12 - 25	18.80	0	3	0	1	0	0	1	5	0.12
> 25	26.15	0	1	0	3	0	0	0	4	0.10
Totals	0.42[a]	1646	459	1551	55	67	170	127	4075	

(a) Based on total exposure received by all regularly badged personnel at the NRTS regardless of contractor

Table XII

FILM BADGES SERVICED AT THE NRTS 1960 - 1961

Year	Regular	Temporary	Total	Approximate Number of PM Coverages
1960	137,436	50,574	188,011	7727
1961	106,357	41,212	147,569	7237

Table XIII

URINALYSIS RESULTS IN 1961

Isotope of Interest	Type Activity	Total Number Performed	% of Total Statistically Significant	Highest Result(a)
β	Gross β	30	17.00	172 ± 16 d/m/5 ml
γ	Gross γ	9,120	4.00	1,900,235 ± 876 d/m/75 ml
U	α	4	0	1×10^{-5} g/l
Pu-239	α	29	0	2×10^{-9} μc/ml
Sr-91	β	2	0	4 ± 8 d/m/ml
Sr-90	β	3,248	2.00	183 ± 8 d/m/75 ml
Be	—	3	0	4×12^{2} μg/l
Co-60	β	1	0	300 ± 75 d/m/450 ml
Ag-110	β	14	0	Insignificant
Cs-137	β	40	0	1,460 ± 10% d/m/1700 ml
H-3	β	3	0	10×10^{-5} μc/ml
1961 Totals		12,494	4.00	
1960 Totals		11,352	1.29	

(a) All less than 10% of the NCRP permissible body burden for the isotope of interest except two I-131 exposures listed under gross gamma activity.

5. FUTURE PROGRAMS

5.1 Research in Film Dosimetry

A staff physicist will conduct experiments during 1962 as follows:

(1) Latent image fading in neutron monitoring film as a function of time interval between exposure and processing under normal conditions experienced at the NRTS. The goal is to extend neutron badge period from the present two weeks to four weeks.

(2) Methods for determining thermal neutron exposures from beta-gamma film densities and exploration of density methods for determining fast neutron exposure.

(3) Response and density ratios of Dupont-558 film packets exposed in the NRTS badges to photons with energies of less than 25 Kev.

5.2 Automatic Film Reader

The development and circuitry work on the new automatic film reader was essentially complete by the end of 1961. Checking and debugging is going on and delivery to the branch is expected in May. Replacing of the lead inserts in all badges, necessary to provide proper format for the reader, will begin in April. This operation will require approximately 30 days.

5.3 Computer Programming

Several additional computer programs are planned for the coming year:

(1) Programs to automate the reduction of multichannel analyzer data.

(2) Programs to automate the reduction of gross gamma, gross beta and alpha counting data.

(3) Program to automate the reduction of telemetering system data.

(4) Program to automate the reduction of well water sample data.

(5) Program for the analysis of variance data.

(6) Programs for other statistical methods used by Health and Safety personnel such as chi square, F-test, t-test, etc.

5.4 Thermal and Intermediate Neutron Problem

Detection and measurement of exposure to personnel from fast neutrons has been provided by the Personnel Metering Branch since its inception. However, no personnel monitoring devices have been devised to measure exposures to thermal and intermediate neutrons. The cadmium filters in the film badges provide an indication of exposure to thermal neutrons through the production of density in this film area by the n, γ reaction of the cadmium. However, at present no routine method has been perfected to supply exposure values for the density found. During 1962 this problem will be explored and an attempt made to arrive at some method for detection and measurement of neutrons in the thermal and intermediate range.

5.5 Reduction in Neutron Film Program

As can be seen in Table X, the processing of neutron film constitutes a large portion of the non-routine work load. New criteria for use of neutron film throughout the reactor areas will be developed to reduce the number of such films in use.

V. ANALYSIS
(Claude W. Sill - Branch Chief)

1. SCOPE

The Analysis Branch maintains and operates a general purpose analytical laboratory from which all AEC and contractor personnel at the NRTS may obtain analyses for any chemical or radioactive material that may be required. The principle effort is directed toward determination of toxic or radioactive materials which could affect the health and safety of personnel working at the NRTS and those in the surrounding communities. Particular effort is made to utilize fully modern techniques of alpha and gamma spectroscopy, whole-body counting and high-speed electronic computers for reduction, analysis and storage of analytical data.

2. SUMMARY OF MAJOR PROGRAMS

2.1 Whole-Body Counting (D. R. Percival and J. I. Anderson)

During the past year whole-body counting has become one of the most important programs of the branch. Most of the impetus for the tremendous acceleration that has taken place was provided in January by the SL-1 incident and a silver-110 spill that occurred at the Engineering Test Reactor. Throughout the remainder of the year, other releases of activity have occurred providing still further incentive to get the program into high gear. A routine whole-body counting program was initiated to determine body burdens of personnel beginning and terminating employment at the NRTS.

The whole-body counter facility provides a means for in vivo detection and analysis of gamma-emitting radioactive contaminants in bodies of personnel working at the NRTS. Concentrations as low as 0.01 microcurie can be detected in a 10-minute count for most gamma emitters which is several orders of magnitude lower than the maximum permissible body burdens in most cases. Most candidates for whole-body counting probably will come from the following categories:

(1) Major radioactive incidents in which the personal protection of individuals involved dictates an immediate assessment of internal contamination followed by possible medical treatment and subsequent uptake and elimination studies.

(2) Minor incidents in which the amount of radioactive material in the body represents little or no biological hazard, but a knowledge of which would aid in pinpointing sources from which further contamination could take place.

(3) Checking people on a routine basis who are not known to have been involved in an incident, but who may have in fact picked up some radioactivity, ie, routine personnel monitoring. It should be emphasized that this is an extremely sensitive method

for determining radioactivity in human beings. Cases of slight internal contamination are being found occasionally where no specific exposure was known to have taken place.

(4) Routine checks of people at both the beginning and termination of their employment at the NRTS for establishment of base lines for future reference and for medical-legal records.

In addition to the obvious value of these records to contractors, an additional benefit will be derived from the data obtained from individuals who have accumulated some internal contamination. Much current information on biological half-life, mode of elimination, etc., is of necessity estimated or extrapolated from research on animals. Data obtained on human beings following accidental exposure could make a significant contribution to the field of radiation biology.

Perhaps the most important conclusion derived from experience on whole-body counting to date is the realization that many isotopes that normally would be expected to be voided in the urine, at least in part, are in fact eliminated by way of the feces. Whole-body data have disclosed the presence of antimony-122 and 125, silver-110, cobalt-58 and 60, zinc-65, and zirconium-niobium-95 in individuals involved in five separate incidents that were not detected in a routine urinalysis and have permitted unequivocal determination of their elimination rates. Concurrent analyses of fecal and urine excreta showed the main elimination route to be by way of the feces with so little voided in the urine as to be undetectable even on a 24-hour specimen. Although antimony, silver and zirconium might be expected in the feces because of the possibility of insoluble forms, zinc and cobalt would not, particularly to such a quantitative extent. The conclusion seems inescapable that the metabolic fate and mode of excretion will be more dependent on the physical properties of the particle with which the radionuclide is associated than with the ionic, periodic-table chemistry of the element. The experience cited above shows conclusively that urinalysis is not a reliable monitoring technique for internal radioactive contaminants in general although it is adequate for certain ones such as iodine. Fecal analysis would be much more inclusive as a detection device but involves prohibitive problems of collection, storage, transport and interpretation of results. On the other hand, whole-body counting is convenient, very sensitive and completely unequivocal. The major disadvantages are the cost of the equipment and the time lost while workers are away from their jobs if they have to go very far to the analytical facility.

The shield for the whole-body counter shown in Figure 15 consists of a steel cylinder 5.5 inches thick and 96 inches long with an inside diameter of 52 inches surrounded by steel slabs 5.5 inches thick. A steel slab 11 inches thick supported on two special roller bearing hinges forms a door at one end of the cylinder. This configuration was chosen to utilize low-background armor plate steel of preatomic bomb vintage that was available at the NRTS. Ventilation is provided by a small blower. Lights and a communications system also are provided.

The chair shown in Figure 15 was designed to position the body on a 50-centimeter arc with respect to the detector and makes the counting rate essentially independent of source distribution for the major portion of the body. It is equipped with an adjustable head rest and is mounted on a pair of sliding rails which permit it to be withdrawn from the vault for ease of subject placement.

(a)

(b)

(c)

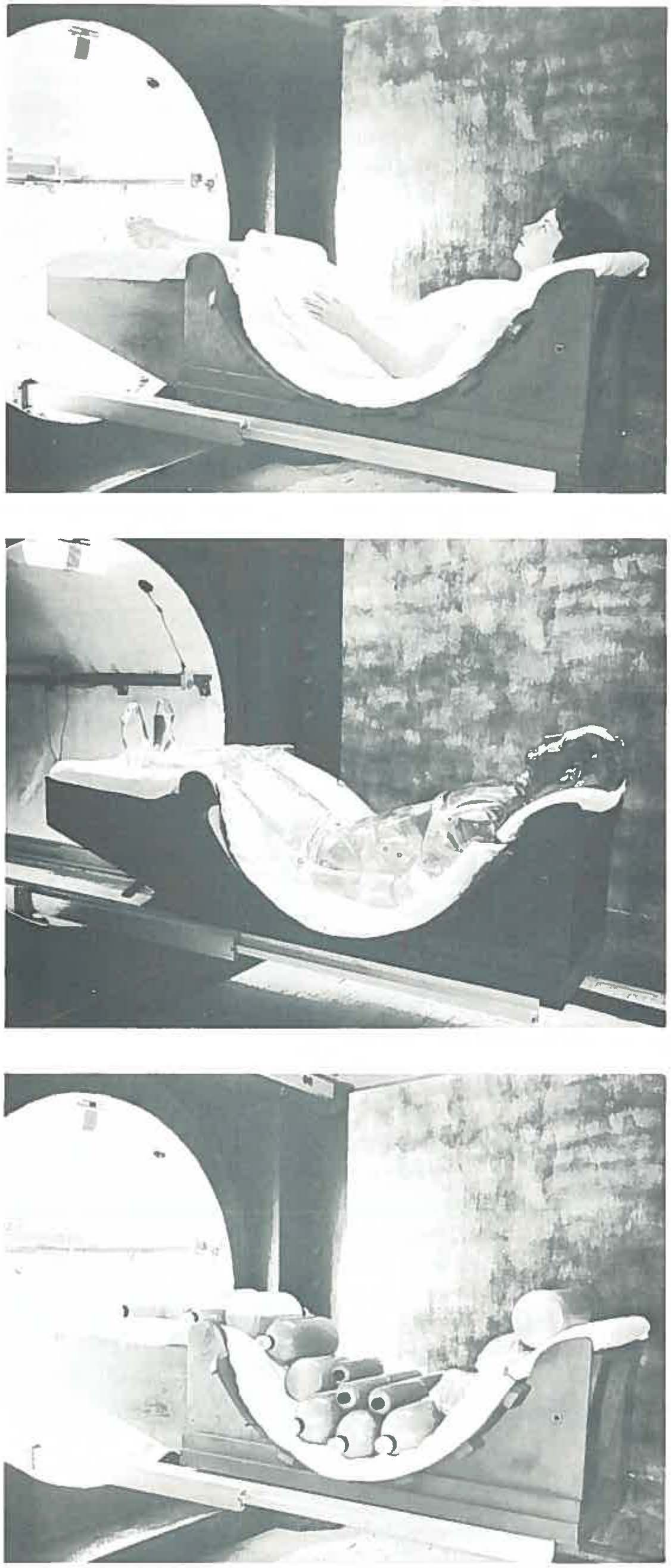


Fig. 15 Steel shield and contour chair showing methods of use and calibration.

The detector is a cylindrical thallium-activated sodium iodide crystal eight inches in diameter and four inches high. The crystal is mounted so that the center of the bottom face is at the center of the 50-centimeter arc chair to minimize scattered radiation from the walls of the shield and to obtain independence of counting rate on source geometry mentioned above. Originally, a five-inch CBS-7819 multiplier phototube was used to convert the scintillations produced in the crystal into voltage pulses which were analyzed by a 256-channel pulse height analyzer. Recently, the crystal was resurfaced to minimize variations in the light-collecting efficiency throughout the surface of the crystal by preferentially controlling its reflectivity. The crystal was recanned in stainless steel with three 3-inch RCA multiplier phototubes integrally coupled as a single unit from which greatly improved resolution of about 10.2% for cesium-137 is obtained at the present time. Also, a 400-channel analyzer is now being used instead of the 256. The additional memory capacity permits background subtraction to be made while the sample spectrum is being obtained with a range of 0 to 2 Mev. The gamma-ray spectrum from the analyzer can be either printed out digitally by an IBM typewriter, plotted on 3-cycle semilog paper with an X-Y recorder or punched on paper tape by a Tally punch and reader shown in Figure 16.

Several methods have been used to calibrate the counter for various radionuclides: (a) A number of point sources of known activity were distributed in appropriate organs of a plastic mannikin (REMCAL) as shown in Figure 15 (b) and the instrument response determined; (b) Instrumental response has also been determined to homogeneous solutions of radionuclides in tissue-equivalent solutions contained in polyethylene bottles arranged to simulate a human subject in the chair as shown in Figure 15 (c). This method has become standard practice since adopting the 50-centimeter arc geometry; (c) An individual to whom a five-microcurie dose of iodine-131 had been administered for diagnostic purposes was used to calibrate for this nuclide. His total excretions were collected until equilibrium distribution was attained in the body. The calibration was then obtained from the activity remaining in the body; (d) In some cases, the activity in the total excreta between two whole-body counts has been used to obtain an approximate calibration factor. This method has been used primarily with people who had some internal contamination of isotopes for which calibrations had not been available previously.

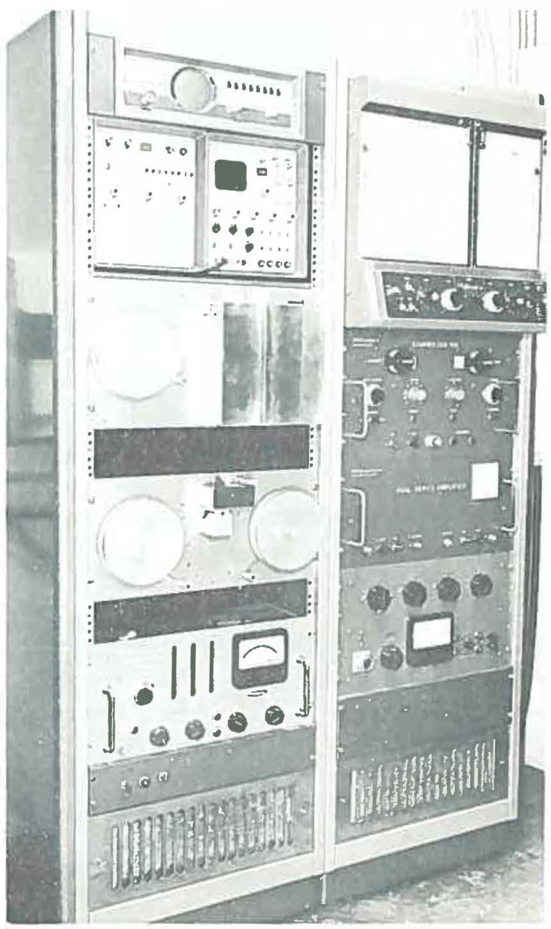


Fig. 16 Control panel for whole-body counter showing 400-channel analyzer, Tally paper punch and read-back device, X-Y recorder and scanner control.

The following standard procedure has been adopted for routine whole-body counting: Prior to the analysis, the individual is required to take a shower in one of the two shower facilities adjoining the counter, taking particular care to get the hair and fingernails scrupulously clean. If the person might have a significant amount of external contamination from having been in a contaminated area, he is required to take a pre-examination shower in another part of the building before being allowed to enter the showers in the counter area. When thoroughly clean, he is provided with a special disposable paper examination gown and sandals shown in Figure 15 (a). Substitution of disposable gowns for the cloth coveralls originally used has several advantages. Unless a prohibitive supply of the coveralls was available, the time required for laundering became an unexpected bottleneck in the rate at which analyses could be made. The gowns are very comfortable, require less storage area and cost no more than the cloth coveralls did to launder. In addition, each subject gets brand new clothing never before worn by others.

The subject removes his sandals, positions himself comfortably in the chair and the chair is centered under the detector. After a 10-minute net count is obtained, the spectrum is examined quickly on the oscilloscope of the analyzer. If it appears acceptable for later analysis, the data is recorded and the subject is permitted to dress and leave. If the spectrum indicates the need for longer counting or further decontamination of the subject, action may be taken while he is still available. Generally, a 10-minute net count provides a sufficiently well-defined spectrum and minimizes the instrument time required per individual. The spectrum is then analyzed by any of several methods depending on its complexity. Generally, a set of standard spectra obtained during calibration of the instrument is available to assist in identification of photopeaks present in the subject spectra. If only one or two isotopes are present and their photopeaks are well separated, direct comparison to the standard spectra suffices. If the spectrum is complex, ie, if the photopeaks of several species merge into a broad, poorly resolved band, standard spectra can be subtracted manually channel by channel until all peaks have been accounted for and their quantities evaluated. If the isotopes present can be identified from the original spectrum, the stripping process is simplfied considerably since it needs to be done only at the previously identified peaks.

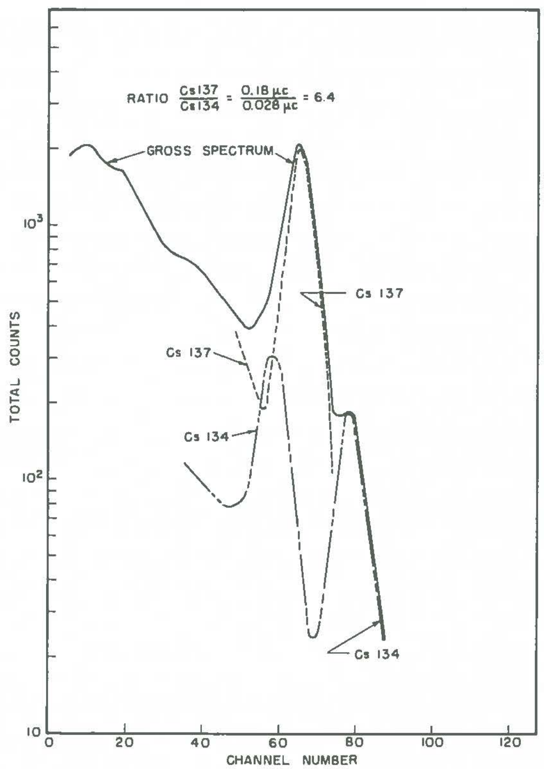


Fig. 17 Resolution of cesium-134 and cesium-137 from a gross spectrum obtained from human subject.

A simple case of spectrum stripping is shown in Figure 17 and demonstrates the excellent resolution of cesium-134 obtained after stripping cesium-137 from the mixed spectrum obtained from a human subject. Cesium-134 activity was only one-sixth that of the cesium-137 and appeared in the mixed spectrum as only a slight shoulder on one side of the predominant cesium-137 peak and a slight broadening on the other. A much more complicated spectrum also obtained from a human subject is shown in Figure 18. The top curve shows the net whole-body spectrum composed of potassium-40, cobalt-60, zinc-65, silver-110 and cesium-134 in descending order of energy after subtraction of background. The other curves show the spectrum remaining after sequential subtraction of standard spectra starting at the high energy end and ending with curve 5 which is the spectrum of cesium-134. Both human subjects received the low-level internal contamination shown while performing their routine assignments and the spectrum stripping of both figures was performed by hand. Programs are presently being written by which quantitative spectral analysis can be facilitated and the manual data reduction eliminated by use of high-speed electronic computers. One program already written will accommodate as many as six components.

Figure 19 shows a comparison of the background spectra inside and outside the shield of the whole-body counter. The prominent peak occurring in the external background spectrum originates from the potassium-40 in the concrete walls, floor and ceiling surrounding the crystal. The steel shield effectively removes most of the external background in the energy range of greatest interest, ie, 0.1 to 2 Mev. The internal background is caused primarily by the inherent activity of the shield, crystal, phototubes and other associated components. Little further reduction in background of practical importance is expected.

Eleven different radionuclides were detected in personnel at the NRTS during the year. Iodine-131 and cesium-137 were the only nuclides positively

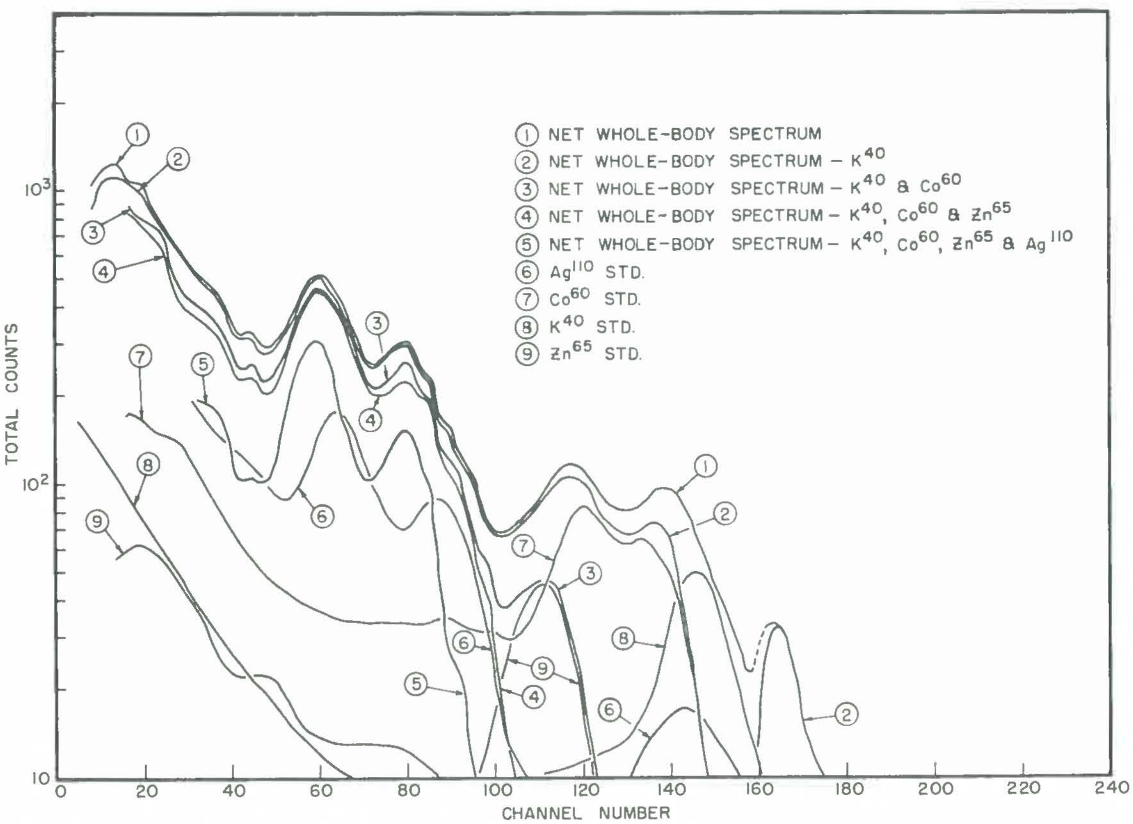


Fig. 18 Resolution of a mixture of 5 different isotopes from a gross spectrum obtained from human subject.

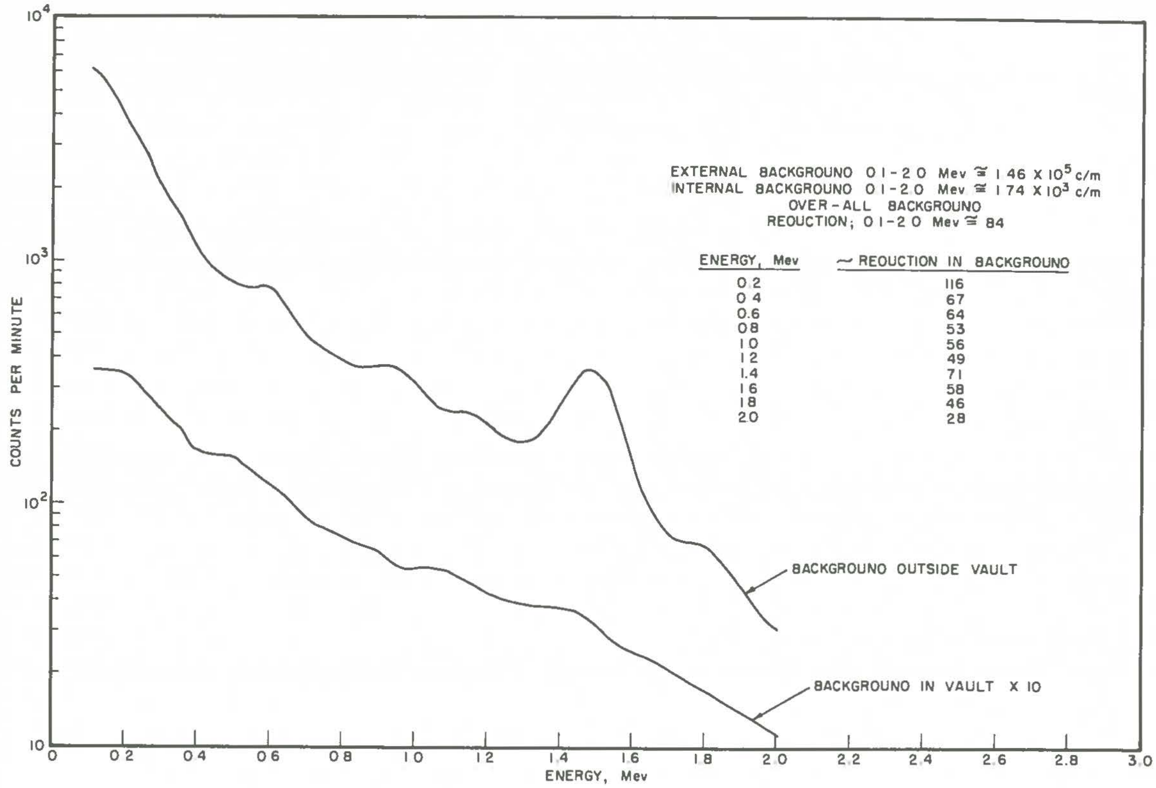


Fig. 19 Gamma spectra of background inside and outside of the steel shield of the whole-body counter.

identified in personnel involved in the initial phase of the SL-1 incident with some zirconium-niobium-95 possibly present. Within one week of the incident, body burdens were in the range 0.1 to 2.6 microcuries for iodine-131 and 0.02 to 0.2 microcurie for cesium-137. For comparison, handbook 69 gives maximum permissible values of 0.7 microcurie for iodine-131 in the thyroid and 30 microcuries of cesium-137 in the total body. Cesium-134 also was identified in some of the people involved in subsequent cleanup and dismantling operations. The maximum quantity of silver-110 resulting from a spill at the Engineering Test Reactor was approximately 0.9 microcurie with the majority of people involved containing less than 0.05 microcurie. The maximum from the zinc-65 incident at the Materials Testing Reactor was about 0.7 microcurie. Other isotopes have been identified in isolated cases throughout the year. Mercury-203, iodine-131, and cesium-134 and 137 were voided in the urine. However, as mentioned above, colbalt-58 and 60, silver-110, zirconium-niobium-95, antimony-122 and 125, and zinc-65 were found in the feces but could not be detected in the urine even though specific attempts were made using 1500-milliliter samples. Isotopes from other sources might act differently, but consideration should always be given to the fact that the radionuclide might be associated with a refractory particle and will act like the particle rather than follow the normal chemistry to be expected from the ionic form.

Approximately 870 whole-body spectra from about 250 different persons were obtained and analyzed in the first year of operation of the counter.

2.2 Application of Electronic Computers to Reduction of Analytical Data (D. C. Foster)

With the availability of a high-speed computer (IBM 1620) in the Personnel Metering Branch, considerable savings of personnel time and increased efficiency of utilization of man power in the Analysis Branch was accomplished. Many routine calculations and data reductions formerly done by hand are now accomplished by the computer.

2.21 Pulse Height Analysis. Identification and quantitative evaluation of gamma-emitting isotopes in samples brought to the laboratory for analysis is frequently accomplished by means of gamma ray spectroscopy. This is especially true when more than a single isotope is present as is frequently the case. Such determinations can be made with little or no sample preparation or chemical separations.

By means of a multichannel analyzer the output of a gamma sensitive detector is converted to a pulse height distribution in which the frequency of occurrence of pulses in a given band of analyzer channels is proportional to the rate of emission of gamma ray photons of a given energy (dependent on the calibration of the analyzer). Interpretation of the complex pulse height distribution from the analyzer in terms of the amounts of each isotope present in a given sample has been done in the past largely by time-consuming hand stripping methods in the case of complex spectra. Even to obtain quantitative values from relatively simple spectra requires considerable hand calculation involving determination of the total number of counts registered in channels corresponding to the principal photopeak of the isotope, the geometric efficiency of the source detector geometry, self absorption, peak-to-total ratio for the particular detector (a function of gamma ray energy), and the decay scheme characteristics of the isotope.

The use of a high-speed computer to eliminate these calculations and some of the human errors involved has been accomplished through two different approaches.

(1) Spectrum Stripping Techniques. A high-speed computer can be programmed to analyze a complex spectrum by means of a technique wherein a "standard" spectrum of one of the gamma-emitting isotopes present is normalized to the spectrum being analyzed (in the major photopeak area) and then is subtracted or "stripped" from the sample spectrum, channel by channel. Knowledge of the source strength of the standard and the normalizing factor permits quantitative determination of the amount of the isotope in the sample, and the residual spectrum after stripping is available for further analysis. In order to avoid the normalization being affected by the contribution of other isotopes in the photopeak areas, the successive subtractions are done beginning with the highest energy photopeak and progressing in order of successively lower gamma ray energy.

(2) Composite Spectrum Analysis. Another approach to the analysis of a composite spectrum is to consider the sample spectrum to be a linear sum of the spectra of the constituent isotopes. The constituent gamma-emitting isotopes are identified by the presence of their characteristic photopeaks and a set of simultaneous

equations are written in which the coefficients are the relative amounts of each component isotope. Knowledge of the source strengths of the standards from which the component spectra are obtained, together with the set of relative amounts of each present (from the solution of the set of simultaneous equations) permits a quantitative determination of the amount of each isotope identified as being present in the sample. An advantage of this method over the stripping technique is that the errors due to statistical uncertainty of the input data are not cumulative as they are with each successive subtraction involved in the stripping technique. An advantage of the stripping technique is that inspection of the residual spectrum after each successive subtraction can reveal the presence of other components present which are unidentifiable from the original sample spectrum. Input data to either of these analysis programs is presently by means of data key-punched from the digital output of the analyzers. The ultimate method being planned is the use of a punched paper tape output from the analyzers as input data. Only the delay in obtaining and installing this paper tape output equipment is holding up utilization of this refinement.

2.22 Data Reduction, Evaluation and Interpretation. The end result of any quantitative technique in an analytical laboratory is a numerical reading or value of some instrument response such as a pulse height analyzer, scaler, photometer, etc. In order to interpret this as a quantitative value of the parameter desired, some calculation, simple or involved, is necessary to convert it to a meaningful result taking into account calibration data, weight or volume normalization, etc. This kind of data reduction lends itself extremely well to computer reduction.

The evaluation of the precision of data by computation of the standard deviation at various confidence levels involves simple but time-consuming calculation if done by hand. Several computer programs have been written to accept different kinds of data from laboratory operations and compute the standard deviation, relative standard deviation and the mean of data in sets. Other programs have been written to evaluate the statistical significance of data obtained under some variation of the parameters involved by computing the Chi square value, value of Fishers F or student t.

Another application of computer technology is in obtaining the best-fit parameters to an analytical expression from experimentally obtained data. This technique is useful in interpolating results for parametric values between those investigated. Programs have been written to do this.

2.23 Programming Methods. The programming that has been accomplished or anticipated makes use of the FORTRAN (Formula Translation system) developed by the IBM corporation for use with their computers. This is essentially a program written for a given computer which processes a program written by an individual in FORTRAN language (and fed to the computer in the form of punched cards or tape) and converts it to an equivalent program in machine language. Algebraic statements may be written in FORTRAN language readily and are sufficiently similar to the usual algebraic form that the system may be learned by a technically trained person quite readily. For instance, the algebraic statement:

$$A_o = A_o (1 - e^{-kt})$$

may be written in FORTRAN as

$$A = AO * (1 - EXP(-KT)).$$

Knowledge of the rules for writing algebraic statements, control statements, memory allocation requirements, and the requirements as to the form of data entering or leaving the computer permit an individual to make efficient use of the computer without undergoing extensive training in the details of machine language programming or computer theory.

Sixteen programs for various purposes have been written and used by personnel in the Analysis Branch and several more are in the process of development. Increased use of this means of data reduction and evaluation will be made as more equipment is modified to produce a form of output suitable for direct data entry to the computer, usually in the form of punched paper tape.

2.3 Fluorometric Determination of Thorium (C. P. Willis)

Investigation of the fluorometric determination of thorium using morin has been completed. The final procedure has a detection limit of 0.01 microgram of thorium and a precision to about 0.5% on five micrograms, both at the 95% confidence level. A highly efficient buffer system is used to give exact control of pH to permit maximum precision. A high concentration of diethylenetriamine pentaacetic acid (DTPA) is used to stabilize the fluorescence and to depress the fluorescence produced by yttrium, scandium, lanthanum and lithium. Triethanolamine is used to eliminate oxidation of the morin reagent in the presence of iron and to prevent local precipitation of thorium during neutralization of solutions with strong sodium hydroxide. Sodium citrate is used to suppress the very sensitive fluorescence produced with zirconium sufficiently to eliminate interference from this source in the concentrations encountered. Both time and temperature of measurement are important and must be controlled. An exhaustive study was made of the effects of most of the other elements in the periodic table on the thorium-morin system and the procedure was revised to minimize their effects. Beryllium, zirconium, titanium, uranium, aluminum, chromium and barium are the only elements that interfere significantly in quantities less than about one milligram. By limiting the total sample taken for analysis to 50 micrograms, as much as 20% zirconium, 10% uranium, 4% titanium and similar concentrations of the other interferences except beryllium can be present without producing detectable interference and still permit detection of as little as 0.02% thorium. These concentrations permit determination of thorium in all ores of practical importance and well below levels permitted by 10 CFR 20 for continuous exposure in air and water without separations of any kind. A single determination can be completed in less than one hour.

Of special interest is the discovery that thorium and morin are present in the fluorescent species in a 1:1 ratio. In order to account for the remaining three valence bonds and six coordination positions of thorium, a 1:1:1 complex is proposed containing DTPA in addition to thorium and morin. Strong evidence is also presented for similar three-way complexes involving Zr-DTPA-morin, Zr-DTPA-citrate and Al-citrate-morin.

2.4 Geochemical Studies Related to the Waste Management Program (D. B. Hawkins)

The purpose of this study is to determine the optimum conditions for the discharge of the maximum amount of low-level liquid waste to the Lost River alluvium without getting a breakthrough of hazardous radioisotopes to the ground water. During the past year the equipment necessary for the performance of this study was designed and purchased. The geochemical laboratory in which this work will be performed was designed and the construction of this laboratory has just recently been completed.

The alluvium in the vicinity of the MTR pond has been sampled by taking 4-inch x 4-inch x 24-foot channel samples down the gravel faces exposed in the gravel pits at MTR, CPP, CFA, and the No. 2 Fire Station as shown in Figures 20 and 21. Each channel sample, eight in all, has been mechanically analyzed to determine grain-size distribution. These analyses have been used as a basis for determining grain-size variations between samples, and as an estimate of the mechanical composition of the material beneath the MTR pond. A comparison of the grain-size distribution of gravel samples obtained from auger-drilled wells with that of the channel samples is being made to determine if auger samples can be used as reliable measures of the mechanical composition of the alluvial sediments. The results of this study will appear as an IDO report.

A program to determine macrochemical composition of the waste released to the MTR pond has been completed. This involved taking 10 samples a week from different parts of the MTR pond and having these samples analyzed for

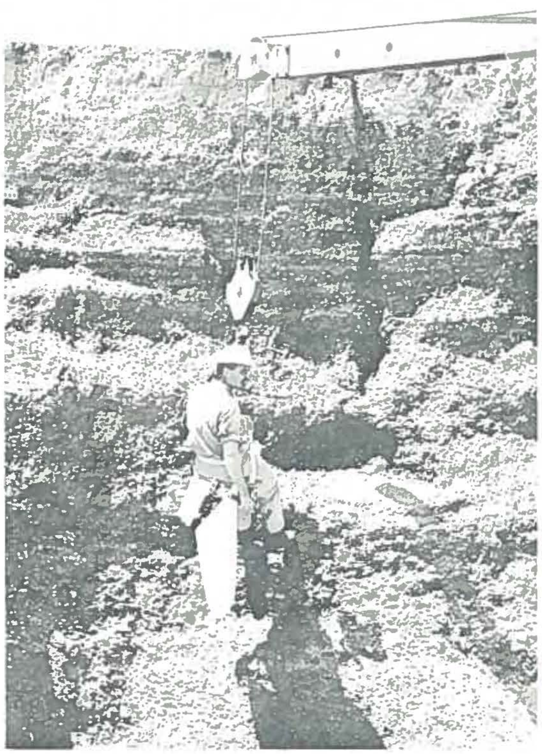


Fig. 20 Channel sampling of gravel face.

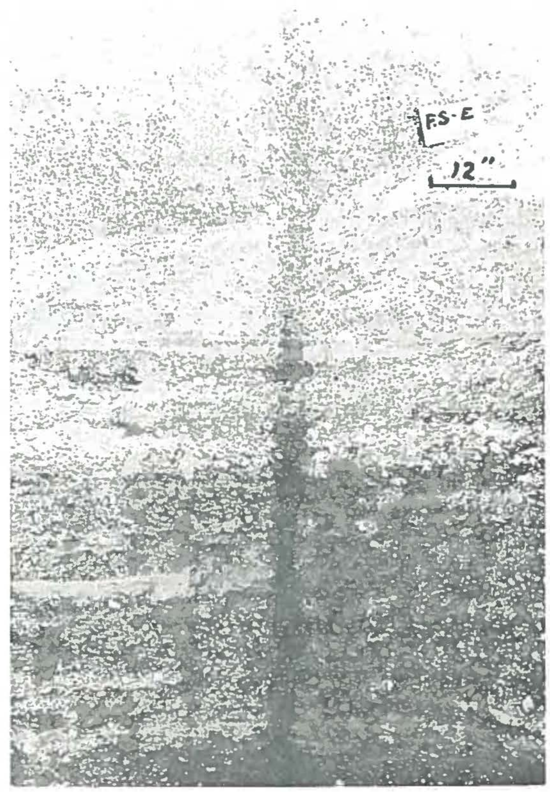


Fig. 21 Typical channel sample.

Na, K, Mg, Ca, Sr, Ba, Al, Cr, Fe, F, Cl, NO_3, CO_3, HCO_3, PO_4, SO_4, pH, and conductivity. The pond was sampled for a period of ten weeks.

2.5 Chemistry of the Actinides (K. W. Puphal)

The known chemistry of the actinide elements was reviewed with particular emphasis placed on the various alpha-emitting isotopes of uranium, neptunium, plutonium, americium and curium. Methods are being developed for the separation and analysis of these elements in urine with the most emphasis placed on plutonium.

A general method of separation and analysis is being investigated which will be applicable to any sample requiring the analysis of any or all of these elements. This would include samples of air dust, soil, water, urine, feces, and possibly samples from chemical processing plant flow-streams.

The method involves a fluoride precipitation with a rare-earth carrier which carries all of the above named elements except uranium. Plutonium is separated from the precipitate by extraction and is subsequently alpha-counted. Most conventional extracting agents now in use for the separation of plutonium require a prescribed oxidation state, usually the quadrivalent. An investigation was made for an extracting agent which was faster than some now in use and also somewhat selective. This resulted in a study of some high molecular weight amines as possible extractants for plutonium. Some of the variables involved in this study were type and concentration of acid, choice of amine, and and a suitable solvent. Plutonium forms anionic complexes in all valence states except the trivalent. This affords a good means of separation from trivalent americium and curium as the latter do not form such complexes. Plutonium was quantitatively extracted as the anionic complex with a liquid amine from a rare-earth fluoride precipitate. Neptunium also extracts and is an interference in the plutonium determination.

One of the major problems encountered in this study was that of finding a stripping agent that would remove the extracted plutonium quantitatively from the liquid amine, still give good phase separation and not introduce extraneous metal ions that would interfere in the subsequent electrodeposition. The plutonium in the anionic form can be removed by several methods such as replacement by a more strongly held anion, reduction of the plutonium to the trivalent state, or by destroying the anionic complex. All of these methods were examined. Concentrated nitric acid both replaces anionic plutonium and also destroys the anionic complex. Some degradation of the organic phase is evident with this reagent.

An investigation to find a good method of electroplating these elements after separation resulted in a modification of an existing method. The method employs an ammonium chloride medium and high current densities with electrolysis times of 40 to 45 minutes for trace amounts of plutonium and shorter times for the trivalent actinides. The activity is deposited on a 0.5-inch-diameter spot on a platinum disc. A precision study on the electrodeposition of plutonium at tracer levels showed less than 2% relative standard deviation, which is the error associated with the electrodeposition and does not include counting error. More than 99.5% of the plutonium was deposited on the disc. A special Teflon cell was fabricated which is threaded into a brass base with the platinum disc held between them. Some work has been done in the separation and analysis of americium and curium. Various oxidants were investigated to obtain americium (VI) and thus separate it from curium (III) by precipitating the latter as the fluoride. A persulfate oxidation system was successful. Further investigation is underway.

Future work involves selective stripping agents for plutonium from a liquid amine in the presence of neptunium. Also, alpha counting of extremely low-level samples by nuclear track counting is anticipated.

2.6 Mill Program for Recovery of Uranium (J. P. Price, H. C. Creviston)

Analyses were made for radium-226 and thorium-230 on 96 river water samples and liquid effluents from mills processing uranium ores for the Division of Licensee Compliance. Since recovery of radium from liquid samples of 1500-milliliter volume is $100 \pm 2.5\%$ and decontamination from thorium-230 and polonium is greater than 10^5 and 10^4, respectively, no further development work seemed necessary on the procedure for radium-226. The procedure for thorium-230 is still lacking in some respects although this isotope can be determined accurately in liquid samples containing very little sulfate or phosphate. Investigation of the proper conditions for a very precise and reliable determination of thorium-230 will be pursued vigorously in the coming year. Experience gained in the very satisfactory development of the fluorometric procedure for thorium-232 is expected to be of considerable assistance in solving some of the vagaries of thorium chemistry.

2.7 Determination of Strontium-90 in Soils and Milk (P. D. LaFleur)

2.71 Soils. Previous methods for the determination of strontium-90 in soils generally have employed acid-leaching processes for removing the strontium from the soil. These processes are incomplete, time consuming, and erratic in the quantity of strontium removed. The procedure developed in this laboratory utilizes the procedure for the dissolution of refractory silicates described in last year's annual report [4] to dissolve the soil completely and make the strontium quantitatively available for analysis. Precipitations of strontium with fuming nitric acid are used almost universally to effect separation of strontium from calcium and decontamination from fission products. These hazardous and time-consuming precipitations are eliminated in the procedure developed. Separation from calcium and decontamination from extraneous activities is effected through the use of chelating agents. The detection limit is about 3×10^{-7} microcuries/gram for 15-gram samples and about 8×10^{-8} microcuries/gram for 50-gram samples. Single samples require approximately 1.5 man-day for analysis while groups of six or more samples require only about 0.3 man-day/sample.

2.72 Milk. For determination of strontium-90 in liquid and powdered milk, partial decomposition of the milk with nitric acid is employed in contrast to a complete decomposition method such as ashing in a muffle furnace. Partial decomposition results in a considerable savings in time, especially in the case of liquid milk samples which must be evaporated to dryness prior to muffling with a great deal of attendant spattering and loss of sample. The detection limit for strontium-90 in liter quantities of milk is 3.5×10^{-9} microcuries/milliliter. Approximately six samples can be analyzed per man-day.

2.8 Nuclear Accident Dosimetry (P. D. LaFleur)

Calibration of the nuclear accident dosimeter (NAD) system was completed during the year. A 256-channel pulse height analyzer with a 3- x 3-inch sodium iodide detector has been calibrated for NAD fission foil analyses. The calibration was performed by irradiating a standard plutonium-239 foil obtained on loan from the Oak Ridge National Laboratory in a known thermal neutron flux in the Advanced Reactivity Measurement Facility at the NRTS. Counting and decay data for the fission products produced by thermal neutron fission were corrected for application to a fast neutron flux which would produce fissions in the NAD fission foils.

2.9 Determination of Tritium by Liquid Scintillation Spectrometry (J. K. Flygare Jr.)

A method for the determination of tritium in water and urine was established during the year. This method has better sensitivity, accuracy and reliability than others reported in the literature for conventional liquid scintillation counting equipment. Special attention was given to purification of the chemicals used in the liquid phosphor counting solution.

A liquid scintillation spectrometer with a two-channel pulse height analyzer was used. Because the beta particle emitted from tritium has a maximum energy of only 18 Kev and is lower than that from other beta emitters, the discriminators are set so that most of the tritium betas will fall in the first channel while those from most other radionuclides fall in the second channel. However, some of the tritium betas will fall in the second channel unless the discriminators are set unnecessarily high. Similarly, because of the continuous nature of beta emission as a function of energy, all beta emitters will have some distribution of particles with energies extending to zero and so will fall in the first channel. The ratio of beta particles falling in the first channel to those in the second for tritium with the discriminator settings used is approximately 14:1. Because most other radionuclides are counted with nearly 100% efficiency in the second channel, the ratio of the net activity in the two channels provides a very sensitive means for detecting contamination in the determination of tritium. The ratio of 14:1 obtained for pure tritium is reduced to about 5:1 when only 1% of the total activity is mixed fission products. Since any sample with a ratio of less than 11:1 is examined for foreign activity, any contamination not detected by a change in the ratio is too small to be significant in the final result. When foreign activity is present, the tritiated water is decontaminated by distillation. Some of the isotopes most likely to interfere because of energy consideration and their ratios are as follows: nickel-63, 67 Kev beta, no gamma, ratio 2.4:1; carbon-14, 155 Kev beta, no gamma, ratio 1.1:1; and chromium-51, no beta, 320 Kev gamma, ratio 1.4:1.

The detection limit of the procedure for water samples is 3.6 pc/ml with a 30-minute count and 10 milliliters of sample. By using the ratio procedure to detect contamination, sample preparation is minimized because raw water and urine can be added directly to the liquid phosphor in most cases. About 20 determinations can be completed per day. When not contaminated with other activities, colored solutions can be corrected for decreased transmittance by adding a known amount of tritium and recounting. The procedure for urine employs a 30-minute count and a three-milliliter sample giving a detection limit of 30 pc/ml which includes the uncertainty caused by potassium-40.

Concentrations of tritium found to date in underground wells range from less than the detection limit of 4 pc/ml to about 900 pc/ml in the U. S. Geological Survey wells around the CPP, from 8 to 39 pc/ml in the two production wells at CFA, 4 pc/ml in the production well at OMRE and 4 to 7 pc/ml in NRF production well No. 2. Above-ground sources of tritium have been found of 7.6 nc/ml in the ETR primary coolant water, 0.4 mc/ml in the condensate from the storage waste evaporator at CPP, 47.6 nc/ml in service wastes from CPP after combination with the evaporator condensate, and 20 nc/ml in the storage-basin water in CPP building 603. A concentration of 11.2 nc/ml was found in the water vapor around the open storage basin, and approximately 100 pc/ml in the urine of personnel working in this area. All the above concentrations vary from day to day and are given only as examples of what has been found.

2.10 General Activities of the Counting Room (A. R. Harbertson)

Because of the increased programs and areas of interest encompassed by the counting room, a full-time physicist and an analytical chemist were added to the staff. Counting room activities can be divided into four major subgroups: (a) physics and mathematics including computer programming, (b) whole-body counting, (c) gamma and alpha spectroscopy, and (d) routine alpha, beta, and gamma counting.

An additional laboratory was added, increasing the floor space by about one-third, and providing separate rooms for whole-body counting, alpha and gamma spectroscopy and routine counting. Two additional 400-channel transistorized pulse height analyzers were obtained from Technical Measurements Corp. Data from the analyzers can be presented either digitally on an IBM typewriter or graphically on an X-Y recorder. Also, a paper tape punch output and read-back device was installed recently to make the analyzers compatible with IBM computer operations. A second large steel shield for a 3- x 3-inch thallium-activated sodium iodide crystal to be used in general gamma spectroscopy also was put into operation.

2.11 Routine Urine Program (LeRoy E. Howard)

A full year's operating experience was acquired with the new method employing gross gamma counting instead of beta counting for routine urinalysis with gratifying results. Not only was the cost of analyses reduced considerably and the results made available much more quickly but the results themselves inspire greater confidence. In every case in which a statistically positive result has been obtained, even by as little as three or four standard deviations, the presence of activity has been confirmed in the human body concerned by in vivo counting in the whole-body counter and the activity has been identified. In addition, several cases have been observed in which most of the activity remained in the original container after the sample had been transferred despite acid treatment. This problem was anticipated and corrected in the new gamma-counting procedure by having the sample collected initially in the counting bottle so that no transfer was necessary. However, as expected, there were a few cases in which the outside of the counting bottles were contaminated by allowing them to be taken out of the laboratory. To guard against this contingency, all samples showing a statistically positive result must be recounted after transferring the sample to a clean counting bottle. The original container is washed with acid both inside and outside until the source of activity has been clearly established.

3. SPECIAL ACTIVITIES

A major portion of the work load of the branch continues to involve special types of analyses or problems requiring the knowledge and skill of highly trained and experienced scientists from several disciplines for proper solutions and evaluation. Generally, they are a one-time occurrence.

3.1 SL-1 Accident (E. R. Ebersole)

Following the nuclear excursion at the SL-1, the efforts of the Analysis Branch were directed toward three separate aspects of the accident. Data concerned with the nuclear aspects were needed urgently. Excretion and whole-body counting data were needed for estimation of internal dose received by personnel involved in recovery operations. Analytical support of environmental monitoring programs was required by the Site Survey Branch and the Ecology Branch. In addition to analytical services directly connected with the SL-1 emergency, normal day-to-day services were provided to other contractors on the site although on a somewhat reduced scale.

Proof of a recent nuclear excursion in a reactor which had not operated for a period of time may be obtained from identification of fission products whose half-life is short enough to preclude any significant inventory remaining in the reactor from previous operation, or by identification of neutron-induced activity in materials not previously exposed to significant neutron flux during normal reactor operation.

Because the presence of certain short-lived isotopes such as iodine-133, iodine-135, and cesium-138 would identify recent fission, samples received at the laboratory were examined for such materials. Gamma spectra of blood smear samples from the clothing of the doctor and nurse who had been in contact with the first body removed from the building failed to distinguish any short-lived isotopes which would identify a recent nuclear excursion. Iodine-131 was the predominant isotope found in urine samples taken from the men who made the first entry into the SL-1 building, and no short-lived isotopes characteristic of recent fission were identified. The same was true of air samples collected inside and outside the reactor building. The preponderance of aged fission products in each case made it impossible to identify any of the short-lived isotopes characteristic of recent fission. Failure to identify short-lived isotopes made it necessary to look for neutron-induced activity in materials present in the reactor building at the time of the accident to establish whether a nuclear excursion had occurred. These data are shown in Table XIV.

At 10 a.m. on January 4, 1961, a nuclear accident dosimeter recovered from the top of the access stairway at the entrance of the reactor floor provided the first evidence of a nuclear excursion. Gold-198 was identified and quantized in the gold foils from the dosimeter. Analysis of subsequent samples for evidence of neutron activation and estimation of energy release was extremely difficult because of high levels of contamination with aged fission products. The analytical laboratory is not equipped with shielded hoods, remote handling devices, and other equipment for analytical work on highly radioactive materials. Because of the urgency of the SL-1 emergency a calculated risk was accepted in handling samples reading up to 50 r/hr in a low-level bio-assay laboratory in order to develop information concerning the nature and extent of the nuclear

Table XIV

ANALYSES FOR NEUTRON-INDUCED ACTIVITY

Sample Description	Date of Analysis	Results of Analysis	Neutrons/cm^2 9 p.m./1-3-61
NAD dosimeter from SL-1 access stairway			
(1) Bare gold foil	1-4-61	Gold-198 identified	1.2×10^8 thermal
(2) Cadmium covered gold foil	1-4-61	Gold-198 identified	—
(3) 20-g sulfur pellet	1-12-61	No phosphorus-32 idendified	$< 10^7$, 2.5 Mev or greater
(4) Fission foils	1-4-61	No activity	—
(5) Chemical dosimeter	1-8-61	840 r, gamma	—
Cigarette lighter screw from first body	1-4-61	Copper-64 identified	9.3×10^9 thermal
Brass watch-band buckle from second body	1-5-61	Copper-64 identified	2.0×10^{10} thermal
Brass pin film badge case from second body	1-5-61	Copper-64 identified	—
Copper wire, screws from control room telephone	1-7-61	No copper-64 identified	—
100 ml blood from first body	1-7-61	No sodium-24 identified	—
Gold ring from third body	1-10-61	Gold-198 identified	9.0×10^9 thermal
Liver from first body, 1200 grams	1-11-61	No sodium-24 identified	—
Liver from second body, 1570 grams	1-11-61	No sodium-24 identified	—
Flexitallic gasket from SL-1 reactor	1-19-61	Cobalt-58 identified	2.5×10^{11} virgin fission neutrons(a)
Flexitallic gasket from SL-1 reactor	1-20-61	Chromium-51 identified	8.0×10^9 thermal(a)

(a) Calculated by Dr. Warren Burgess, Phillips Petroleum Co.

excursion. Even at these limits several samples had to be decontaminated in other facilities to levels which could be tolerated.

All analytical work connected with the SL-1 incident was performed under a general philosophy that all samples would be decontaminated until either a clear and unequivocal gamma spectrum of the activity sought was obtained or until no activity of any kind remained. The quantitative determination of the isolated activity was made from the photo peak of the gamma spectrum and was corroborated by total counting in a gamma well-crystal where this was possible. Before identification of the isotope was considered absolutely positive, its gamma spectrum had to agree with the known spectrum of that isotope, the activity had to follow the known chemistry of the element in question, and, where it was possible to determine, the isotope had to exhibit the proper half-life. The isotopes identified in SL-1 samples met at least two and in most cases all three of the above criteria.

The second piece of evidence of a nuclear excursion was obtained at 7 p.m., January 4, 1961, from copper-64 identified in a brass screw from a cigarette lighter taken from the first body recovered. This was followed by copper-64 found in a brass watch-band buckle taken from the second body and gold-198 found in a gold ring taken from the third body recovered. The copper-64 and gold-198 in the above samples were separated chemically and quantitative values obtained for each isotope. Neutron doses were calculated from these data and are given in Table XIV.

Approximately 75 hours after the accident a 100-milliliter blood sample was secured from the first body recovered by use of a mortician's trocar. The unfortunate delay in obtaining the samples was caused by associated technical problems such as availability of trained personnel, autopsy permission, and the high level of contamination of the bodies. Following chemical separation of fission product material from the sample, no sodium-24 activity was detected. As approximately seven half-lives had elapsed between the accident and completion of analysis, the upper limit for blood sodium-24 activity at the time of the accident was estimated to be less than 450 d/m/ml of blood. Following autopsy, liver tissues from two of the deceased were checked for sodium-24 activity even though calculations showed such activity would be impossible to detect due to the lapse of time following the incident. As expected, no sodium-24 was detected.

Two weeks following the accident a new flexitallic gasket which had been installed on one of the control-rod assemblies during reactor shutdown, and thus had never seen any neutrons prior to the accident, was brought to the laboratory for analysis. The highly contaminated gasket, approximately 50 r/hr, was decontaminated in hot nitric acid and then the residual stainless steel analyzed for chromium-51 and cobalt-58. A thermal neutron dose was estimated from chromium-51 activity and a virgin fission neutron dose was estimated from the cobalt-58 activity by Dr. Warren Burgess of Phillips Petroleum. The calculated neutron doses are given in Table XIV.

The problem of defining the magnitude of the excursion adequately was highly complicated by the degree of contamination of all samples with aged fission products and the paucity of suitable samples for this purpose. However, on January 6, particulate material was shaken from the clothing of the first two bodies recovered and separated into metallic-appearing and non-metallic-appearing samples at the MTR hot-cell facilities. These samples were dissolved in the remote facilities at the Chemical Processing Plant, total and isotopic uranium determined, and an aliquot sent to the Health and Safety laboratory for the determination of short-lived isotopes for the estimation on the energy release of the nuclear excursion. It was decided to attempt the determination of 9.7-hour strontium-91 since no significant amount of this isotope would remain from previous reactor history, and determination could be made through the 50-minute yttrium-91m daughter. The entire aliquot was committed to this determination since the sample contained only 34 micrograms of uranium. The total number of fissions was calculated from the strontium-91 data and the uranium content of the sample, assuming no fractionation of the strontium-91 from the uranium fuel. The number of fissions also was calculated from the strontium-91 and strontium-90 ratio. The number of fissions estimated by both methods is given in Table XV.

A subsequent attempt to determine zirconium-97 through its niobium-97 daughter on contaminated clothing in order to verify the number of fissions was unsuccessful. Because of the nature of the radiation field in the reactor building, no other suitable samples could be obtained for this type of analysis without undue exposure of personnel.

Although precautions were taken to minimize internal contamination of all who entered the SL-1 area, spot urine samples were collected from each individual following the completion of his mission within the area. All urine samples were screened by gross gamma counting and those showing significant activity were analyzed spectrally to identify the isotopes present. In all samples in which activity was found, the major isotope was iodine-131. Traces of cesium-137 and barium-lanthanum-140 also were identified in samples from those who made the first entries into the reactor building. Strontium-90 analyses were made on initial samples from each individual in which the iodine-131

Table XV

ESTIMATION OF ENERGY RELEASE

Sample Description	Date of Analysis	Isotopes Identified	Fissions, Calculated
Sample shaken from clothing of first two bodies and dissolved at CPP. Aliquot furnished for analysis			
(1) Metallic appearing sample (25 r/hr at 1 ft)	1-6-61	Strontium-91 and uranium determined	1.5×10^{18}, assuming no loss of Sr-91
	1-6-61	Strontium-90 determined at CPP	2.0×10^{18}, based on Sr-91 to Sr-90 ratio
(2) Rock and gravel sample (20 r/hr at 1 ft)	1-6-61	Strontium-91 identified	
Clothing sample from third body. Dissolved at CPP	1-10-61	No zirconium-97 identified.	

activity was greater than 10^3 d/m/75 ml of urine. Both spot and 24-hour urine samples were collected at intervals from those persons whose initial samples showed significant activity, and excretion curves for both iodine-131 and strontium-90 were plotted for these individuals. The infinity dose to the thyroid was estimated from the excretion data for 16 men with the highest excretion rate of iodine-131 and ranged from a high of 5.5 rads for one individual to a low of 0.3 rad. All others involved in recovery operations received less than 0.3 rad to the thyroids. The strontium-90 dose to the bone was calculated for three men with the highest strontium-90 excretion rate using the power function model and ranged from 10 to 1 millirads for the first year. All others involved in recovery operations received less than 1 mrad/year to the bone from strontium-90.

A whole-body spectrum obtained in the late afternoon of January 4 on one of the individuals involved in the first entry into the reactor building indicated that the major internal contaminant was iodine-131 with traces of cesium and barium-lanthanum-140. Inasmuch as the spectrum of this individual did not show any significant activity other than iodine-131 and because of the job requirements of the emergency, fecal samples were not collected. If the inhalation experiences of this individual may be taken as representative, the dose to the upper respiratory tract and gastrointestinal tract was minor.

Whole-body counting of seven persons receiving the highest internal contamination was begun on January 9 and repeated at intervals through the next three months. Cesium-137 elimination rates were obtained and dose estimates made from the whole-body data. The infinity cesium-137 dose, assuming muscle as the critical organ, was less than 32 millirads for the individual with highest contamination.

Analytical support was provided to the Site Survey Branch and to the Ecology Branch to assist in environmental monitoring following the SL-1 accident. Two hundred twenty vegetation samples were screened by gross gamma counting and representative samples examined spectrally. Iodine-131 was the major isotope found beyond the immediate SL-1 area. Twenty-eight milk samples and 13 jackrabbit thyroids were analyzed for iodine-131. During the first two months following the SL-1 accident more than 650 high-volume air samples were screened by gross gamma counting. Representative samples were examined spectrally and quantitative values of air activity were provided to the Site Survey Branch from the spectra obtained.

3.2 Criticality at Chemical Processing Plant (E. R. Ebersole)

At approximately 10:05 a.m., January 25, 1961, the Analysis Branch received information that the Chemical Processing Plant had been evacuated and that a radioactive cloud was headed in the general direction of the Central Facilities Area. Air sampling devices were turned on immediately, and at 10:15 a.m. the first activity was detected at the Health and Safety laboratory. Cesium-138 was the predominant isotope found in air samples collected between 10:20 a.m. and 10:35 a.m. in the Central Facilities Area and in the laboratory, indicating that a nuclear excursion had occurred. Film badges from personnel evacuated from the CPP were immediately brought to the laboratory, and the indium foils removed and screened in a gamma well-counter for neutron-induced activity. The indium foil from two film badges showed evidence of a small amount of activation. Sulfur pellets from these two badges showed no detectable phosphorus-32. The whole-body thermal neutron dose to the two individuals estimated from indium foil data was less than 10 millirems. Blood samples from the two individuals showed no detectable sodium-24 and whole-body counting gave no evidence of sodium-24.

Four nuclear accident dosimeter (NAD) systems from the CPP were analyzed. Only one gave evidence of having seen any neutrons. The gold foils from the NAD system located outside of H cell contained a detectable amount of gold-198 and the estimated thermal neutron dose seen by this system was 6.4×10^7 neutrons/cm^2. The sulfur pellet and the fission foils contained no detectable activity. However, manganese-56 was identified in the stainless-steel container used to enclose the fission foils.

3.3 Checklist for Sampling After Radioactive Incident (A. R. Harbertson)

In the event of accidents around nuclear reactors or where radioactive materials are being processed or stored, proper samples may provide extremely important information if taken in time. For example, what is the nature of the incident? Is it nuclear in origin and, if so, what was the cause and is it still taking place? What is the extent of damage, the area involved and the hazards presented to humans? How long before even limited access to the area may be permitted? What basic scientific facts may be gleaned from the incident that may have great value and application to future programs of a similar nature? These were the types of questions most frequently asked immediately after the SL-1 incident of January 3, 1961.

The second question asked most frequently concerned why certain data or types of information had not been obtained. As the result of experience gained during the SL-1 accident, the fault can be attributed in most cases to lack of adequate and timely samples. Frequently, collection of samples is very erratic and lacking in overall direction and coordination, particularly in times of emergency when they may be of greater importance than at any other time. The causes usually can be attributed to thoughtlessness or forgetfulness, or ignorance of the importance and urgency of obtaining samples, the kind of samples necessary or desired, or indeed, what constitutes a sample from which meaningful information can be derived.

Most people not directly concerned with the analytical work or the need are completely unaware that something as commonplace and inconspicuous as an electric light bulb can provide invaluable information about the causes and effects of nuclear incidents. The sodium in the glass, the tungsten in the filament and copper in the base and wires can be used to measure both the fast and thermal neutron flux at that geographical location from which the energy expended in the nuclear excursion might be estimated. Also, even though there might be a prohibitive amount of external contamination, the contents of the bulb will be protected completely by the glass in which the wires are embedded even if the bulb itself is broken. The samples can be obtained free of contamination quickly simply by breaking the inner glass. The high degree of external contamination with gross fission products and the valuable time consumed in obtaining adequate decontamination, particularly when looking for short-lived isotopes so vital to identification of the cause and extent of the nuclear excursion, was one of the outstanding characteristics of the SL-1 incident.

A checklist of common items which might be found around nuclear reactors and which could provide invaluable information is given in Table XVI.

Table XVI

COMMON ITEMS FROM WHICH VALUABLE INFORMATION CAN BE DERIVED FOLLOWING A NUCLEAR EXCURSION

Film Badges and Dosimeters

a. Gamma rays

b. Beta rays

c. Alpha tracks

d. Neutron tracks

e. Activation foils including gold, silver, cadmium, indium, sulphur, etc.

Air Samplers

a. Constant air monitors

b. Respirators (face masks)

c. High- and low- volume samplers

d. Fallout plates

e. Carbon cartridges

f. Millipore filters

g. Precipitrons

h. Cascade impactors

Direct Measuring Equipment

a. Ion chambers

b. Geiger counters

c. Scintillation crystals

d. Neutron counters

e. Proportional counters

f. Flux wires or foils

g. NAD systems

h. Hand and foot counters

Ecological

a. Water

b. Soil

c. Animals

d. Plants

e. Milk

f. Swipes

Personal

a. Blood

b. Nose swipes

c. Urine

d. Ear wipes

e. Sputum

f. Hair

g. Whole body, body parts

h. Finger nail swipes

i. Gold or silver teeth, also some porcelain

j. Dentures

k. Pencils, pens, tie clasps

l. Pocket money

m. Eye glasses

n. Cigarette lighters and holders

o. Gold, silver, brass rings

p. Earrings, bobby pins

q. Buttons, zippers

r. Shoes, nails, clothing including protective clothing, shoe covers, etc.

s. Screwdrivers, pocket knives and similar pocket tools or objects

t. Watches, belt buckles, bracelets and other jewelry

u. Keys, key chains

Miscellaneous

a. Metallic objects of almost any kind

b. Light bulbs

c. Sight gage glasses or other glass objects such as laboratory glassware

d. Tap water

e. Electrical wires or cables

f. Telephone drop wire and handsets

g. Nails, screws, bolts

h. Tools

i. Doorknobs, hardware

3.4 Determination of Beryllium in Meteorites

Development of modern theories for both synthesis of the elements and formation of the solar system depends to a considerable extent on knowledge of the cosmic abundances of the elements. Any tenable theory must account for both their concentration and isotopic distribution. The light elements lithium, beryllium and boron are destroyed rapidly by thermonuclear processes at the high temperatures and pressures existing in stellar interior where the heavier elements are made. Consequently, knowledge of their concentrations would be particularly helpful in determining the mechanism by which the light elements are produced, the stage of evolution of the solar system during which their formation might have occurred, and the associated time sequences involved. The very sensitive fluorometric method for the determination of beryllium at submicrogram levels has been combined with the potassium fluoride fusion method for dissolution of refractory silicates to give an elegant method that is particularly applicable to the determination of beryllium in meteorites. The average concentration found for 12 chondrites and two achondrites was 0.038 ppm or 0.64 atom per 10^6 atoms of silicon. The only iron meteorite analyzed contained less than 1 ppb as expected. The value of 0.64 is about 30 times smaller than the value of 20 generally used and will necessitate revision of some of the current theories of nucleosynthesis and cosmogenesis.

3.5 Beryllium in Urine

During the development of a fluorometric procedure for the determination of beryllium in urine, no beryllium was ever detected on the unspiked samples. Since 1500-milliliter samples were used and the detection limit of the procedure was 5×10^{-10} gram, the beryllium content of natural unexposed urine can be at least as low as 3×10^{-13} gram/ml. Although the beryllium content of urine is very difficult if not impossible to interpret, it may be surmised that any concentration higher than the above figure represents an exposure although it might have resulted from the natural level of beryllium in some geographical areas. Conversely, the lack of any detectable urinary excretion does not indicate absence of exposure, particularly with respect to deposition of the oxide in the lung leading to berylliosis.

3.6 Determination of Radon-222 (R. W. Henry)

At the request of North American Aviation, three air samples were analyzed for radon-222. The air samples were collected in rubber meteorological balloons from fissures at the Craters of the Moon National Monument. The concentrations of radium-222 in the balloons at the time of the sampling were found to be less than 2 pc/l based on the data obtained from the first analyses. Subsequent analyses on the samples showed that the radon concentration in the balloons did not decay off completely but decreased to a constant value of about 0.5 pc/l after decaying for eight half lives. It was also found that when similar containers or polyethylene breath bags were filled with nitrogen (containing less than 0.003 pc/l radium-222) the apparent radon concentration in the containers increased with time to about 0.6 pc/l. As yet, the source of this radium-226 contamination has not been determined. Consequently, storage of air samples in meteorological balloons and polyethylene bags is not permissible for periods of time longer than a few hours before the analysis.

3.7 Training Programs and Visitors

Another group of trainees under the AEC Health Physics Fellowship Program were given instruction and laboratory exercise each for a period of a week. Also, an officer of the U. S. Air Force completed a one-year tour of duty at this laboratory to receive instruction in bio-assay and techniques of radioactivity measurements to enable him to set up adequate programs of similar nature for the Air Force. Visitors from India, Denmark, Italy, England, and France, in addition to many others from installations in the U. S., were shown the facilities available at this laboratory and introduced to certain philosophies of operation and procedural methods in use. A member of the staff of Montana State College was employed during the summer months doing research work in the Radioactivity Measurements Section and a physics professor from San Diego State was employed during the first six months of the year in establishing methods for calibration of the whole-body counter.

4. ROUTINE ACTIVITIES

(D. G. Watson)

A statistical summary of routine analyses completed during the year is given in Table XVII. The analyses shown represent only those of a recurring nature on the routine health and safety program. In addition to the 24,394 analyses listed, approximately 2000 gamma spectra were obtained. Many of the spectra were used primarily for qualitative identification of isotopes but about 10% were evaluated quantitatively.

5. FUTURE PROGRAMS

5.1 General

It is expected that routine services to contractors and to the Ecology and Site Survey programs will increase somewhat because of increased size and complexity of the reactor programs and the increased use of the whole-body counting and gamma spectroscopy. However, the urinalysis program has been simplified considerably and the main emphasis will be placed on whole-body counting, computer applications and chemical development.

5.2 Geochemical Investigations (D. B. Hawkins)

As stated previously, this study is an attempt to determine the optimum conditions for the safe discharge of low-level liquid wastes to the environment. This study will be carried out by passing simulated and actual low-level liquid wastes through glass columns containing the fine-grained portion of the Lost River alluvium. The decontamination of solutions of the isotopes strontium-90, cesium-137, cerium-144, cobalt-60, and chromium-51 will be studied as a function of the chemical composition of the waste solution, the length of the columns, and the flow-rate and temperature of the waste-solution, as well as the particle size and ion exchange capacity of the column material. A portion of this work will be devoted to the study of the behavior of clinoptilolite from a nearby deposit as material for the decontamination

Table XVII

STATISTICAL SUMMARY OF ROUTINE ANALYSES PERFORMED

Urine	
Gross gamma	9,118
Strontium-90	3,249
Cesium-137	40
Plutonium-239	29
Phosphorus-32	18
Gross beta	10
Mercury	8
Silver-110	6
Uranium (natural)	4
Beryllium	3
Cobalt-60	2
Transuranium elements	2
Lead	1
Tritium	3
Iodine-131	1
Total	12,494

Miscellaneous	
Gross beta on carbon cartridge filters	1,182
Uranium on air dusts	580
Strontium-90 in bones, other material	360
Beryllium, thorium, on air dusts	126
Gold-198	36
Indium-116 in indium foil	21
Silver-110 in feces	19
Cobalt-58 in nickel foil, anti-freeze	6
Copper-64 in copper foil	5
Cobalt-60, Zinc-65 in excreta	4
Radon-222 in air samples	4
Manganese-56 in manganese foil	2
Dysprosium-165 in dysprosium foil	2
Nitrate in air samples	2
Alpha on smear	1
Phosphorus-32 in sulphur	1
Plutonium in nose swipe	1
Manganese-54 in ethylene glycol	1
Cobalt-60 in ethylene glycol	1
Iron-59 in ethylene glycol	1
Total	2,355

Water	
Gross alpha	1,024
Gross beta	1,064
Tritium	696
pH	191
Gross gamma	227
Sodium	169
Radium-226	96
Thorium-230	96
Uranium	79
Strontium-90	50
Fluorescence	48
Cobalt-60	53
Cesium-134, 137	39
Iodine-131	7
Chloride	4
Zirconium-95	2
Thorium-232	1
Cobalt-58	1
Chromium	5
Total	3,852

Gross Gamma Counting	
Hi-vol carbon cartridges	2,565
Vegetation	990
Animals, animal dissections	693
Filters, fallout papers, smears	607
Milk	412
Soil	159
Film badge neutron	106
Chemical dosemeters	51
Excreta	37
Spray solution	19
Snow	17
Plastic bags	17
Fission foils	6
Blood	5
Threshold detectors	5
Gas mask respirators	3
Bone	1
Total	5,693
Grand Total	24,394

of radioactive waste solutions. From the results of this general study, an equation will be obtained which should allow the calculation of the amount of waste which can be safely discharged to the environment. It is believed that once this equation is obtained it will be necessary to evaluate only a few factors such as chemical composition of the wastes, the exchange capacity of the soil, etc, in order to apply this equation to waste solutions and soils quite different from those originally studied.

As part of the preceding work, after the waste solutions have been passed through the columns, the columns will be eluted with various reagents to see how strongly the different isotopes are held by the soil. In addition, the soil will be disaggregated and the mineral fractions reponsible for most of the retention properties will be determined.

5.3 Precipitation of Thorium with Barium Sulfate (C. P. Willis)

While investigating the effect of various elements on the thorium-morin reaction, it was discovered that thorium can be removed quantitatively from acid solution on a barium sulfate precipitate. This appears to be a particularly elegant method for separation of thorium. Pyrosulfate fusion can be employed for dissolution of refractory materials including thorium itself, and the thorium then can be precipitated by addition of soluble barium salts to the sulfate solution. Most other components of the sample will remain in solution and can be discarded. Particularly, beryllium, zirconium, titanium, uranium, and most other serious interferences on the fluorometric determination of thorium by the morin procedure will be eliminated in the acid sulfate solution. The barium sulfate then can be dissolved easily in alkaline DTPA solution and the thorium determined fluorometrically. Investigations will be initiated to determine optimum conditions such as acidity, concentrations of various elements, range of thorium accommodated per unit barium, etc.

5.4 Determination of Thorium-230 and Radon-222

Investigation of the optimum conditions for the determination of thorium-230 in mill effluents and solids will receive increased emphasis in an attempt to finalize the procedure during the coming year. Particularly, differences in the procedures using TTA and Primene JM-T will be resolved. A unitized all-glass system for collecting and concentrating radon-222 will be constructed. The problems of system efficiency, sample storage and analysis of radium-226 by emanation methods will be studied using the new apparatus.

5.5 Automation of Gross Gamma Counting

Gross gamma counting of urine and other types of samples will be automated using an automatic sample changer and punch tape read-out of the data. Computer programs will be written to read the data from the punched tape, make the necessary computations, and punch the derived information in cards. Final reports will be prepared from the punched cards on the IBM 407 tabulator for distribution to interested persons. This program will eliminate a great deal of tedious manual computation and report preparation.

5.6 Determination of Yttrium by Morin Fluorescence (R. W. Henry)

The investigation of interferences in the analysis of beryllium by morin fluorescence indicated that yttrium also might be determined by a similar procedure. Since yttrium apparently forms a stronger complex with DTPA than with morin, EDTA or NTA will have to be used in the procedure. Under these conditions, beryllium, thorium, zirconium, scandium, lanthanum, and lithium also will fluoresce, and a separation of yttrium from these elements must be worked out.

5.7 Whole-Body Counting Program

Because of the great sensitivity of in vivo counting of human beings and elimination of the many uncertainities associated with conventional urinalysis, whole-body counting will receive much greater attention than in the past. For example, a request has already been received for a whole-body survey of all personnel working at a particular facility employing approximately 180 persons. In addition to the increased use of the whole-body counter for practical analyses, additional calibration studies will be made to determine instrumental response as a function of geometrical shape, size, position, and effective Z-number of the body mock-up and the complexity of the gamma spectrum obtained. Also, a series of curves will be compiled relating instrument response to size of crystal vs energy of the gamma ray for large sources approximating the human body. Studies will be initiated to determine whether information (both practical and usable) can be obtained from relatively unsophisticated and inexpensive whole-body counters employing minimum shielding and size of crystal.

5.8 Computer Applications

A computer program will be written to convert 200 channels of punched-tape data from a whole-body spectrum to 40 punched cards for input to the data reduction programs and storage of the original spectrum. Computer-derived information and the residual spectrum from data reduction programs will be punched into cards. The computer-derived information cards will be merged with key-punched supporting information cards and will be machine-punched into a summary card which will become a part of the individual's permanent radiation record. Final reports for distribution to interested persons will be prepared on the IBM 407 tabulator from the summary cards, eliminating much tedious manual report preparation. In addition, the residual spectrum following spectrum stripping will be listed from punched cards on the tabulator and when desired will be plotted mechanically from punched cards.

The same general program will be applicable to all gamma spectra on various types of samples.

6. TALKS AND PUBLICATIONS

The following talks and papers were presented during 1961:

(1) "Analytical Problems Associated with the SL-1 Incident" was presented by Earl R. Ebersole at the Health Physics Society Meeting in Las Vegas, Nevada, June 13 to 16, 1961.

(2) Two papers entitled "The Whole-Body Counting of Persons Involved in the SL-1 Criticality Accident of January 3, 1961" and "Whole-Body Counting of Persons Involved in the Silver-110 Incident at the National Reactor Testing Station" by L. L. Skolil,

J. I. Anderson, and A. R. Harbertson were presented by L. L. Skolil at the Health Physics Society Meeting in Las Vegas, Nevada, June 13 to 16, 1961.

(3) Two papers entitled "The Fluorometric Determination of Submicrogram Quantities of Thorium" by Claude W. Sill, Conrad P. Willis, and J. Kenneth Flygare Jr., and "Analytical Aspects of the SL-1 Accident" were presented by Claude W. Sill at the Seventh Annual Meeting on Bio-Assay and Analytical Chemistry in Chicago, Illinois, October 12 and 13, 1961.

(4) A seminar on the "Use of Multichannel Analyzers in Alpha and Gamma Pulse Height Analysis" was given by Alan Harbertson to graduate students and faculty members of Montana State College, Bozeman, Montana, on October 31, 1961.

The following papers were published during 1961:

(1) The Fluorometric Determination of Millimicrogram Quantities of Uranium in Air-Dusts and Smears, Claude W. Sill and Phillip D. LaFleur, IDO-12017.

(2) "Determination of Excitation Spectra with a Recording Spectrophotometer", Claude W. Sill, Anal. Chem., 33, 1579 (1961).

(3) "Transmittance Spectra of Color Filters", Claude W. Sill, Anal. Chem., 33, 1584 (1961).

(4) "Improvements in the Fluorometric Determination of Submicrogram Quantities of Beryllium", Claude W. Sill, Conrad P. Willis, and J. Kenneth Flygare, Jr., Anal. Chem., 33, 1671 (1961).

(5) "Decomposition of Refractory Silicates in Ultramicro Analysis", Claude W. Sill, Anal. Chem., 33, 1684 (1961).

VI. HAZARDS CONTROL

(R. V. Batie - Branch Chief)

1. SL-1

The SL-1 accident of January 3, 1961, was a Class I disaster by IDO standards, and in follow-up support the Hazards Control Branch entered into numerous aspects of assistance and collection of pertinent data.

The first awareness of an incident was via the ADT alarm, servicing automatic heat detector devices in the ceiling of the reactor operating floor. Heat detectors are a component of the fire detection system and ADT signals are received at the Central Fire Station. This system, which was provided to give prompt alarm in the event of fire, apparently was activated by an excessive temperature rise in the region above the reactor floor. If a heat detector head had not been activated, there may have been a serious delay in discovery of the accident since no plant personnel survived to report the occurrence. The Central Facilities fire crew responded and on arriving at the scene made the initial entry, determined the existence of high radiation fields, took precautionary action, searched for survivors, determined that no fire existed, and provided information and assistance for key personnel who subsequently arrived and made the initial entries onto the reactor floor. The benefits of fire department training in radiation protection was evidenced by the early monitoring and contamination control exercised. From personnel film badges worn by the eleven firemen who responded to the SL-1 alarm, eight received penetrating radiation exposures ranging from 0.03 to 0.45 r. The maximum of the other three was 1.07 r.

The branch chief served as coordinator and advisor to the disaster control group assembled in headquarters in the early hours after the incident, primarily in the collection of initial information and coordination of support equipment. Two branch personnel served several shifts at the field control point performing such services as: acting as coordinator in the control trailer; maintaining an entry log which included name, mission, entry location, date, time, dosimeter and film badge reading; issuing of dosimeters and film badges; suiting personnel in protective clothing; instructing personnel in use of breathing apparatus; and procuring supplies. One entry was made for recovery of the nuclear accident dosimeter located at the entrance to the reactor operating floor.

A variety of personnel groups and equipment were brought into the field control point, and close observation and coordination was maintained to keep safety and fire hazards to a minimum. Liaison also was provided to maintain emergency fire protection equipment, water supply, and fixed systems in service during recovery operations.

The Fire Department provided ambulance service for the victims, available emergency equipment and supplies, and assistance in decontamination of protective and mobile equipment. Fire Department personnel washed down contaminated roadways. The department's equipment and personnel also were utilized in preparation for poisoning the reactor with a boron solution; however, this approach was subsequently abandoned early January 4.

The collection of data for investigating groups and management included: depositions of all Health and Safety personnel participating in SL-1 activities from the time of the accident through January 14, 1961; compilation of all Health and Safety Division surveys and appraisals of Combustion Engineering from 1957 through 1960; compilation of consolidated report on IDO Health and Safety Division Emergency Capability and Preplanning; collection and formulation of technical report data subsequent to the accident regarding environmental monitoring, aerial monitoring, installation and operation of SL-1 control point, nuclear dosimetry, planning and Health and Safety liaison with Combustion Engineering; and preparation and coordination of applicable sections of the SL-1 accident report.

In May 1961, General Electric was given a letter contract to recover the SL-1 reactor vessel, dismantle the reactor building and equipment, and investigate for causative factors. Quarterly radiation exposures were accumulated in a matter of minutes during most of the decontamination and demolition work prior to the movement of the reactor vessel; hence, a large number of people were needed. Approximately 90% of the branch personnel made one or more voluntary entries into the SL-1 building in the course of cleanup and work preparatory to moving the vessel. Close liaison was furnished General Electric in safety and fire considerations throughout the course of this work. The availability and scheduling of all Health and Safety Division personnel used by General Electric during this phase was coordinated through the branch.

The Fire Department participated in the film reconstructing the sequence of events following the accident.

2. DISASTER PLANNING

The Hazards Control Branch has been delegated responsibility in several functions of the overall Emergency and Disaster Planning. Special attention has been given to the type of disaster in which a centralized field control point would be established.

2.1 Procedures

Specific branch plans have been formulated, published and instituted relative to delegation of responsibilities and reponse action in an emergency. The plans include damage assessment capability. On notification of a field disaster involving radiation, action would provide immediate delivery of designated equipment to a field control point. A generalized plot plan as shown in Figure 22 incorporates the basic facilities and provides the traffic pattern needed to effectively service and operate a control point. Alternate approach roads to reactor areas have been preplanned and action initiated to provide all-weather access in the event the normal access road is untenable. Fire department emergency preplanning and action procedures are detailed in department bulletins covering receipt of alarms, notifications, ambulance procedures, plans for mobilization assistance, fire preplanning, radiation, plan for dispersal of men and equipment, and procedures for operating at plant fire emergencies involving radioactive materials.

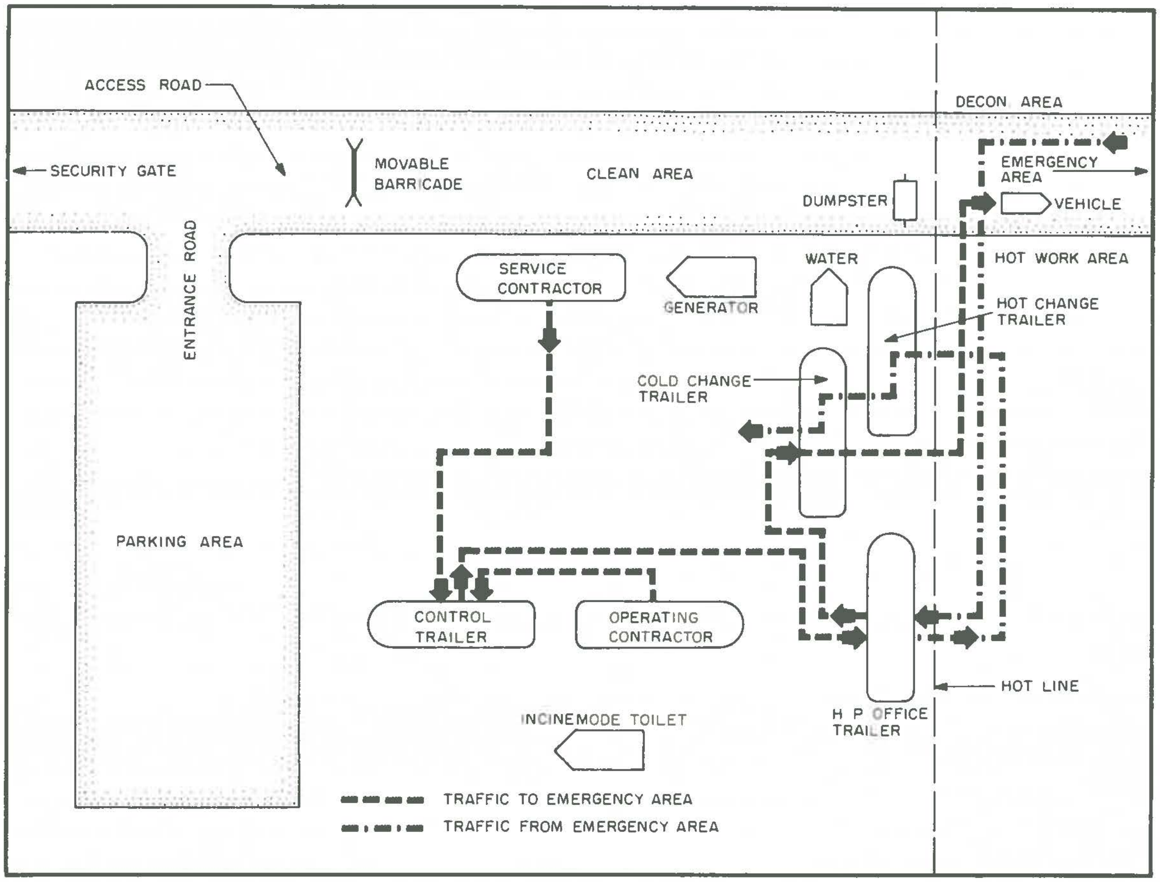


Fig. 22 Suggested control point plot plan.

The emergency plans of Phillips Petroleum, NRF, Argonne National Laboratory, OMRE, and ML-1 facilities have been reviewed for functional detail and continuity with IDO standards. Appropriate comments have been submitted for improvement modification as necessary.

Difference in emergency signal at some facilities has instigated special efforts to standardize both sounding device and signals within the NRTS complex.

Ambulance usage during the SL-1 emergency was confined to the site; however, high-level contamination prompted the procedure to restrict off-site transport of contaminated patients without medical approval and avoidance of using an ambulance for contaminated bodies per se. In the SL-1 activities, the ambulance initially contaminated in handling the first victim was subsequently used to avoid contaminating additional equipment. Decontamination of the ambulance required some dismantling and replacement of parts, and resulted in the unit being out of service for nine months. A large portion of this time was due to parts procurement delays brought about by strike action at the supplier's plant. Future procurement of ambulances will include consideration for cove base plates, and smooth interior surfaces without unnecessary trim.

2.2 Training

At least one evacuation drill was conducted at most operations and construction facilities at the NRTS. Such drills were observed and any areas of deficiency in equipment or personnel action was brought to management's attention for correction.

Fifty-two persons from AEC and various contractors completed the American Red Cross standard first aid course given by Fire Department instructors. Several small groups received specialized training in resuscitation.

Notification tests were made of AEC and contractor personnel on the emergency roster to appraise the availability of a representative control group during a weekend. The exercise included queries to verify responsibility assignment and follow-up action.

All fire department officers and a number of firemen received 24 hours of radiation protection training on a practical level from a health physicist. Some months later, a second series was provided for review and additional training.

Ninety percent of the branch personnel received some direct experience in conditions associated with high levels of radiation and contamination through voluntary work associated with the SL-1 dismantling operations.

The presentation of "tactical fire problems" to fire department officers has continued to develop judgment and action evaluation of potential disaster scale conflagrations.

Instructor hours devoted to brigades and fire deparment crews amounted to 198 and 1235 hours, respectively. While this training was almost a routine, one of the prime objectives is to instigate effective action in an emergency.

Three branch personnel have been active in Radiological Assistance team functions.

2.3 Equipment

Four house-type trailers are in the final stages of modification to provide services for: cold change, hot change, HP office, and control trailer. A 9.3-kw generator trailer is capable of providing electrical service and lighting as needed. There are 13 small generator plants on two-wheel trailers for field sampling, a water trailer, and a contractor office trailer.

This equipment is on standby for control point service and is maintained at the CFA equipment yard. Eight vehicles, equipped for hauling trailers, are available day and night. Driver assignments have been preplanned.

Drinking water provisions have been provided and field toilet facilities are being evaluated.

The storage and emergency supplies of respirator equipment, clothing, and rations have been preplanned with consideration for adequate quantity and distribution for maximum availability. Provisions are established for delivery of back-up supplies to the control point as necessary. A detailed inventory of NRTS operating contractor supplies of respirators, protective clothing, portable radiation instruments, and radio equipment is on file.

Actual experience with self-contained breathing equipment, during the SL-1 emergency, at sub-zero temperatures indicated the need for a device to prevent the exhaust valves on the units from freezing. All of the fire department masks as well as the standby self-contained units were subsequently equipped with nose cone devices which prevent freeze-up of the exhalation valves.

Six of the fire department masks used by officers have been equipped with voice-paks to enable them to give audible directions to crew members while wearing the self-contained units.

A new 4-cfm breathing air compressor brings the fire department transfer capacity to 5-3/4 cfm and emergency air storage has been increased from 600 to 1500 cubic feet.

2.4 Communications

Communcations available in any emergency include nine portable radios and two desk units for emergency trailers on the site radio network which would tie in with existing fixed and mobile radio units, a two-way local intercom for control point trailers, and portable public address speakers for outdoor use. Planning includes a minimum of three telephones in control and office trailers with available field connections and provisions for one direct line to headquarters.

3. SAFETY ENGINEERING
(D. H. Dierks - Safety Engineer)

The Safety Engineering program provides coordination, administration and guidance through day-to-day contacts, field and procedural reviews, annual surveys, interpretation of established codes and standards, engineering design reviews, development of new or revised standards or policies, meetings and seminars, dissemination of educational material, incident investigations, statistical reports, and other media for study, research or evaluation.

3.1 Disabling Injury Experience

The combined NRTS disabling injury experience shown in Figure 23 reflects no significant change in the last four years. The rate is average in comparison to overall AEC activities. Actual cases were two less than in the previous year and include the three SL-1 military fatalities; however, lessening of man-hours worked held the injury frequency rate at approximately the same level.

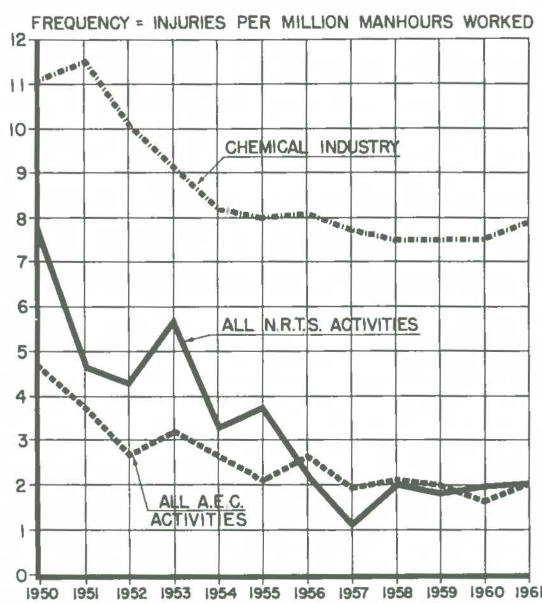


Fig. 23 Disabling injury frequency rate comparison.

The combined NRTS activities, which include construction accidents, experienced only one disabling injury to every four of the chemical industry (per frequency rates as compiled by the Bureau of Labor). The chemical industry is considered comparable to operational activities at the NRTS.

Table XVIII relates the number of disabling injuries from NRTS activities to the accident type.

For this comparison, IDO direct experience was included in operations and architect engineer, service, lump-sum, and cost-plus contractors experience was included in construction.

The operations man-hours worked were approximately 5.7 times those of construction and by using this comparison, the operations activities were 7.1 times as safe as construction activities. Yet NRTS construction experienced disabling injuries at only 40% of the national rate for the construction industry. The total number of disabling cases for each group in 1961 was less than the previous three-year average. The comparison of accident types to disabling occurrences shows a lessening of disabling injuries from categories of falls, struck by or against, and magnifies the injuries from fume exposure and explosion. The SL-1 accounted for the total explosion experience, and fume exposure on a coal tar roofing application caused three of the four inhalation cases.

Table XVIII

COMPARISON OF DISABLING ACCIDENT TYPE TO AREA OF ACTIVITY

	3-Yr. Avg., 1958 to 1960			1961		
Accident Type	Operations	Construction	Total Avg.	Operations	Construction	Total
Fall - different level	1.3	4.3	5.6	—	3	3
Struck by	2.3	3.3	5.6	—	2	2
Striking against	3	1	4	1	—	1
Temperature extremes	0.3	1.7	2	—	—	—
Fall - same level	1	0.7	1.7	—	1	1
Caught in or between	0.3	1.3	1.6	2	—	2
Over-exertion	—	0.3	0.3	2	—	2
Inhalation or absorption	0.3	—	0.3	—	4	4
General (explosion effects)	—	—	—	3	—	3
Totals	8.5	12.6	21.1	8	10	18

3.2 Severity Rate

The severity rates as shown in Figure 24 are compiled from actual calendar days lost as a result of disabling injuries and/or scheduled charges of days assigned to permanent partial disability or fatality.

The NRTS severity rate skyrocketed to the alarming figure of 2016 because of the 18,000 days chargeable as a result of three fatalities at the SL-1. The three fatalities are being carried on military records. While duplication of charges is not normal, it is shown on NRTS records to reflect the site experience. Without these charges, the NRTS severity rate would have been 19.

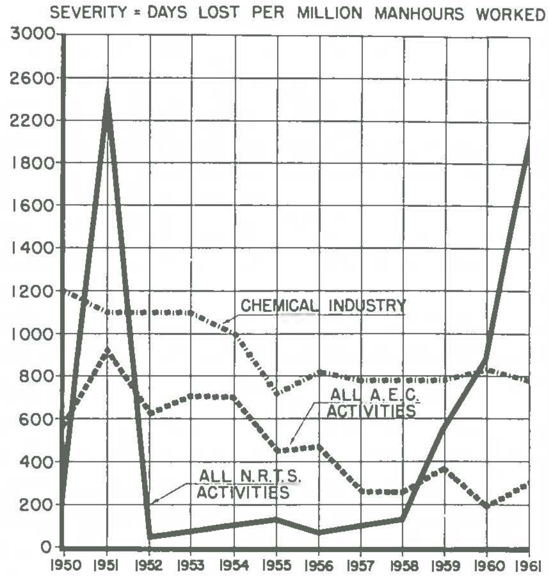


Fig. 24 Injury severity comparison.

3.3 Motor Vehicle Experience

NRTS government motor vehicle accident experience for 1961, inclusive of all accidents regardless of cost, was 7.8 accidents per million miles of travel with overall miles driven totaling approximately 10 million. In reporting motor vehicle accidents wherein $50 minimum loss is used, the NRTS experience rate was 64% less than that of the average AEC facility. Considering damage figures from all NRTS motor vehicle accidents, the costs per thousand miles of travel was $1.70 in 1961 for an increase of 200% over 1960. This increase was due to collision of a bus with a private vehicle, with damages in excess of $10,000. The accident occurred when the private vehicle traveling at high speed, crossed over the center line on a long curve and struck the left front of the oncoming bus. The driver, sole occupant of the private vehicle, was killed instantly and is the first fatality which in any way involved NRTS government motor vehicle operations.

3.4 Property Damage Loss

Government property damages exclusive of motor vehicles and fire losses totaled $4,535,037 during the year 1961. The SL-1 loss alone totaled $4,350,000, which covers equipment and material loss plus costs of initial recovery, control, cleanup, and associated work exclusive of analytical investigation.

3.5 Radiological Shipments

Phillips Petroleum has been assigned safety responsibility for off-site shipments through a contract modification. A Phillips procedure was established to implement the assignment and define functional criteria; however, during a transition period, IDO furnished close surveillance of the activity. IDO direct safety surveillance of off-site shipments should, henceforth, be limited to those shipments by NRTS contractors which are not handled through the Phillips traffic agent.

In conjunction with the Phillips assignment of safety responsibilities, commercial trucking carriers serving the NRTS have received notification and attended review meetings relative to tie-down criteria and past deficiencies. The major carriers have indicated their intent to furnish adequate anchoring and tie-down equipment to meet IDO standards. Licensee service has replaced the Phillips long-haul trucks and they are operating within acceptable standards.

The justification for maintaining a safety surveillance program on outgoing radiological shipments has been evident from experience. Inadequacies in physical tie-down or transport equipment continue to be found on shipments presented for transport by local or commercial carriers. In one case, for example, a 126-ton cask on a rail car was adequately secured; however, a car deficiency allowed a severe car rocking and had it not been corrected would almost certainly have resulted in a serious rail incident.

3.6 Activities

Seat belts have been provided in government vehicles at the NRTS since 1955. While their use has been encouraged through occasional publications and handouts, no specific policy had been issued. On June 9, 1961, IDO Announcement 70 was issued making the driver responsible for his and passenger use of seat belt equipment where provided. Enforcement provisions were included. Several sets of pictorial case histories were provided the contractors for display or as a visual aid in a safety meeting. The use of seat belts has improved and is credited with saving a government employee from serious injury during a head-on collision.

To enhance general safety attention within the IDO Health and Safety Division, monthly safety meetings of personnel were established as routine within each branch of the division. Assistance in subject material or presentation is provided on request.

Annual industrial safety surveys were made of all Phillips facilities at the NRTS. The safety survey of A1W, S1W, and ECF facilities operated by Westinghouse Electric was conducted in accordance with liaison agreements with PNROO. The safety surveys of TREAT, EBR-1 and II, and OMRE areas at the NRTS were conducted with the COO safety and fire protection engineer.

Liaison work was performed between E & C Division and H & S Division in the design of the new H & S Building 690 in the CF technical center, from establishment of basic criteria and layout through Title I and II reviews.

Records of four principal contractors at the NRTS applying for AEC or state award considerations on man-hour accumulations without a disabling injury were audited. Affirmed man-hour accruals were:

Company	Man-hours	Period
Phillips Petroleum	2,500,000	2/6/61 to 10/30/61
General Electric	3,167,036	5/23/58 to 1/29/61
Westinghouse Electric	1,260,220	12/1/60 to 9/30/61
Argonne National Laboratory	1,250,000	5/3/56 to 1/1/62

In addition the Idaho Operations Office was eligible to receive state and AEC award considerations for 1,791,269 man-hours for the period 2/16/60 to 1/1/62.

3.7 Off-Job Safety

It is now recognized that an off-job safety program has a beneficial effect on employees and job program. Training received on the job (ie, first aid, driver training, etc) obviously has application and effects on an employee's off-duty activities. However, little directed effort has been made in the past to non-job-connected aspects of safety.

Following a series of publications and a period of emphasis on the site seat belt program, a program was instigated within the IDO and enlarged to the NRTS contractors wherein seat belts could be procured by individuals for their personal vehicles at favorable prices. This program was well received and is a continuing service.

A most informative magazine titled, "Family Safety", published quarterly by the National Safety Council has been subscribed to for the entire complement of AEC-IDO personnel. Many individuals have reflected an appreciation for management interest and the informative subjects covered in the magazine.

Site safety, fire, and industrial hygiene personnel have been active in community safety affairs for the past four years through organization of the Eastern Idaho Safety Engineers. Outstanding contributions have included: evaluation of city fire water supply, rewriting of city explosives ordnance; safety organization and program proposal for the City of Idaho Falls; and participation in the Idaho Falls mayor's traffic committee.

4. FIRE ENGINEERING

(R. J. Beers - Fire Protection Engineer)

The fire engineering program has been developed to provide service to all NRTS contractors. The major activities of the program include: review of design for new facilities, detailed fire engineering surveys of existing facilities, consulting services on special problems, development of site standards, assistance with development of plant fire prevention programs, assistance in setting up plant fire equipment inspection, testing and maintenance programs, research on new fire protection developments, and fire tests of new industrial materials. The most significant program change in 1961 was reorganization of the fire prevention program resulting in a reduction in manpower. The primary purpose of the fire engineering program is to provide plant fire protection which is commensurate with "improved risk" standards. This is in keeping with AEC policy and is aimed at minimizing property damage losses and interruption of operations due to fire. The NRTS fire loss record up to and including 1961 has been quite acceptable. It should be noted that fire engineering is only a small part of the overall effort. The NRTS fire department deserves credit for a good portion of the success.

4.1 Fire Loss Experience

Comparative loss figures listed in Table XIX, other than NRTS actual losses, are theoretical NRTS losses based on the overall AEC, "improved risk" insurance companies and national loss rates. All losses are based on NRTS valuation, in other words, had fire losses occurred at the NRTS at the same

Table XIX

NRTS FIRE LOSS COMPARISON BASED ON NRTS DOLLAR VALUATION

Year	NRTS Valuation	Actual NRTS Loss	AEC Comparative Loss	Improved Risk Comparative Loss	National Comparative Loss
1961	$363,770,000	$6,860	$20,051	$101,856	$545,655
5-Yr. Avg.	254,778,000	7,279	19,018	69,631	382,471

frequency and severity as those that were experienced in the areas used for comparison, the property damage loss due to fire at the NRTS would have been as listed in Table XIX.

In examining the data in Table XIX, it is evident that the NRTS fire loss experience for 1961 was very favorable as compared to the previous five-year average actual NRTS loss and theoretical AEC, "improved risk", and national losses. The 1961 NRTS fire loss was 94% of the previous five-year NRTS average loss, 36% of the AEC average loss, 10% of the "improved risk" average loss and 2% of the national average loss.

Three of the 24 fires which occurred at the NRTS in 1961 resulted in 95% of the $6,860 property damage loss. The largest single fire loss, amounting to $4,660, occurred at the OMRE impurities loop on September 27, 1961. A fire at the MTR crystal spectrometer on March 27, 1961,caused a $1,100 property damage loss and an EOCR building wall insulation fire September 22, 1961,caused a $750 property damage loss.

It is evident that the majority of the fire loss resulted from relatively few fires. One large fire could reverse the favorable loss experience shown in Table XIX and it is this type of loss that fire protection efforts are aimed at preventing.

4.2 Surveys

Annual fire protection engineering surveys were conducted at CFA, SPERT, CPP, MTR-ETR, GCRE, ML-1, AREA Hot Cell, OMRE, EBR-I, BORAX, TREAT, and NRF. Major fire protection improvements were made in many existing IDO facilities as the result of previous surveys. Adequate fire protection was provided in IDO facilities that were built during the year and the surveys did not reveal a need for major improvements in any of these areas. Most of these benefits resulted from thorough design reviews and good cooperation from the IDO Engineering & Construction Division. Some fire protection improvements were noted at XOO facilities, but action on major projects previously proposed is still lacking. XOO contractors did appear more receptive and demonstrated greater interest in the 1961 surveys than those of previous years. It is anticipated that action on recommendations included in 1961 XOO survey reports will improve significantly.

4.3 Major Fire Protection Improvements

New sprinkler systems included an automatic dry pipe sprinkler system in the SPERT control building and an automatic pre-action sprinkler system with fog heads over the combustible paraffin shielding at MTR.

Fire protection water systems were improved in three areas. Two 2,000-gpm fire pumps, one electric and one diesel driven (surplused from MTR), were installed at the CPP area. A new 750-gpm electric driven fire pump and an additional 50,000-gallon water storage tank were installed at the SP RT area. The CFA water system was expanded to the west side of the area with a new loop of 8-inch and 10-inch pipe. The new loop provides adequate fire water supply to the new Technical Center area, increases the supply to certain existing areas and provides a good water supply for future expansion.

Fire barriers (fire resistive partitions) were installed between the TR oil-filled transformers and between GCRE transformers and building wall openings. Fire doors were installed at the openings in the fire wall between CPP-601 and CPP-630.

A new foam fire fighting system was installed at the west side of the A1W hull. Three "Cardox" CO_2 hose reels and a fire detection system were installed at the OMRE particulate removal loop.

Adequate fire protection was provided in new facilities. In addition to fire alarm boxes, extinguishers and hose stations, special built-in systems included automatic sprinkler systems in the MTR-ETR storage and receiving building, the MTR alpha chemistry building, the new NRF warehouse, and the CPP hot pilot plant; automatic fire detection systems in SPERT IV and several EBR-II locations; and piped MET-L-X systems in the EBR-II sodium boiler plant and one reactor tank room.

4.4 Tests

Tests conducted during the year revealed the following:

(1) Certain materials used to "fix" contaminated particles on ground surfaces were found to be highly flammable during application. Appropriate precautionary measures were taken.

(2) The new "A-B-C" powder type fire extinguisher was found to be effective on ordinary combustibles and flammable liquids as advertised. It was also found to be more effective on rubber tire fires than any other type of portable extinguisher. As a result, these extinguishers are now provided on all long-haul vehicles.

(3) Metal boxes full of paraffin were tested to determine if the rupture discs were adequate under fire conditions. The excessive vapor pressure was not relieved since the rupture discs did not fail as intended. The box bulged and ripped open in a number of places releasing burning vapor. It was recommended that the existing boxes be modified and design of new boxes be adequate.

(4) A new type of fire-retardant paint was tested and found to be suitable for use at the NRTS. The paint shop has indicated acceptance for ease of application and less objectionable odor which has been a problem with fire-retardant paints previously used.

The Hazards Control Branch has always advocated the need for special fire protection in connection with the use of organic coolants at elevated temperatures. Most of these organics are solid at room temperature and appear hard to ignite, thus leading to a false sense of security. Efforts to convince others of the hazards had not been very successful. In order to illustrate the hazards of organics when heated above their flash point, which is the case during reactor operation, three separate fire demonstrations were conducted. Twenty-five gallons of a common organic material were heated and ignited, then dumped to simulate a spill fire. The result was a spectacular fire which was very difficult to extinguish. As a result of the demonstration, opinions have changed and there is no longer reluctance to accept the need for special fire protection.

Figure 25 shows a fire demonstration with organic coolant in which two operators attack a Santowax-R spill fire (20 to 25 gallons) with 15-lb CO_2 extinguishers. The picture illustrates the limited extent of control just before running out of extinguishing agent.

Fig. 25 Organic (Santowax-R) fire demonstration.

4.5 Fire Prevention

The fire prevention program was completely reorganized during 1961. The three fire inspectors previously assigned to carry out fire prevention activities, under the direction of the fire protection engineer, were transferred back to the fire department. Two of these inspectors were reassigned as fire combat officers. One is responsible for fire alarm testing, coordinating fixed fire protection equipment tests between contractors and fire department, maintaining up to date information on fire protection equipment at all NRTS facilities, and training fire department personnel on location and operation of all fixed fire protection equipment. Most of the responsibilities previously assigned to the three fire inspectors, with the exception of alarm testing, have been delegated to the contractor responsible for each facility. A new fire protection technician assists the fire protection engineer and carries out inspector duties that cannot be re-delegated. The technician is assisting with surveys and design reviews, following installation, testing, and acceptance of fixed fire protection equipment, and assisting contractors in setting up fire prevention programs and fire equipment inspection-testing-maintenance programs. Fire inspections in the few IDO buildings not assigned to contractors are being conducted by fire department officers. Detailed fire inspections in construction areas are being conducted routinely by the field safety engineer with general reviews made weekly by fire department officers. These changes have resulted in a reduction in AEC manpower and assignment of more responsibility to the contractors.

4.6 Future Program

The prime objective for the year 1962 is the correction of major fire hazard conditions and completion of built-in fire protection projects now under consideration. These include protection of Class II (combustible vapor barrier) roofs at ETR, removal of gravity feed oil tanks in ETR buildings, sprinkler systems at NRF, new water system and sprinkler systems at OMRE, sprinkler system at EBR-II warehouse, and piped dry chemical system at GCRE heater pit. Fire protection in new facilities will include sprinkler systems at EOCR and the CFA technical center.

5. FIRE PROTECTION

(A. M. Hess - Chief of Fire Department)

The Idaho Operations Office furnishes professional fire protection services for the entire NRTS from four fire stations strategically located throughout the site in such a manner that no facility is more than 10 minutes distant from the nearest fire station. The fire department complement is comprised of 48 men, operating around the clock on the two-platoon system.

The larger site facilities are provided with Class "A" fire alarm systems which transmit signals over an underground and an above ground circuit, while the minor plant areas are provided with Class "B" systems which transmit signals over a single above-ground circuit to the headquarters fire station. All systems transmit both manually operated and automatic signals as necessary.

One inspector tests and inspects all fire alarm devices once each month to assure reliable transmission of signals. He also inspects and tests all built-in fixed fire protection systems on a frequency basis sufficient to assure their reliability.

The fire department provides site-wide training in first aid courses, ambulance service under the direction of the Medical Branch, fire protection training demonstrations, standby protection during hazardous work operations, minor maintenance and recharge of fire extinguishers, servicing of self-contained breathing apparatus, investigation and correction of suspected hazardous situations, and maintenance of all fire loss statistical records.

The growth of the fire department during the past year centered primarily around the IDO assumption of full fire protection responsibilities for the ITS-ANP facilities. An existing fire station was manned by a three-man engine company, accomplished through the hiring of six new personnel, the reassignment of two inspectors to line lieutenants, and transfer of one ambulance and two fire trucks formerly used by General Electric. One pickup truck was assigned to the station complement for fire inspection service.

Table XX shows NRTS fire protection status for the year 1961.

5.1 Training

The new fire department training field was utilized almost daily throughout the spring, summer, and fall months and has permitted the most comprehensive field training in the history of the IDO Fire Department. Department crews from all four fire stations spent six hours each bi-weekly period training at the field, and recently a cold weather night training session was added for each fire crew. In-plant fire brigades are trained by two fire department training officers, and the training field is utilized as much as possible to help accomplish this.

Table XX

NRTS FIRE PROTECTION STATUS

	1961	3-Yr Average
Fire loss ($)	6860	6101
Fires	24	20
Investigations	48	37
Ambulance responses	63	86
Fire department training (hr)	1235	1053
Fire department training (man-hours)	6175	5291
Plant brigade training (hr)	198	190
First aid training (persons)	52	52
Fire extinguishers serviced	1242	1142
Breathing apparatus serviced	255	200

Operations at many site facilities involve bulk quantities or systems of potentially hazardous combustibles. The training field has been used extensively to educate selected operating groups in the fire properties of such materials and the best extinguishment techniques.

An officers' "tactical fire problems" program was continued. This program is designed to be held quarterly, with plant safety personnel planning the problem around real or potential fire situations in their plants, and presenting them to all fire department officers in sealed envelopes. Each officer then writes out his complete approach as though he were the officer in charge at the scene. Afterward, the various approaches are evaluated and a critique held to consolidate the best approach possible.

Two additional fire department personnel received American Red Cross Instructor certificates during the year, bringing to five the number of instructors in the department. These instructors trained 52 site personnel in first aid including 16 from the IDO Health and Safety Division. They also have been called upon to instruct various off-site groups.

5.2 Miscellaneous

The fire department served as co-host with the Idaho Falls fire department for the Idaho State Fire School, held August 17 - 19, 1961. August 18 was devoted to an all-day series of training demonstrations conducted by the department at the training field. The demonstrations illustrated the techniques employed to control fires involving large volumes of flammable liquids, controllable volumes of pyrophoric metals, three-dimensional flammable liquid spill fires and broken flammable liquid-carrying pipes, building interior fires, fires involving radioactive materials, and aerial ladder rescue operations. Figures 26 and 27 illustrate fire-fighting demonstrations.

Fig. 26 General view of firefighting operations on a large-scale flammable liquids fire demonstration.

Fig. 27 General view of firefighting operations on a large-scale flammable liquids fire demonstration.

The training demonstrations were attended by 145 fire officers and firemen representing most of the fire departments in the state. During the business meeting at the fire school, Training Officer E. G. Dingman was elected vice president of the Idaho State Fire School Association for the year 1962.

5.3 Future Planning

Future planning will place greater emphasis on pre-fire planning designed to increase the fire department capabilities for controlling large scale incidents which may include rescue operations, explosions, or radioactivity.

A fire department training manual, which has been in development for about two years, should be ready for printing by January 1963.

6. INDUSTRIAL HYGIENE

(B. J. Held - Industrial Hygiene Engineer)

The industrial hygiene program, now in its third year at the NRTS, has progressed to the point where more time could be spent on research type projects in addition to routine duties.

6.1 Special Projects

6.11 NRTS Respiratory Program Evaluation. Deficiencies found in the respiratory equipment and procedures during the SL-1 incident precipitated a complete evaluation of both the emergency and operational respiratory programs.

The emergency program now in effect consists of stockpiling full-face assault masks in various locations. Procedures for face-fitting and proper usage have been prepared.

A small light-weight emergency evacuation respirator also was desired for use during CPP RaLa operations. A pocket mouth-piece respiratory available on the market was modified to meet NRTS specifications (see Figure 28). Respirator changes included a combined particulate filter and activated charcoal cartridge, and modifications on the original design.

The unit is shirt-pocket size, has a low breathing resistance, and costs less than half of any approved half-face mask on the market. A good fit is possible on almost anyone as the lips can make a positive seal.

Some broad changes were recommended in operational usage of respirators after conducting mechanical leakage and face-fitting tests on the type of half-face mask used at the NRTS. Face-fitting tests on different makes of half-face masks were so poor that the pocket mouthpiece respirator was investigated for operational usage.

Fig. 28 Pocket mouthpiece respirator.

It was possible to fit almost everyone with the mouthpiece respirator, hence, it will be standardized for operational usage. The existing stock of half-face masks will be used only by those who can get a face seal (approximately 50% of the workers). Reordering the half-face masks is not encouraged because of their deficiencies.

The manufacturer of the self-contained breathing equipment used at the NRTS developed, at the request of the branch, an adapter for switching their mask to any Army assault mask canister, as shown in Figure 29.

The canister can be used for emergency escapes from radioactivity-contaminated air if the bottled air is depleted. Use of the canister in known areas of low activity will conserve the bottled air for more harmful atmospheres.

Fig. 29 Self-contained breathing unit with canister attachment.

Mechanical leakage and face-fitting tests were conducted on full-face canister masks. A commercial make of full-face canister mask was recommended for standardization at the NRTS.

Both the self-contained and in-line breathing equipment programs were reviewed. No basic changes were recommended other than more limited usage of demand-type equipment while positive pressure equipment can be used in any concentration of airborne contamination.

Mechanical leakage tests of masks have been conducted on a respirator test branch, shown in Figure 30, purchased from the Chalk River Site of Atomic Energy of Canada, Ltd.

As very little work is being done in the United States on mechanical leakage tests or respirators, this work will continue at the NRTS to aid all AEC sites in mask selection.

The entire respirator program evaluation will be published in IDO-12020 in April 1962.

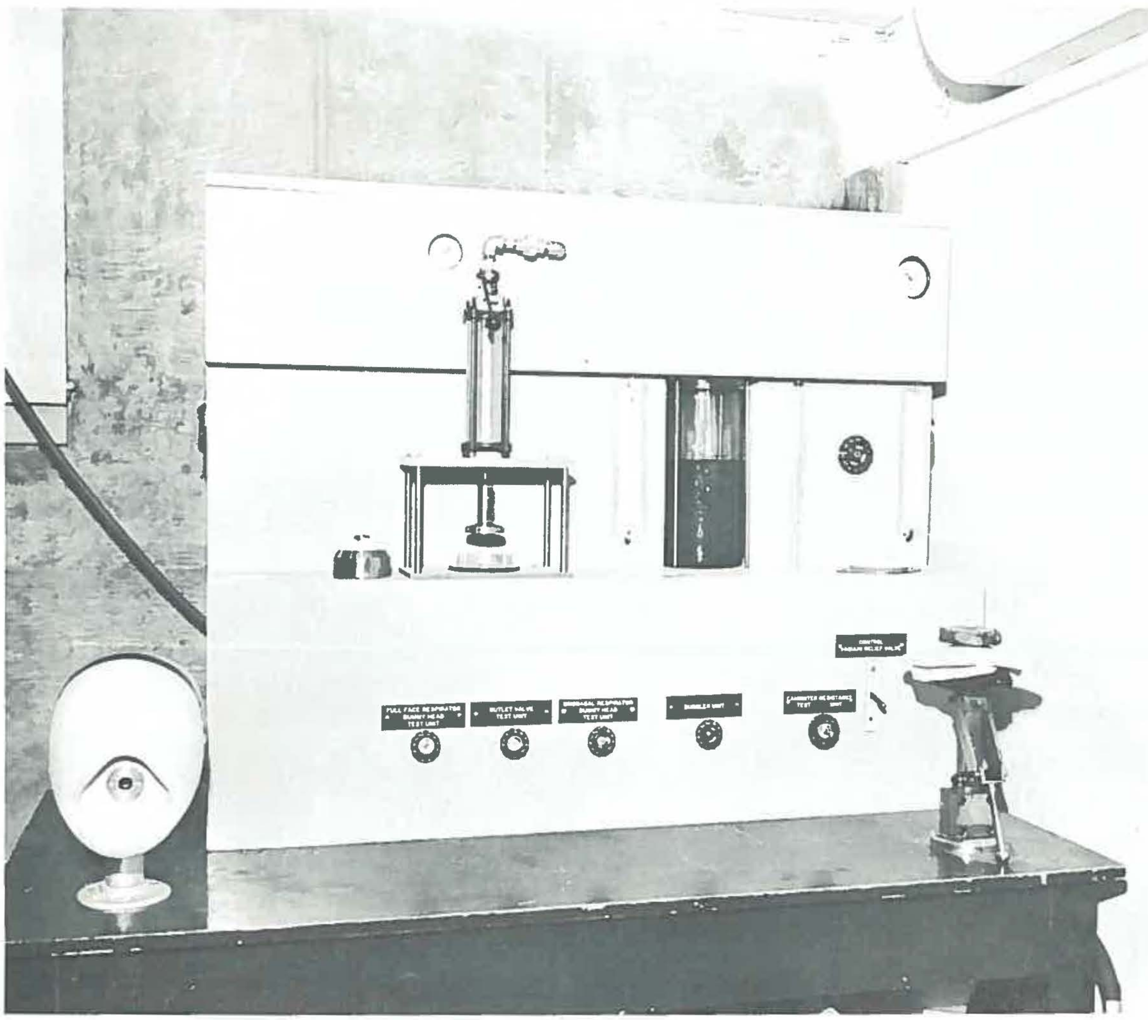


Fig. 30 Respirator test bench.

6.12 Filter Advisory Committee. The industrial hygiene engineer organized and is chairman of the Filter Advisory Committee (FAC). The other FAC members are: George Wehmann, IDO health physicist; Ralph Anderson, Phillips Petroleum industrial hygienist; David Mousseau, Phillips engineer; and Robert Fletcher of the Phillips Technical Division. Filtration problems arising among any of the IDO contractors are referred to the FAC. XOO contractors also are invited to participate and are already making use of some of the services available.

The first action by the FAC was an in-line testing program. A smoke photometer was purchased and dioctyl phthalate (DOP) generators constructed. Tests run to date indicate that less than half of the high efficiency filter installations had the 99.95% efficiency on 0.3-micron sized particles as required. Efficiencies ranged as low as 70% on some filter installations.

The FAC recommended the elimination of high efficiency filters in all laboratory fume hoods. A study of fume hood usage showed that high efficiency filtration was completely unwarranted. In some instances, a lower efficiency filter was desirable, but usually no filtration at all was necessary at the NRTS.

The removal of high efficiency filters from the fume hoods had some indirect benefits. Cost of filtration was lowered but, even more important, hood face velocities were increased on many hoods that were previously below standards.

The FAC currently is writing specifications for various types of filters and filter boxes, procedures for installation of filters, and a guide for filter selection, and is continuing the in-line test program.

6.13 Organic Reactor Coolant Study. The IDO and Phillips industrial hygienists began work on developing sampling methods for determining air concentrations of Santowax-R.

Both Whatman 42 filter papers and electrostatic precipitators were found to be acceptable, although wet methods are necessary for the low boilers (ie, material such as benzene whose vapors boil off at low temperatures). However, a determination of the wax may be sufficient since the low boiler concentrations stay constant under given conditions and can be estimated.

The organic coolant study will continue in order to get further information on toxicity. Economic means for filtering the wax are being investigated and a model ventilation system is now being constructed to further this study.

6.2 Routine Activities

Regular duties during the year consisted of making annual surveys at MTR, ETR, CPP, CFA, AREA, SPERT, GCRE, ML-1, and NRF; providing consultant and survey services to AEC and NRTS contractors; being a member of the aerial monitoring team; setting up and maintaining emergency respiratory equipment, clothing, and emergency food stockpile; and supervising the bacteriological water sampling program.

There were 61 requests during the year for consultant services. These services included requests for information ranging from the toxicity of various substances to the design of noise enclosures and ventilation systems.

Surveys requested for ventilation, noise instruments, lighting, excessive heat, or air contaminants totaled 55. A brief breakdown is as follows:

Phillips Petroleum	18
Construction	17
Argonne National Laboratory	7
Atomics International	4
Westinghouse Electric	4
U. S. Atomic Energy Commission	4
General Electric	1

Lectures were given during the year to the monthly nurses' meeting and IDO Security on respirators and to HP fellowship students on industrial hygiene at the NRTS.

6.3 Future Program

(1) Continued investigation on the organic reactor coolant is scheduled for 1962. Further information regarding toxicity, filtration, and breakdown products will be sought.

(2) Mechanical leakage studies of various makes of half-face and full-face respirators will continue.

(3) Testing of a perchloric acid filter is scheduled to determine the feasibility of requiring it in all perchloric acid hoods.

7. NUCLEAR SAFETY ENGINEERING
(Aubrey O. Dodd - Nuclear Safety Engineer)

Activities of the nuclear safety engineer covered the following areas: (a) review and approval of certain fissionable materials shipment originating at the NRTS or at off-site IDO sub-contract facilities, and those originating elsewhere, but which utilize NRTS, AEC, or sub-contract carrier equipment; (b) review and comment on nuclear aspects of design drawings for plant modifications or new facilities, such as fuel-storage buildings, vaults, canals, shipping containers; (c) preparation of IDO contractor standard requirements in the area of nuclear safety of fissionable materials outside reactors; and (d) continuation of nuclear accident dosimeter coverage program for all NRTS facilities. Also, the nuclear safety engineer served as member and secretary of the IDO Nuclear Safety Committee. This committee reviews periodically the various IDO reactors, critical facilities and chemical processing plant for overall nuclear safety and reports its findings to the manager.

7.1 Routine Activities

Review and approval for nuclear safety of fissionable materials were made on nine schedule-controlled shipments. Six of these were transported via contract carrier, with three via AEC vehicle. The greatly reduced number of reviews performed by this branch reflects the changeover from AEC-carrier operation to the sub-contract carrier. In the latter case, the Phillips Nuclear Safety Committee reviews and approves each shipment scheduled by their traffic agent, whether for Phillips or some other contractor. At present, shipments for non-Phillips contractors, via AEC vehicle or, if under non-Phillips waybill, via contract carrier, are reviewed and approved for nuclear safety by the Hazards Control Branch. Reviews involved such factors as nuclearly safe design of containers, fuel mass limits per container and carrier, spatial arrangement of cargo, and safe securing of containers on carrier.

Seventy-seven nuclear accident dosimeters (NAD) are now in place at the various nuclear facilities at the NRTS. This is an increase of 17 over last year. This program is administered and coordinated by IDO for all contractors regardless of operations office affiliation. The dosimeters are provided without charge to the contractor, and the periodic changes of gamma units, and analysis in the event of exposure, are provided as a service by the IDO Health and Safety Division. Two NAD's were analyzed during 1961 as a result of the SL-1 reactor accident and the ICPP criticality accident. Both units showed neutron activation, but neither provided data suitable for neutron energy discrimination because of massive shielding of the neutron source.

7.2 Special Activities

Review comments were prepared on various regulatory documents dealing with the problem of nuclear safety in the transport of fissionable materials. Comments were prepared on the revision of 10 CFR 72, the proposed AEC Manual Chapter 0527, and the Interagency Committee's draft proposal of technical standards for regulations governing radioactive material shipments. A workshop session on the subject of nuclear safety in the transport of fissionable materials was conducted in Idaho Falls for a group of representatives of AEC operations offices having nuclear materials management responsibilities.

The nuclear safety engineer served as secretary of the IDO Nuclear Safety Committee, participating in reviews and writing reports on the ML-1 facility, the STPF, SPERT IV, and the ICPP. In addition, a separate review of Aerojet General Nucleonics for nuclear safety of fissionable materials outside of reactors was completed in 1961. This review covers nuclear safety aspects of shipping, handling and storage of fissionable materials, and nuclear accident dosimetry coverage.

The nuclear safety engineer served as a member of the committee which investigated the criticality accident at the ICPP on January 25, 1961, and prepared Appendix IV of an IDO report [5].

7.3 Future Programs

Responsibility for damage assessment in the event of nuclear attack on the NRTS was assigned to the nuclear safety engineer. This capability will be exercised in future Operation Alert Civil Defense exercises.

Basic nuclear safety standards pertaining to fissionable materials outside reactors are in preparation and will appear in the next revision of the IDO Standard Health and Safety Requirements Manual. These will reflect current development in transportation regulations affecting fissionable materials. They also will include requirements for incorporating elements of nuclear isolation in the construction of fuel storage vaults and shipping containers.

A program for testing and calibrating nuclear accident dosimeters is scheduled for 1962 in conjunction with the SPERT I power transients and destruct test.

8. TALKS AND PUBLICATIONS

(1) "New Hazards in Firefighting" was presented at the AEC-Contractor Safety and Fire Protection Conference in Washington, D. C., by R. J. Beers, Fire Protection Engineer.

(2) "Fatal Reactor Accident Proves Value of Training", an article published in Fire Engineering Magazine, by E. G. Dingman, Captain, Fire Department, and R. J. Beers, Fire Protection Engineer.

(3) "Radiation Hazards in Firefighting", a three-day course, was presented to 30 police and fire department personnel from throughout the State of Idaho at Boise by E. G. Dingman, Fire Department.

(4) "Planning Ventilation for Nuclear Reactor Facilities" was presented by B. J. Held, Industrial Hygiene Engineer, at the American Industrial Hygiene Association Annual Meeting in Detroit, Michigan.

(5) "High Efficiency Filter Program at the NRTS" was presented by B. J. Held, Industrial Hygiene Engineer, at the 7th Annual Air Cleaning Conference in Brookhaven, New York.

(6) "Health Protection Problems of the SL-1 Clean-up" was presented by D. H. Dierks, Safety Engineer, at the Fifth Annual Meeting of AEC-Contractor Health and Safety Personnel at Oak Ridge, Tennessee.

(7) "Administrative Aspects of Nuclear Safety in the Transport of Fissionable Materials" was presented by Aubrey O. Dodd, Nuclear Safety Engineer at the Institute of Nuclear Materials Management meeting in Denver, Colorado.

9. NRTS HEALTH AND SAFETY INFORMATION BULLETINS - 1961

No.	Date	Title
20	2/24/61	"Hilti DX Powder Assist Tools"
21	3/13/61	"Problems Experienced in the Use of Scott Air Paks"
22	5/12/61	"Gasoline Delivered by Mistake in Place of No. 2 Fuel Oil"
23	6/14/61	"Pitch Fume Exposure"
24	6/27/61	"Health and Safety Loan Films"
25	8/3/61	"SO_2 From Burning Tote Boxes"
26	8/21/61	"Nuclear Accident Dosimeters and the NRTS Complete Personnel Dosimetry System"
27	9/11/61	"Availability of Whole-Body Counting Service to NRTS Contractors"

VII. SITE SURVEY
(W. P. Gammill - Branch Chief)

1. SL-1 ACCIDENT

1.1 General

From January 3 until January 15, the primary function was to maintain health physics control at the scene of the accident. Following that date, health physics support was provided to the operating contractor, and greater emphasis was placed on physical monitoring of the surrounding area. Many of the activities associated with these functions, as well as much of the data collected by the branch, are reported in IDO-19302 [3].

Activities of the branch during the first 12 hours following the accident included participation in rescue operations, establishment of emergency control point, monitoring of all personnel and equipment leaving the area, and personnel decontamination. Many deficiencies were noted during this period, for instance, inadequacy of high range beta-gamma survey instruments (maximum of 500 r/hr), face-piece fogging and supply valve freezing of self-contained breathing apparatus due to the -10°F outside temperature, space limitation in the emergency decontamination trailer, and inadequacy of personnel decontamination facilities at the NRTS.

After the initial rescue effort, with the assistance of the NRTS radiological assistance team and other contractor personnel, health physics coverage was provided for all personnel making entries beyond the SL-1 control point. Many individuals worked in excess of 120 hours per week during this period, and yet it was impossible to perform the innumerable data-collecting and research functions which were considered desirable.

1.2 Monitoring

1.21 Air. One of the first actions taken following notification of the radiological incident was the activation of an 11-station, high-volume air sampling network by means of a telephone signal. Each sampling unit was fitted with an MSA-2133 prefilter for particulate collection and an activated charcoal filter for collection of the iodine isotopes. Analysis of the sample collected at Atomic City, the nearest off-site population, indicated that the cloud was essentially all iodine-131. The average concentration in air at that location for the first 16 hours following the accident was approximately 5×10^{-11} $\mu c/cc$. From air and vegetation sample correlation studies, the maximum off-site concentration of iodine-131 in air was estimated to be approximately 1.5×10^{-10} $\mu c/cc$. From air samples collected at Atomic City during the six-week period following the accident, the calculated infinity thyroid dose for an adult was approximately 35 millirads.

When the branch was relieved of the primary health physics responsibility at the SL-1 control point, a special high-volume air sampling network was established around the reactor out to distances of about 1-1/2 miles. Significant, but non-hazardous, iodine-131 concentrations were measured for several weeks and the network was discontinued on March 6.

1.22 Soil. A program to investigate the extent and type of soil contamination outside the perimeter fence at the SL-1 reactor was undertaken. A preliminary instrument survey to determine the scope of contamination was finished in May and collection of about 260 samples was completed in June. Three samples were taken at each intersection point on a 100-foot grid. A surface sample 6 x 6 x 1 inches was taken with a specially designed sampler and samples from 1 to 2 inches deep and 2 to 6 inches deep were taken with a soil tube.

It was found that the activity in the top inch of soil is largely due to discrete particles. The highest activity exceeded 1000 times normal background (10 counts/minute/gram) for NRTS soil and consisted of zirconium-95-niobium-95, ruthenium-103, -105, cerium-144, and possibly cesium-137 and uranium-235. The distribution of radioactivity in the surface samples is shown in Figure 31. Some contamination was detected in the deeper samples taken near the fence. It is thought that the distribution of activity in the soil in June reflects dispersion by wind, water, and man rather than the initial spread due to the incident. It is anticipated that additional horizontal and vertical spread will be accomplished by these same agents.

1.23 Water. Increased emphasis was placed on the water sampling program of production wells in the vicinity of the SL-1 for several weeks following the accident. As expected, no increase in the radioactivity level of the water was detected.

1.24 Direct Radiation. A 28-station radiation survey grid was established around the SL-1 on January 5. Weekly surveys on this grid were made to determine the decay rate of the source. The apparent half-life increased from about 30 days in early January to about 120 days in June. By the first of July, it was impossible to follow the decay in this manner because of the effect of decontamination progressing within the facility; hence, the surveys were discontinued.

1.25 Contamination Control. One of the problems not fully discussed in IDO-19302 [3] concerns the control of radioactive contamination. A number of events had taken place to make this situation less than desirable. These were:

(1) Prior to setting up the decontamination trailer, a number of contaminated individuals were transported to other areas for decontamination, thus contaminating several vehicles.

(2) Facilities not intended for decontamination purposes were used and had to be immediately isolated and decontaminated,

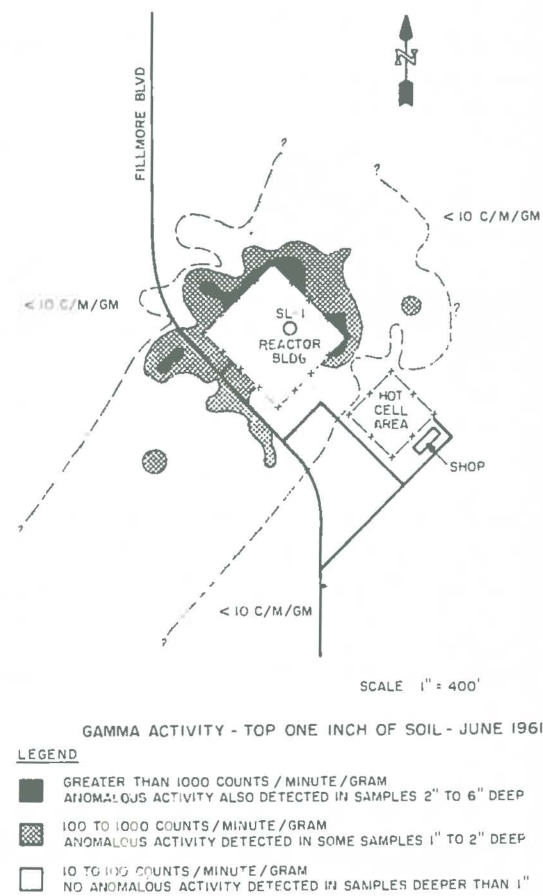


Fig. 31 Soil contamination in vicinity of SL-1, May 1961.

(3) Roads and the ground outside these facilities had to be barricaded and either decontaminated or given a temporary seal coating.

The most extensive problem of this type was the medical dispensary where cross traffic patterns by personnel inexperienced in contamination control had spread small amounts of radioactive material to rooms outside of the basement decontamination area. Meticulous, complete surveys of all suspected buildings and vehicles plus resurveys after decontamination were required, not only at the NRTS but the AEC Headquarters building and all motor pool vehicles and buses at Idaho Falls. Health Physics control also was required for numerous contaminated items recovered from the control zone. Documents, instruments and vehicles were given cursory surveys and decontaminated within the SL-1 control area. Final surveys and decontamination were accomplished at specialized locations within the Central Facilities area.

About four miles of the public highway and site roads leading into Central Facilities had been contaminated by vehicles. Decontamination crews utilizing GM-type road scanners, portable instruments and vacuum cleaners surveyed and decontaminated as necessary. By January 17, approximately 30 miles of road had been surveyed and from 90 to 95% of the detected activity removed.

By April, operations at SL-1 were such that decontamination of the adjacent road could be started. From the intersection with U. S. highway 20 to within 100 feet of the GCRE gate, approximately two miles, the road exhibited varying degrees of contamination. There were large areas of particulate activity ranging up to 25 rads/hr. Approximately 500 man-hours were spent in decontamination of this road.

Where individual particles were scarce a small industrial vacuum cleaner was used. In the more highly contaminated areas, particles were washed to the sides of the road by the blast of water at 600-psi pressure. The high pressure water stream was provided by a large fire engine which was supplied with water from a 5000-gallon tank trailer. Where the activity was clinging to the road surface, the force of this water proved sufficient to erode the blacktop surface. This method was satisfactory except near the SL-1 gate, the section of the road used by Combustion Engineering for a decontamination area, and at the intersection of Fillmore and U. S. 20. These surfaces and the road shoulders to the bottom of the borrow pit were sprayed with fixer to prevent the spread of contamination. The road was opened for limited traffic on April 16 and for all traffic on April 26. Instructions were posted to remain on the blacktop, and a security post was established at the highway intersection. A resurvey of the road on May 3 showed no new contamination and a maximum of 35 mrad/hr at three feet, over the road shoulder near the SL-1 gate.

1.26 <u>SL-1 Core Removal.</u> Health physics support was provided during removal of the reactor core from the building and subsequent movement over 30 miles of highway to the GE-ANP facilities. No serious health physics problems were encountered during this operation.

1.3 SL-1 Burial Ground

A special burial ground for disposal of solid radioactive waste was established in the vicinity of the SL-1. It involved an enclosure of approximately four acres. This was provided to accommodate the dismantling operation with a minimum exposure of personnel and cost in connection with the handling of waste. The SL-1 waste shown in Table XXXIII on page 111 was disposed of at this location.

2. HEALTH PHYSICS SECTION
(George Wehmann - Chief)

2.1 Environmental Monitoring

2.11 Aircraft Nuclear Propulsion Program. The section was engaged in monitoring for the final power test conducted at the Initial Engine Test Facility. This test was terminated on March 30, 1961. Both mobile and fixed monitoring equipment were utilized. During this test approximately 3400 curies of short-lived mixed fission products were released to the atmosphere. No significant amounts of radioactivity were detected in the field as the result of this program.

2.12 Idaho Chemical Processing Plant (ICPP) (Richard Ostler). Section activities at this installation in 1961 were limited to monitoring all RaLa runs (dissolution of short-cooled MTR elements) except numbers 50 and 51 and the monitoring of the criticality incident in January. Table XXI lists the approximate amounts of activity released to the atmosphere as the result of each RaLa run. The increase in the amount of activity in 1961 as compared to 1960 is due to the increase from 12 runs in 1960 to 17 runs in 1961. The amount of radioiodine released per run continues to be reduced as shown in Table XXII.

2.13 Atmospheric Monitoring for Radioactive Iodine. Continuous air sampling for radioiodines was conducted at 13 stations on the NRTS in 1961 as compared to eight stations in 1960. These samplers utilize a carbon cartridge which is composed of a cylinder of flexible acetate plastic, 5/8 inch in diameter, two inches in length, open at both ends. The cylinder is filled with 12- x 30-mesh activated carbon with a 5/8-inch circle of 60-mesh brass screen at each end to hold the carbon in place, and a piece of 5/8-inch Tygon tubing approximately 3/16 inches long as a retaining ring to hold the screens in place. A 5/8-inch disk of all-dust filter paper, MSA, BM-2133, is inserted at one end between the screen and retaining ring as a particulate filter.

Samples are collected weekly for analysis. The pre-filter is removed and counted for gross beta activity while the carbon cartridge is counted in a deep well scintillation counter. In March, 1961, a computer program was established which permits automatic calculations of air concentrations and theoretical dosage to the human thyroid. The dose calculations are based on the assumption that all of the activity collected on the carbon cartridge is iodine-131. This assumption tends to maximize the dose. Table XXIII lists these calculated thyroid doses for 1961 and 1960 for on-site stations.

Table XXI

RADIOACTIVITY RELEASED TO THE ATMOSPHERE DUE TO RALA OPERATIONS

Run No.	Date of Run	Radioiodine (curies) I-131	I-132	Beta Activity Minus Iodine (curies)
50	January 4-5	1.5	9.7	0.7
51	January 17-18	18.1	113.6	4.3[a]
52	February 7-8	1.6	15.2	1.9
53	February 28-March 1	1.5	2.4	0.4
54	March 21-22	1.0	13.1	2.0
55	April 11-12	1.0	0.1	1.0
56	May 2-3	1.0	5.0	0.8
57	May 23-24	1.8	24.2	1.1
58	June 13-14	1.6	1.6	1.5
59	July 10-11	2.5	2.8	4.5
60	August 15-16	2.2	1.1	2.0
61	September 6-7	2.7	13.7	0.9
62	September 26-27	2.4	7.4	1.6
63	October 17-18	1.3	6.8	0.4
64	November 10-11	0.4	3.4	0.2
65 & 66	November 28-30	1.5	6.5	45.2
	Total activity 1961	42.1	226.6	68.5
	Total activity 1960	32.0	176.4	26.5
	Total activity 1959	227.2	1015.5	219.1

(a) Includes 2.4 curies attributed to the criticality accident on January 25, 1961.

2.14 Weapons Test Fallout Program. The monitoring program for determining fallout from atmosphere weapons testing was resumed on September 7, 1961, at the request of the Division of Operational Safety, AEC headquarters. The program procedures are nearly the same as those used in the past. The samples are collected using a Staplex Model TFLA Hi-Volume air sampler at a rate of approximately 35 cubic feet per minute, with a four-inch-diameter MSA, BM-2133 all-dust filter. A portable Nuclear Chicago Model 2612 beta-gamma survey instrument is used for beta activity determinations. The evaluations in 1961 were performed 24 hours after the end of the collection period. The unshielded GM tube is held on the center line of the filter, and by direct

Table XXII

AMOUNT OF RADIOACTIVITY RELEASES PER RALA RUN

Year	No. of Runs	Radioiodine (curies) I-131	Radioiodine (curies) I-132	Beta Activity Minus Iodine (curies)
1959	16	14.2	63.5	13.7
1960	12	2.7	14.6	2.2
1961	17	2.5	13.4	3.9

ratio, the activity compared with that of a one-microcurie strontium-90 standard source. The same beta-gamma instrument is used to determine the external gamma radiation level by surveying an area of approximately 10 square feet at a height of three feet above the ground. The average closed-window reading recorded in milliroentgens per hour. The results for the last four months in 1961 are summarized in Table XXIV.

For comparison, results of a continuous low-volume air sampler located in Idaho Falls indicate that the average air concentration was less than one picocurie per cubic meter for the first eight months of 1961. External gamma radiation measurements taken in conjunction with this program showed no increase over previous background levels.

Table XXIII

MAXIMUM CALCULATED THYROID DOSE

Location	Annual Total (millirem)(a) 1961	Annual Total (millirem)(a) 1960
EBR-I	5.4	2.0
CFA	4.9	2.6
MTR-ETR	3.3	2.3
CPP North	53.	38.
NRF	3.3	2.9
ANP	4.0	3.2
SPERT	13.	2.5
OMRE	5.3	2.0
SL-1	3.2	—
GCRE	3.4	—
ML-1	3.6	—
Fire Station No. 2	7.5	3.7
EBR-II	2.3	—

(a) Assuming all activity on the charcoal to be due to iodine-131.

2.15 External Radiation Monitoring Program. Film badges are located at 290 stations throughout the NRTS and surrounding area as a means of monitoring for external radiation. Table XXV indicates the location of these monitoring areas along with the number of stations at each location.

Badges for off-site locations were changed every six weeks in 1961 as compared to monthly in 1960. On-site badges were changed every six weeks the first half of 1961 and quarterly the second half of 1961 as compared to monthly in 1960. The problem of "light leaks" reported in 1960 did not occur in 1961. It was very apparent that the red semi-transparent plastic film badges were filtering out that portion of the solar spectrum causing the light fogging.

Difficulty was encountered when the exposure time was extended to a quarter, due to the collection of moisture in the badges. The percentage of loss due to moisture for a six-week exposure time was less than 4% while it was approximately 33% for a quarterly exposure time. Due to the high percentage of loss for quarterly exposure times, badges will be changed every six weeks in 1962 until a satisfactory method of eliminating the moisture has been found.

With the exception of the stations surrounding the NRTS burial ground and the SL-1, all results were not significantly above the present lower detection limits of 10 millirem. The results of film badges around SL-1 are included in IDO-19302 [3] dealing with the SL-1 accident. The average external radiation dose rate at the perimeter fence of the NRTS burial ground was determined from the film badges in the area. These dose rates are given in Figure 32. Though these do not appear significant, they correlate very well with the radiation survey of the burial ground.

Table XXIV

FIELD DETERMINATIONS OF RADIOACTIVITY IN AIR DUE TO FALLOUT

	Radioactivity Concentrations (pc/m^3)		
Month	High	Low	Average
September	13	3	7
October	30	4	13
November	31	4	14
December	15	5	11

Table XXV

FILM BADGE LOCATIONS

Location	No.	Location	No.
Idaho Falls	1	LPTF	8
Minidoka	1	SPERT	15
Dietrich	1	OMRE	4
Carey	1	SL-1	14
Aberdeen	1	GCRE	4
Telemetering stations	11	ML-1	13
EBR-I	5	TREAT	14
NRTS burial ground	45	EBR-II	8
CFA	4	Lincoln Boulevard	21
MTR-ETR	12	State Highway 88	19
ICPP	24	State Highway 22	8
NRF	8	State Highway 28	8
ANP	1	U. S. Highway 20	39

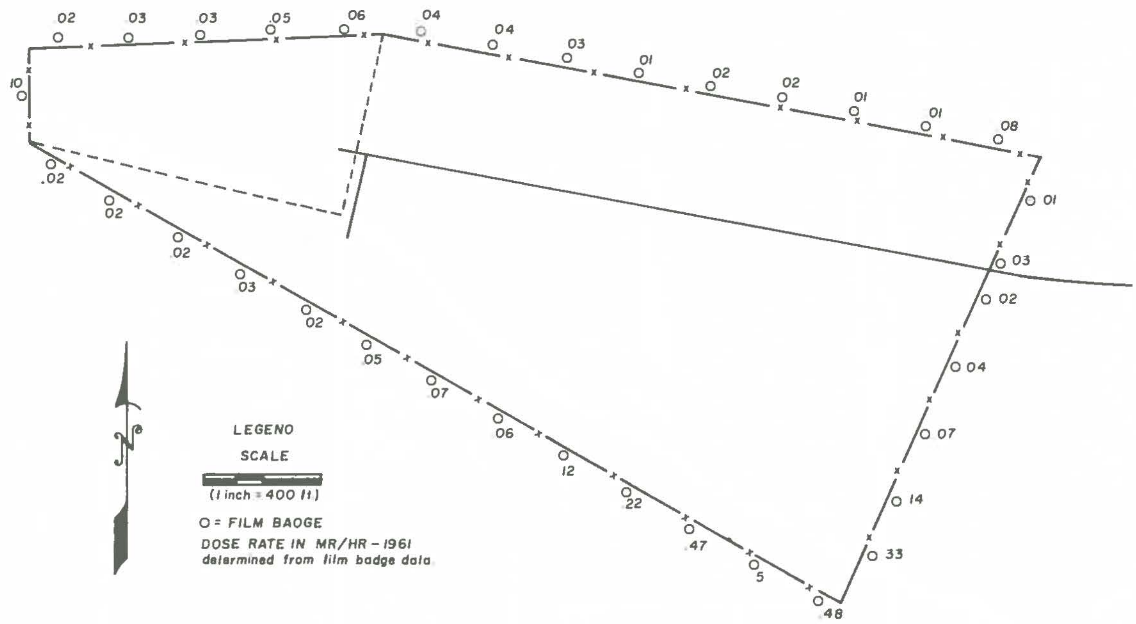


Fig. 32 Dose rate calculations for NRTS burial ground determined from film badge data.

2.16 Ground Radiation Survey Program. Surface contamination surveys were conducted at 10 facilities in 1961. No detectable contamination above previously determined background levels was found at OMRE, EBR-I, BORAX, LPTF, or IET. The contamination levels along the water discharge stream at GCRE were a maximum of 1 mrad/hr, or a factor of six below levels reported in 1960. The results of the surveys surrounding the ICPP, MTR-ETR and NRF are summarized in Figures 33, 34, and 35. The radiation levels within the burial ground are continually changing as open trenches are filled with radioactive waste and old ones covered over with dirt.

2.17 Road Radiation Survey Program (Darrell Newcomb). As a result of the contamination spread by vehicles involved in the SL-1 accident, a more efficient method of surveying the roads on the NRTS was devised. In cooperation with the Instrument and Development Branch, a road scanner was developed which reduced road surveying time to one-third of that previously required. The scanner consists of a 20-foot boom mounted on the front bumper of a 3/4-ton pickup truck. Three 7-foot probes hang by small chains to within three inches of the ground. Each of these probes contains six GM tubes connected in parallel with a cable leading to the truck cab where a GM instrument is connected to each probe. The earphone plug of each instrument is then connected to a single transistorized amplifier which provides an audible signal. Each end of the boom is equipped with a red flag and a flashing amber light for traffic safety.

The three detector probes have a combined length of 21 feet which is sufficient to cover one lane of traffic and adjacent shoulder as shown in Figure 36. The instrument is not calibrated and is used simply as a radiation detector. Three- to four-mr/hr particles can be detected at speeds of one to two miles per hour. The presence of a particle is indicated by a frequency increase of the audible signal. By turning off each of the GM instruments in turn, the

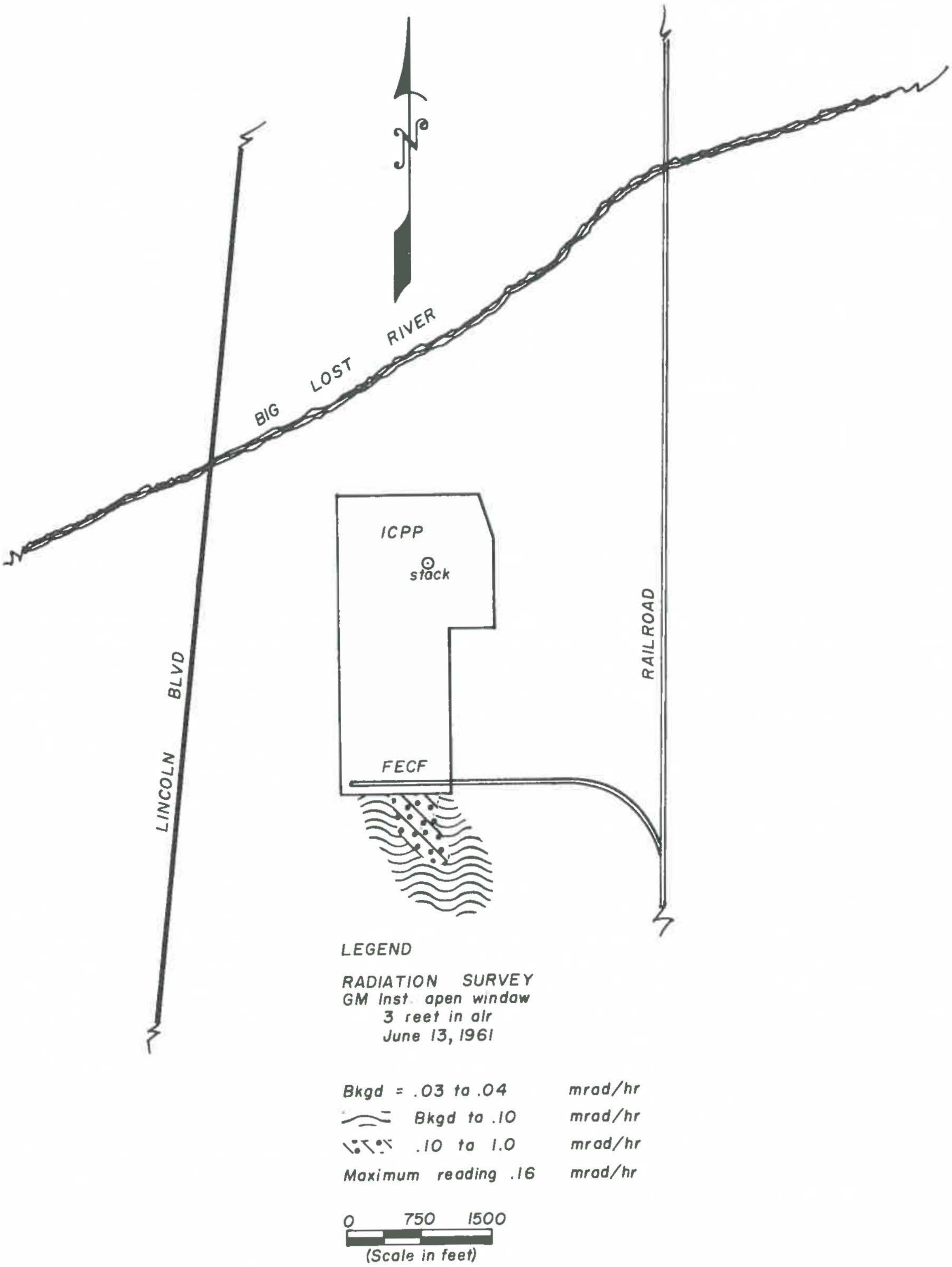


Fig. 33 Ground radiation surveys surrounding ICPP in 1961.

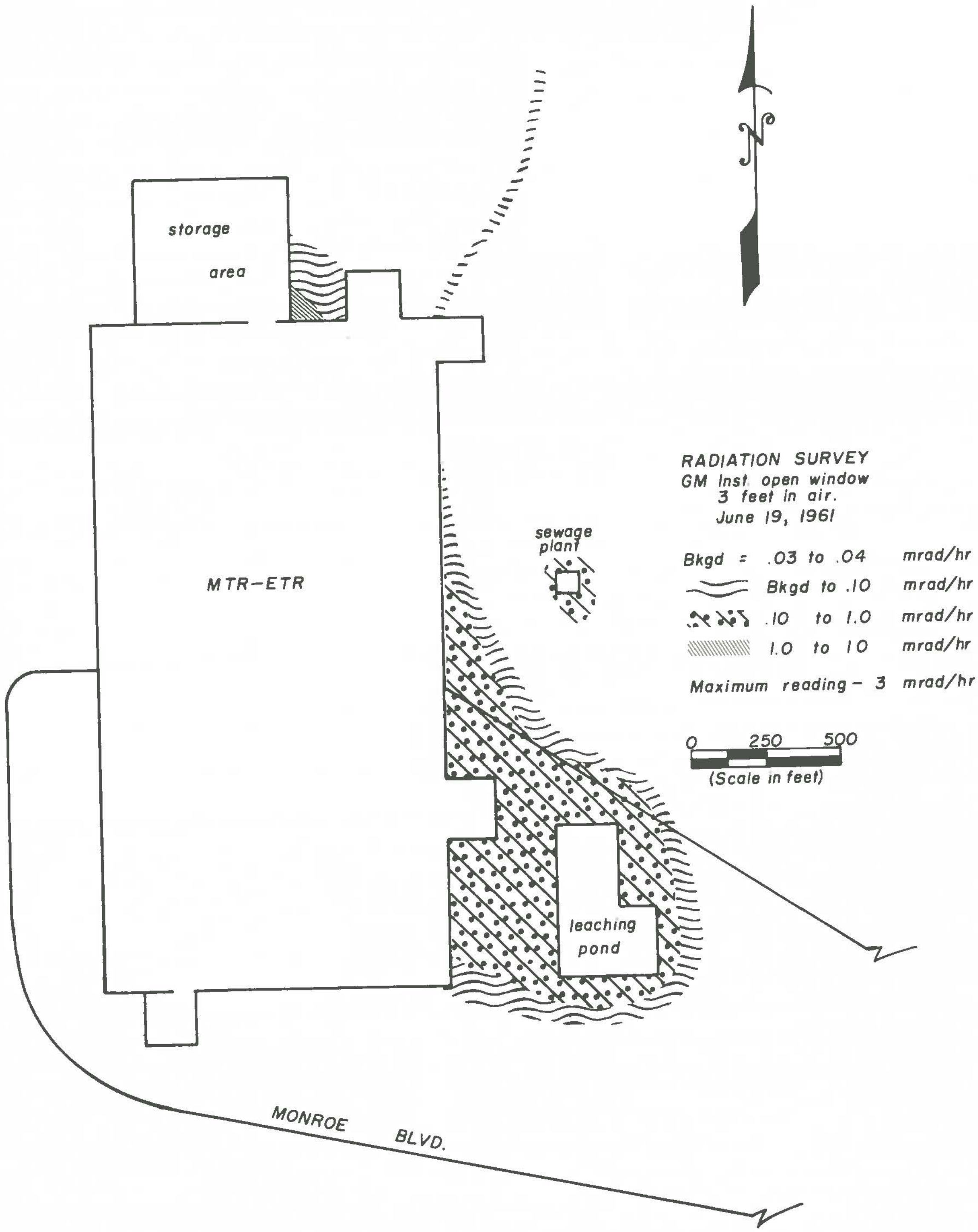


Fig. 34 Ground radiation surveys surrounding MTR-ETR in 1961.

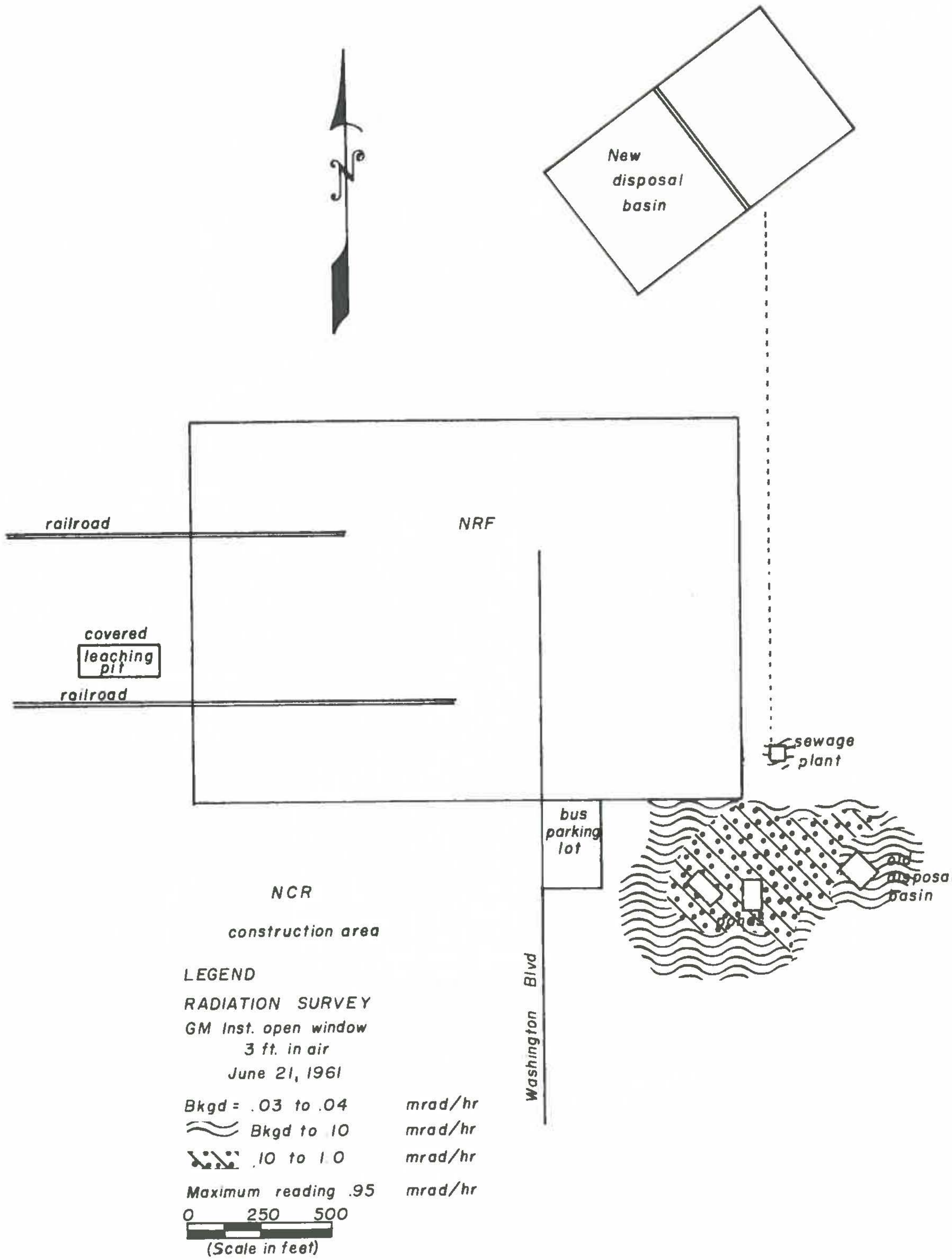


Fig. 35 Ground radiation surveys surrounding NRF in 1961.

probe nearest the particle can be determined. The particle is then isolated by the use of a portable survey instrument and picked up with an industrial type vacuum cleaner powered by a 2-kw generator mounted in the rear of the truck (Figure 37).

The roads surveyed in 1961 together with the number of detected particles and maximum individual particle dose rates are summarized in Table XXVI. The major source of these radioactive particles was undoubtedly the SL-1.

Fig. 36 Road scanning unit.

The new scanning instrument will greatly facilitate periodic surveys of roads at the NRTS as well as provide a rapid means of determining contaminated areas following an accident.

Fig. 37 Decontamination of NRTS roadways.

2.18 Radioactive Waste Discharged to the Atmosphere. The estimated amount of gaseous and particulate radioactive waste discharged to the atmosphere increased in 1961 over previous years. Table XXVII lists the plant facilities and the estimated waste discharged by each.

Records show that the increase in activity in 1961 can be attributed almost entirely to operations at MTR-ETR. Isotopic composition of wastes discharged to the atmosphere is shown in Table XXVIII.

Table XXVI

SUMMARY OF NRTS ROAD SURVEY PROGRAM, 1961

Roads Scanned	No. of Particles	Range of Individual Particle Dose Rates (at 1 in.)
U. S. Highway 20	100[a]	10 mr/hr to 5 r/hr
Site roads	75	10 mr/hr to 15 r/hr

(a) This does not include the decontamination of U. S. Highway 20 performed during the first month after the SL-1 accident.

2.2 Special Activities

2.21 ICPP Criticality Incident. On January 25, 1961, at 9:53 a.m. a report was received of an evacuation in progress at the ICPP. The incident was confirmed at 10:02 a.m. when a dose rate of nearly 20 mr/hr was noted by a health physicist responding to the incident. Immediately a roadblock of the main north-south road, Lincoln Boulevard, was established. A maximum dose rate of 30 mr/hr was observed on this road. Monitoring of the cloud continued as it moved in a southerly direction. As the cloud passed over the Central Facilities area a maximum dose rate of 4 mr/hr was noted at the Health and Safety building, CFA-646.

A high-volume air sampler utilizing as MSA, BM-2133 pre-filter and a carbon cartridge was operated outside building CFA-613. Analytical results of the sample taken between 10:20 a.m. and and 10:35 a.m. showed the presence of cesium-138, rubidium-88, rubidium-89, strontium-91, yttrium-91, and barium-139, all short-lived isotopes which could be present only after a nuclear criticality. During the afternoon, six special high-volume air samplers were placed along Portland Boulevard

Table XXVII

RADIOACTIVE WASTE DISCHARGED TO THE ATMOSPHERE, 1961

Plant	Beta-gamma Activity (curies)
MTR	209,631
ETR	125,793
ANP	2,524
ICPP	327
Other[a]	191
Total 1961	338,466
Total 1960	254,626

(a) ANL, GCRE, SPERT, NRF, SL-1

Table XXVIII

ISOTOPIC COMPOSITION OF RADIOACTIVE WASTE DISCHARGED TO THE ATMOSPHERE

Isotope	Half-Life	Beta-gamma Activity (curies)
Argon-41	1.8 hr	217,900
Xenon-137, 138	3.9 min, 17 min	65,600
Krypton-88, 89	2.8 hr, 3.2 min	46,000
Iodine-132	2.4 hr	205
Iodine-131	8.04 day	125[a]
Krypton-85	9.4 yr	3
Unidentified		8,633
Total		338,466

(a) Includes an estimated 80 curies released as the result of the SL-1 accident.

downwind from ICPP because of the possibility of another excursion. Personnel surveyed all areas outside the plant perimeter fence, including the construction areas, but no detectable, residual contamination could be found.

The aerial monitoring team, which was dispatched from Idaho Falls at 10:25 a.m. first monitored the CFA vicinity but could not detect any activity above background. Following directions given by the Weather Bureau, the cloud was detected near the Big Southern Butte, which is about 13 miles from the ICPP. Cloud tracking operations continued until the cloud dissipated.

2.22 ETR Air Cooled Loop Experiments. The General Electric Experimental Loop 99 located in the ETR reactor was operated for the first time in January 1961. Because of the calculated release rates, the section was requested to perform downwind monitoring continuously for the first test. Analysis of the samples taken during the first 72 hours indicated the actual release rate to be a factor of 10 or more below the calculated rate, posing no hazard to personnel on- or off-site. Consequently, the downwind monitoring was terminated prior to the completion of the first test.

2.23 Field Release Test III. Convair, a division of General Dynamics Corp. under contract to the Air Force Special Weapons Center, conducted a series of simulated meltdown experiments of TORY II-A type fuel samples. These tests, referred to as FRT-III, were performed at the NRTS test grid 3 located three miles north of the ICPP. The experiments consisted of a total of four releases, three "closed" and one "open". A total effluent collector was used on the closed releases. A failure of this collector occurred during test 2, resulting in surface contamination of the furnace and the burnup of a plywood shield. The open release allowed the effluent to disperse onto the test grid.

Convair placed various types of sample collectors on the 50-, 100- and 200-meter arcs. Based on the expected release of approximately three curies of iodine-131, a sampling program for iodine-131 on the 400- and 800-meter arc was planned which would include: (a) sampling in the vertical up to 80 feet; (b) comparison of efficiencies of carbon cartridge vs silver-nitrate treated filter media; and (c) comparison studies of deposition velocities using carbon-coated gummed paper, plain gummed paper, and small trays of grass. Due to unfavorable meteorological conditions, the open test was delayed nearly three weeks. Thus the iodine-131 inventory had decayed to less than 0.4 curie, which was not sufficient to provide data which would be statistically significant. For this release the monitoring plan was not activated.

2.24 In-place Filter Testing Program. The NRTS Filter Advisory Committee, which was formed in the spring of 1961, made possible a program for in-place testing of high efficiency filters by the purchase and assembly of the necessary testing equipment.

The equipment can be divided into two packages: (a) the generation of a suitable aerosol and (b) the equipment to detect the aerosol. The aerosol generators were constructed from a model loaned by the Naval Research Laboratory, Washington, D. C. The generator produces a polydispersed aerosol by the atomization of liquid dioctyl phthalate (DOP) with compressed air. Adjustment of the particle size range may be obtained by varying the supply of air pressure. At 30 psi the aerosol particle size ranges from 0.3 to 2.0 microns with a median size of 0.9 micron. Further refinement of the particle size may be made by adding a jet impactor to the generator; however, for in-place testing these impactors are not required.

The aerosol detection is based on measuring the light scattering power of the aerosol in the air stream. A Sinclair-Phoenix Smoke Photometer and associated equipment was purchased for this purpose. This equipment was assembled on a laboratory cart (Figure 38). The range of concentration observable with this instrument is about 100,000. This large range is obtained on a single-scale logarithmic amplification of the photocurrent from a photomultiplier tube illuminated by the forward scattered light. A recorder provides a continuous record of the variation in the mass concentration.

Fig. 38 In-place filter-testing equipment.

Briefly, the testing program required that the aerosol be introduced upstream of the filter. Then the air concentration of the aerosol both up and downstream of the filter are measured with the photometer. The ratio of these concentrations provide a measure of the efficiency of the filter. Of the first four filter installations tested efficiencies on 0.9-micron-sized particles ranged from 93.0 to 99.8%.

The aerosol generating unit requires a 15 cubic foot displacement of air at 30 psi to provide sufficient aerosol to test an air stream with a flow rate of 1000 cubic feet per minute. To date, a compressed air supply of this size has been difficult to find at some plants, and plans have been made to obtain a portable compressor of the proper size to be used solely for this program.

2.25 Civil Defense Activities. Civil defense activities included participation in two test programs, Operation Alert-1961 (OPAL 61) and Operation Headline. The OPAL 61 exercise postulated a nuclear detonation on the west boundary of the NRTS with an approximate yield of 10 megatons. Advice pertaining to the effects that this "Nudet" would have on the NRTS was furnished the IDO Control Group.

As a consequence of participation in these activities, a circular slide indicator was designed and constructed. All of the data presented on the indicator was derived from two publications issued by the U. S. Superintendent of Documents [6, 7]. Therefore the indicator does not furnish any new information regarding the basic phenomena of nuclear detonations. The main purpose of the indicator is to provide in a consolidated and easily understood form, most of the data initially necessary in the event of nuclear warfare. Basically, the information has been divided into three logical categories: (a) estimating location of detonation, (b) estimating weapon size and type, and (c) estimating resultant effects.

The indicator provides over 1000 "bits" of information on both surface and air bursts. The information includes fallout pattern dimensions for various meteorological conditions, dose calculations, human casualties percentages, physical damage areas, effects of thermal radiation to humans, and fallout decay values.

2.26 Research Activities (F. Grossman and A. Western). The major research activity centered on the development of an ultra-high-volume electrostatic sampler (HIVES) by U. S. Public Health Service personnel assigned to the branch. The sampler was developed for rapid sampling of large volumes of air (1000 to 2000 cfm) for quantitative determinations of trace amounts of strontium-90 and cesium-137.

The sampler is truck mounted (Figure 39) and can be quickly moved to and operated in remote areas. The truck is equipped with a 150-volt ac gasoline motor generator which allows the unit to be operated completely independent of external power sources. Two radio frequency dc power supplies provide the potentials of 12,000 to 15,000 volts to the ionizing section and 4500 volts to the collection plates.

The air to be sampled passes horizontally through one end of the sampler first into the ionizing section where a positive charge is imparted to the airborne particles and then through the closely spaced (0.17 inch) parallel collection plates where the charged particles are forced by an electrostatic field to deposit on the ground potential plates. The clean air then passes through a variable speed squirrel-cage blower which discharges into the vertical duct. The collection section is divided into four modules with each consisting of an open-end, four-sided lucite box which contains 65 parallel aluminum plates.

Two methods were used in determination of the actual collection efficiency of the HIVES. One method involved operation of the sampler at 1000 standard cubic feet per minute downwind of an aerosol generator and measuring the air concentration of the aerosol upstream and downstream of the electrostatic precipitator. Air stream samples were collected on two-inch-diameter HA Millipore filters sampling at 1.65 cubic feet per minute for periods ranging from 10 to 25 minutes, depending upon the distance from the aerosol generator. The number of particles collected on the millipore filters was determined by using an oil immersion optical microscope. Two runs were obtained indicating that no particles were bypassing the collection plates.

Fig. 39 High volume electrostatic sampler (HIVES).

The second method of determining actual efficiency utilized a Sinclair-Phoenix Smoke Photometer and a dioctylphthalate (DOP) generator. A rather simple equipment arrangement was used to establish the efficiency of the HIVES. The DOP smoke generators were located approximately 10 inches in front of the ionizing section and operated at 25 psi to generate a 0.9-micron particle. The intake probe of the smoke photometer was placed inside the exhaust stack so that a sample was taken of the downstream air only. This arrangement permits immediate determination of the aerosol concentration without tedious sample preparation and counting procedures used in the above mentioned method of determining actual efficiency. This method also indicates a collection efficiency of greater than 99.9%.

2.3 Routine Activities

2.31 Shipment (George Ball) Seven hundred eighty radioactive shipments leaving the NRTS were processed. Shipments were checked for compliance with all applicable regulations and radiation surveys were made periodically. One hundred eighty-four of these were unescorted shipments which required Bureau of Explosives Excessive Curie Permits. Table XXIX gives a breakdown of this group.

Table XXIX

NUMBER OF SHIPMENTS REQUIRING BUREAU OF EXPLOSIVES APPROVAL

Curies	No. of Shipments
More than 1,000,000	4
100,000 to 1,000,000	18
10,000 to 100,000	26
1,000 to 10,000	45
500 to 1,000	5
100 to 500	26
Less than 100	60
Total 1961	184
Total 1960	144

2.32 Telemetering System (Boyd Mortensen). Considerable time and effort was spent working in close cooperation with the Instrument and Development Branch with the radiation monitoring telemetering system. During April the system was shut down for revision of the reporting system and remodeling of the trailers which house the equipment. During the shutdown an evaluation of the station was conducted and revisions made in accordance with changes in operations at the NRTS.

Although the system is not operational, studies have been performed to determine the collection ability of the sampling media utilized and to make comparison studies with existing field sampling equipment.

A suitable method of housing the high-volume air samplers was developed. However, due to numerous erroneous signals, this equipment does not have the capability of being activated remotely. Development of suitable equipment to guard against these erroneous signals is complete. Personnel assisted in the radio transmissions checks between the master station and field units and relay stations.

2.33 Emergency Planning. Design for modification of four trailer houses was performed. These are to be used in the event of any emergency where additional facilities are needed for reentry to an evacuated area. Designation and a brief description of the function of each trailer are listed below.

Control Trailer: To be used by the Health and Safety Coordinator as a control point for all field operations.

Cold Change Trailer: Before entry to contaminated areas all personnel will remove personal clothing in this trailer and be issued protective clothing and respiratory protection.

Hot Change Trailer: All personnel returning from a contaminated area will be screened through this unit for removal of contaminated clothing and minor personnel decontamination.

Health Physics Trailer: The health physics field office will be located in this trailer. Personnel entry records will be kept and film dosimeters and portable survey instruments will be available here.

2.34 Applied Health Physics Trailing Program (L. J. O'Neill). An 11-week applied health physics training program was presented for AEC Health Physics Fellowship students. This program is sponsored by the IDO Health and Safety Division with cooperation of Aerojet General, Argonne National Laboratory, Atomics International, Phillips Petroleum and the U.S. Weather Bureau, and is administered by the Oak Ridge Institute of Nuclear Studies. This year seven trainees were accepted: four from the University of Kansas, two from the U.S. Air Force and one from the U.S. Public Health Service.

2.4 Future Plans

(1) More field runs will be made to substantiate the actual collection efficiency of the ultra-high-volume electrostatic precipitator over the entire range of 1000 to 2000 cubic feet per minute. In addition the relative collection efficiencies of the bug screen, ionizing section and collection section will be determined. An investigation will be made to determine the most feasible method for the removal and complete recovery of collected air particulate from the collection plates for radiochemical analysis. Ultrasonic cleaning methods appear to satisfactorily fulfill this need and also will be tested in 1962.

(2) Modification and equipping of the four emergency trailers will be completed early in 1962. Conversion of 17 mobile power plants from gasoline to propane also is scheduled.

(3) Personnel will participate in environmental monitoring following the proposed destruction of SPERT-I which is scheduled for late summer, 1962.

(4) A satisfactory source of compressed air for use in the in-place filter testing program will be obtained and improvements on the aerosol generator will be made. A detailed report on the filter testing program at the NRTS will be prepared.

3. RADIOACTIVE WASTE MANAGEMENT SECTION
(Bruce L. Schmalz - Chief)

3.1 Operational Data and Experience

Radioactive waste at the NRTS results from reactor operation, fuel processing and ancillary operations such as laboratories, laundry, test facilities, etc. This waste occurs in solid, liquid, and gaseous forms, or as mixtures.

3.11 Liquid Waste. The volume of liquid waste discharged to the environment during 1961 was slightly greater than that discharged during 1960. Table XXX lists the plant areas at the NRTS and the amount discharged by each.

During the year the presence of significant quantities of tritium in liquid waste streams was recognized. The figures in Table XXX do not include tritium activity due to the fact that it was not included in previous years. It is estimated that approximately 1000 curies were discharged during 1961 in addition to the amounts of radioactivity shown.

Much time and effort has been devoted to evaluating the many possible sources of tritium at the NRTS. Major methods of formation include the following: [8]

(1) Production of rather large quantities by means of ternary fission in reactor fuel elements.

(2) Formation by means of the (n,α) reaction with lithium-6 present in brazing fluxes used in the fabrication of some reactor fuel elements.

Table XXX

LIQUID WASTE DISCHARGED TO GROUND AT NRTS, 1961

Plant Facilities	Volume of Waste (gallons)	Beta-gamma Activity (curies)
MTR-ETR	234,624,000	3530
ICPP	188,000,000	39
NRF	24,547,000	19
CFA	38,000,000	3
ANL, GCRE, ANP, OMRE, SPERT	10,006,000	1
Total 1961	495,177,000	3592
Total 1960	484,698,000	3517

(3) Production of tritium in the beryllium reflectors of the MTR and ETR via the following reactions:

$$Be^{9}\ (n_f, \alpha)\ He^{6},\ He^{6} \rightarrow Li^{6} + \beta,\ Li^{6}\ (n, \alpha)\ H^{3}.$$

These first two methods probably contribute the majority of the tritium which is discharged from the ICPP. However, the percentage of that presently being discharged from the MTR and ETR, which is attributable to each of these methods, is unknown.

Other isotopes identified in the liquid waste discharges are shown in Table XXXI.

The amount of alpha-emitting isotopes disposed was insignificant. The difference between the activity isotopically identified and the gross amount reported in Table XXX is mainly due to isotopes with less than 30-day half-life.

The largest volume and amount of activity was discharged into a seepage pond accommodating discharges from both the MTR and ETR. The mean rate of discharge for 1961 was 642,000 gallons per day. The fluctuation in discharge volume as well as the amount of radioactivity is illustrated in Figure 40. Provision was made for discharging waste to the pond by pumps rather than by gravity after difficulty was experienced with the gravity flow system. This permitted an increase in the volume delivered and a consequent rise of approximately nine inches over previous high water levels.

A decrease in permeability of the pond has occurred during recent years. Investigations during 1961 partially explained this problem as due to the presence of a silica gel sludge. This was attributed to the precipitation of

Table XXXI

RADIOACTIVE ISOTOPES IN LIQUID WASTE DISPOSALS

Isotope	Half-life	Beta-gamma Activity (curies)
Chromium-51	26 day	116
Cerium-141, 144	32 day, 290 day	95
Iodine-131	8 day	80
Strontium-89, 90	50 day, 27.7 yr	61
Cadmium-115	54 hr, 43 day	54
Zirconium-Niobium-95	65 day, 35 day	41
Ruthenium-Rhodium-106	1 yr, 30 sec	26
Cesium-137	33 yr	7
Cobalt-60	5.25 yr	7
Total		487

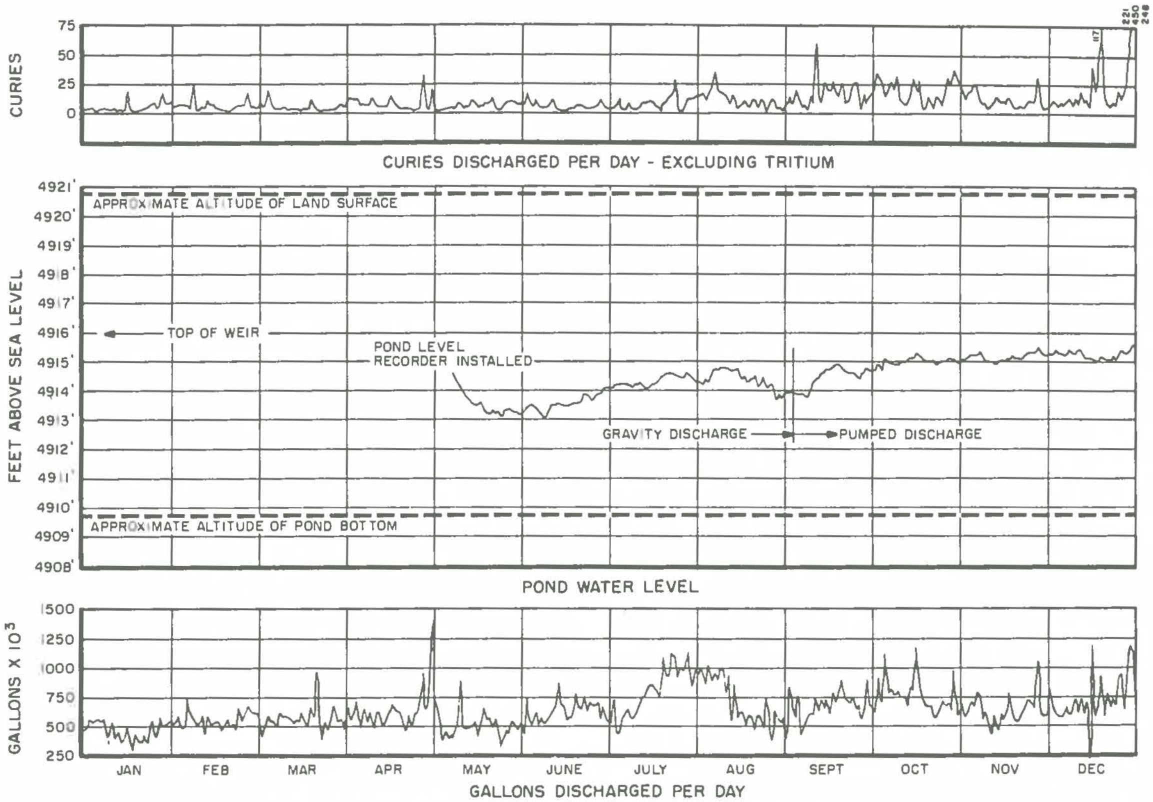


Fig. 40 MTR-ETR liquid waste disposal, 1961.

SiO_2 at low pH. The low pH was created by discharge to the pond of sulfuric acid used in demineralizer processes. The SiO_2 accrued by the concentration of natural ground water in the cooling towers.

A program to determine the macrochemical composition of the liquid in the pond was performed by the Analysis Branch. Table XXXII is a summary of this information covering a period of three months.

3.12 Solid Waste. The volume of solid waste disposed of at the NRTS increased during 1961. The increase in activity can be attributed primarily to disposal of the GE-ANP in-pile loop from the ETR, which contained approximately 100,000 curies of mixed fission and corrosion products. Table XXXIII shows the origin and estimated amount from each plant operation.

Table XXXII

CHEMICAL COMPOSITION OF MTR-ETR POND WATER

Location	pH	Conductivity (micromhos/cm)	Parts Per Million Ca^{++}	Mg^{++}	Na^{+}	Cl^{-}	NO_3^{-}	SO_4^{--}
Near inlet	3.0	1584	105	27.9	103	32.7	5.5	549
Far end	3.2	1422	90	24.9	93	33.4	5.7	531

Table XXXIII

DISPOSAL OF SOLID WASTE BY BURIAL AT THE NRTS, 1961

Plant	Volume of Waste (cubic yards)	Beta-gamma Activity (estimated curies)
ANL	79	79
AREA	3	Insignificant
CFA	51	1
GCRE	35	3
ANP	220	126
ICPP	501	372
MTR-ETR	1,214	122,411
NRF	992	10,984
OMRE	316	Insignificant
SL-1	539	63
SPERT I & III	6	Insignificant
Sub-total	3,956	134,039
Off-site other than NRTS	6,101	21,000
Total 1961	10,057	155,039
Total 1960	7,108	9,246

The solid radioactive waste disposal operations were routine and uneventful during 1961 with one exception. A shipment of off-site waste originating at Isotopes Specialties Co., Burbank, Calif., arrived at the NRTS with contamination leaking from the container. The railroad car used to transport the shipment required decontamination at a cost of $5900.

3.2 Research Involving Waste Disposal to the Lithosphere (W. S. Keys)

3.21 General. Drilling of observation wells, geophysical logging, water quality, and hydrological investigation continued. A detailed report covering the aspects of this work was released in December 1961 [9]. A brief summary of the work follows.

3.22 Drilling. A drilling contract was awarded to Andrew Well Drilling Contractors on June 15, 1960. This contract was completed on April 6, 1961 [10]. The total contract expenditure was $72,829.32 and resulted in 5865 feet of hole in 19 new wells and 2 deepened wells.

Twenty-two small-diameter wells (1-1/2 inch) involving 1062 linear feet of hole were drilled and cased in the alluvial regolith within a radius of 500 feet of the MTR-ETR pond. These wells were drilled with rotary-auger type equipment furnished under the cooperative program with the U. S. Geological Survey.

The purposes of the drilling programs were (a) to provide means for delineating the distribution of discharged waste both in the regolith and in the basalt bedrock, and (b) to perform geophysical studies to determine the stratigraphy and hydraulic characteristics of the permeable water-bearing zones. Holes in the regolith at the NRTS burial ground also were drilled for the purpose of monitoring movement of radioactive material by leaching of buried waste. Movement is considered very improbable and none was detected.

Figure 41 is a map of the holes in the MTR-ETR and ICPP vicinities.

3.23 Investigations in the Vicinity of the MTR-ETR Pond. Detailed delineation of the perched water in the vicinity of the MTR-ETR pond continued. Figure 42 shows the area and altitude of this water during March 1961. The water level in the pond is approximately 4915 feet. The altitude of the perched water ranges from 4865 feet in the wells nearest the pond to 4750 feet in well 74, which is 2368 feet west. The regional water table is approximately 460 feet below the land surface at 4460 feet.

The investigation of the water in the alluvial regolith is not complete. Preliminary results show that saturation and detectable contamination extends more than 500 feet from the pond. Figure 43 is a plan map showing the area of saturation immediately overlying the basalt. It also shows the area containing detectable radioactive contamination, as determined by measurements of residual activity in samples. Apparently, moisture and radioisotopes from the pond also are moving by unsaturated flow. This is illustrated by the section profile, shown in Figure 44.

It is apparent that saturation of the alluvium adjacent to the MTR-ETR buildings has been fortunately prevented by a ridge on the surface of the basalt.

The following isotopes have been identified in the saturated zones: hydrogen-3 (tritium), iodine-131, cobalt-60, silver-110, chronium-51, and cerium-144. The specific conductance, sodium concentration and temperatures of the water in the perched zone are attenuated with distance, and all show the same relationship. Figure 45 shows specific conductance of the perched water. The configuration is also typical of temperature and sodium concentration.

Tritium is not considered susceptible to exchange and is therefore accepted as a nearly perfect tracer. The presence of tritium in observation wells as of July 14, 1961, is shown in Figure 46. It can be seen that the concentration of this isotope is apparently attenuated with distance from the pond. This phenomenon is contradictory to the accepted theory and has not been conclusively explained. Further investigations are continuing.

3.24 Investigations in the Vicinity of the ICPP. Ninety-nine percent of the volume of radioactive liquid waste from the ICPP is discharged into a well which penetrates 150 feet below the water table. Wells have been drilled to penetrate below the water table to intercept and study the movement of this waste. Earlier work consisted of taking water samples from these wells

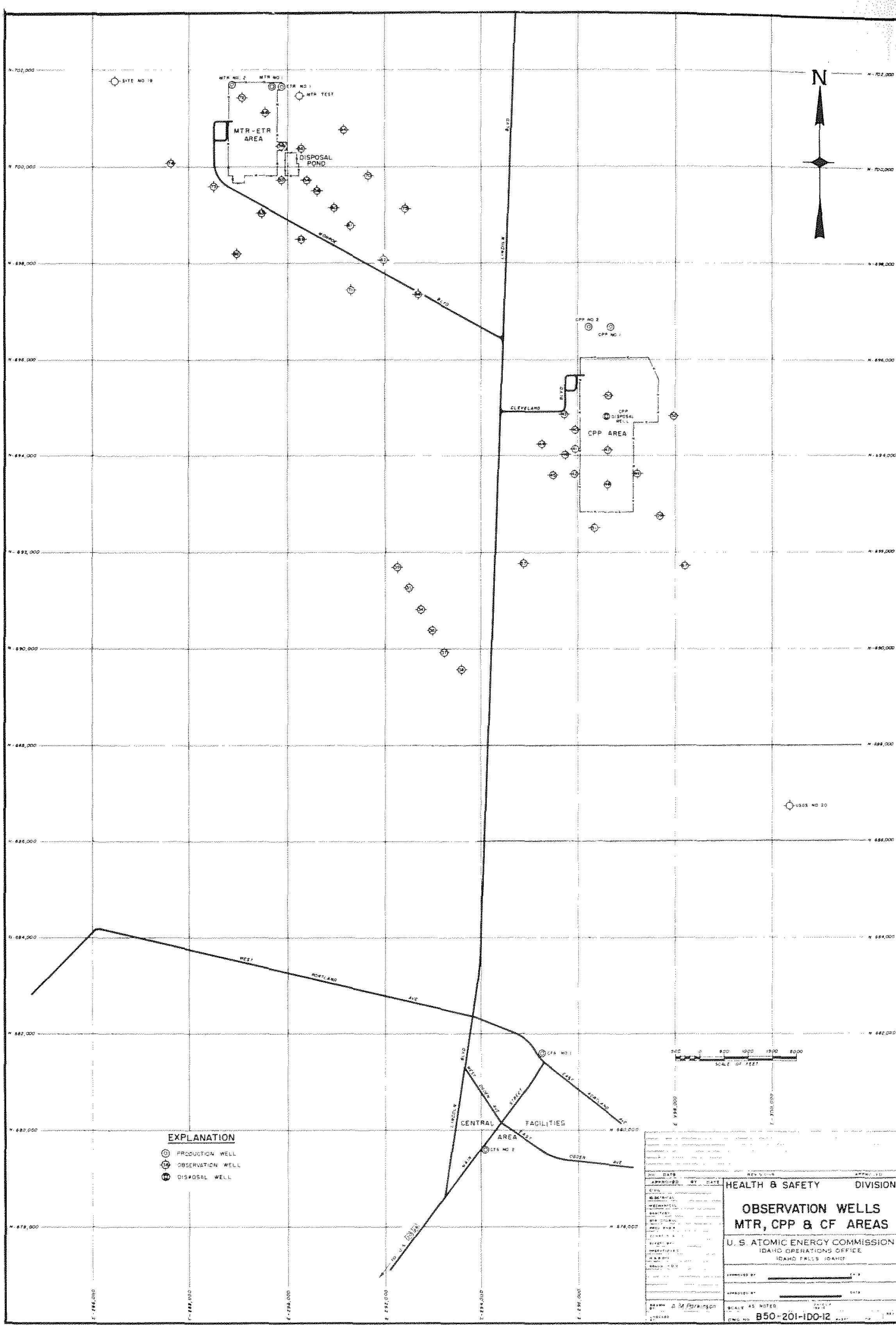


Fig. 41 Map of observation wells.

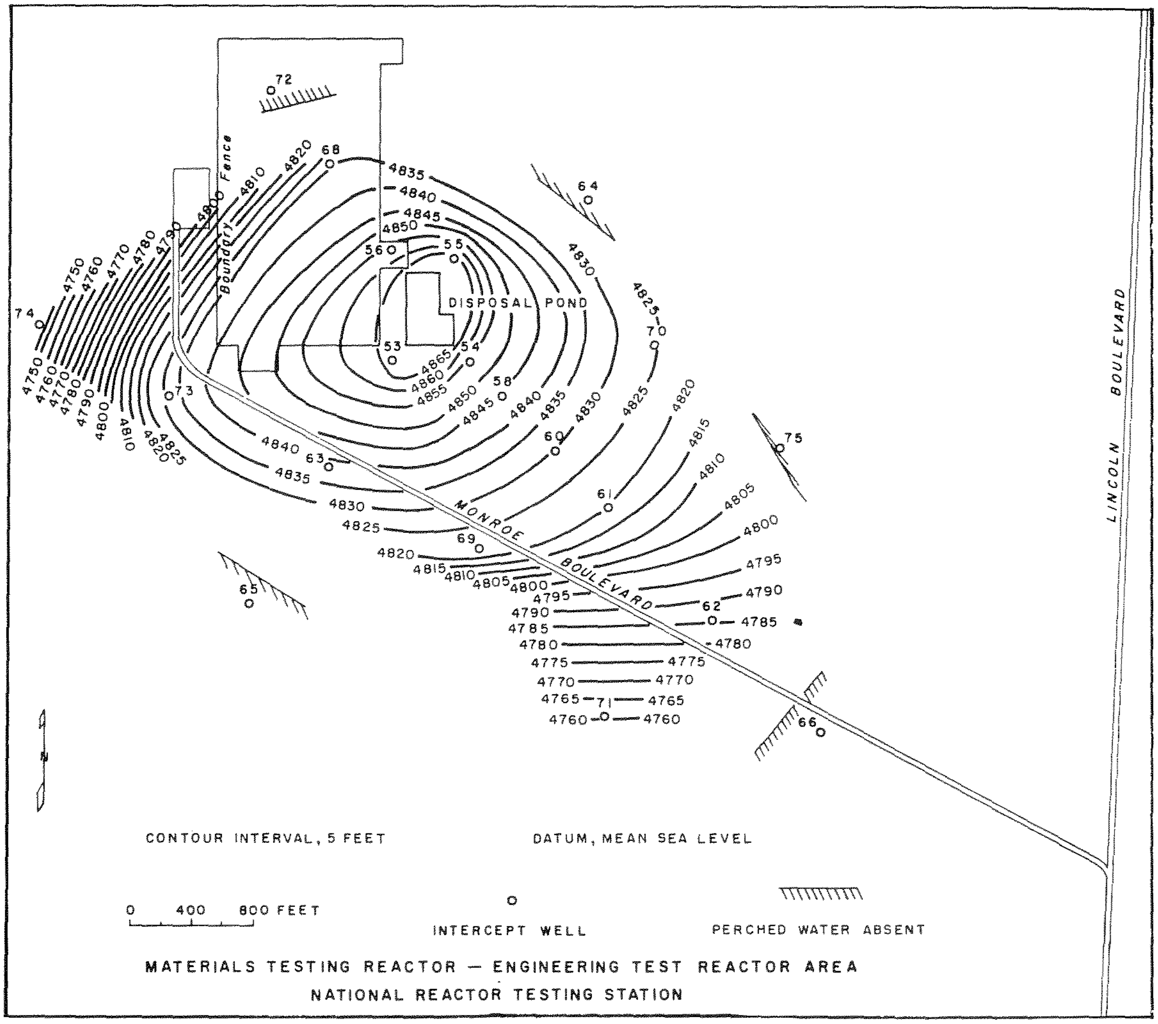


Fig. 42 Water-level contour map of MTR-ETR area. Drawing courtesy USGS.

and analyzing them for gross beta and gamma radioactivity and chemical quality. As relatively large amounts of common salt have been discharged, the presence of waste has been detected by sodium and chloride ions. This work was continued during 1961 and indicates that the salt is migrating. The presence of salts as far away as three miles has been indicated by electrical conductivity determinations performed on water samples.

During the first 11 months of 1961 there was no tritium discharged to the regional underground water at the ICPP. The concentration of this isotope in the isolated aquifer of the observation wells remained relatively constant during this time. The situation during the last six months of the year is illustrated in Figure 47 which shows the isopleths of tritium concentration on August 14, 1961, in the wells within 3000 feet of the disposal well.

The presence of tritium also was detected in wells up to four miles from the ICPP. The existence of this isotope at this distance is evidence of the contaminating effects of the discharge of waste on the ground water. This discovery is of considerable significance and offers a potential technique

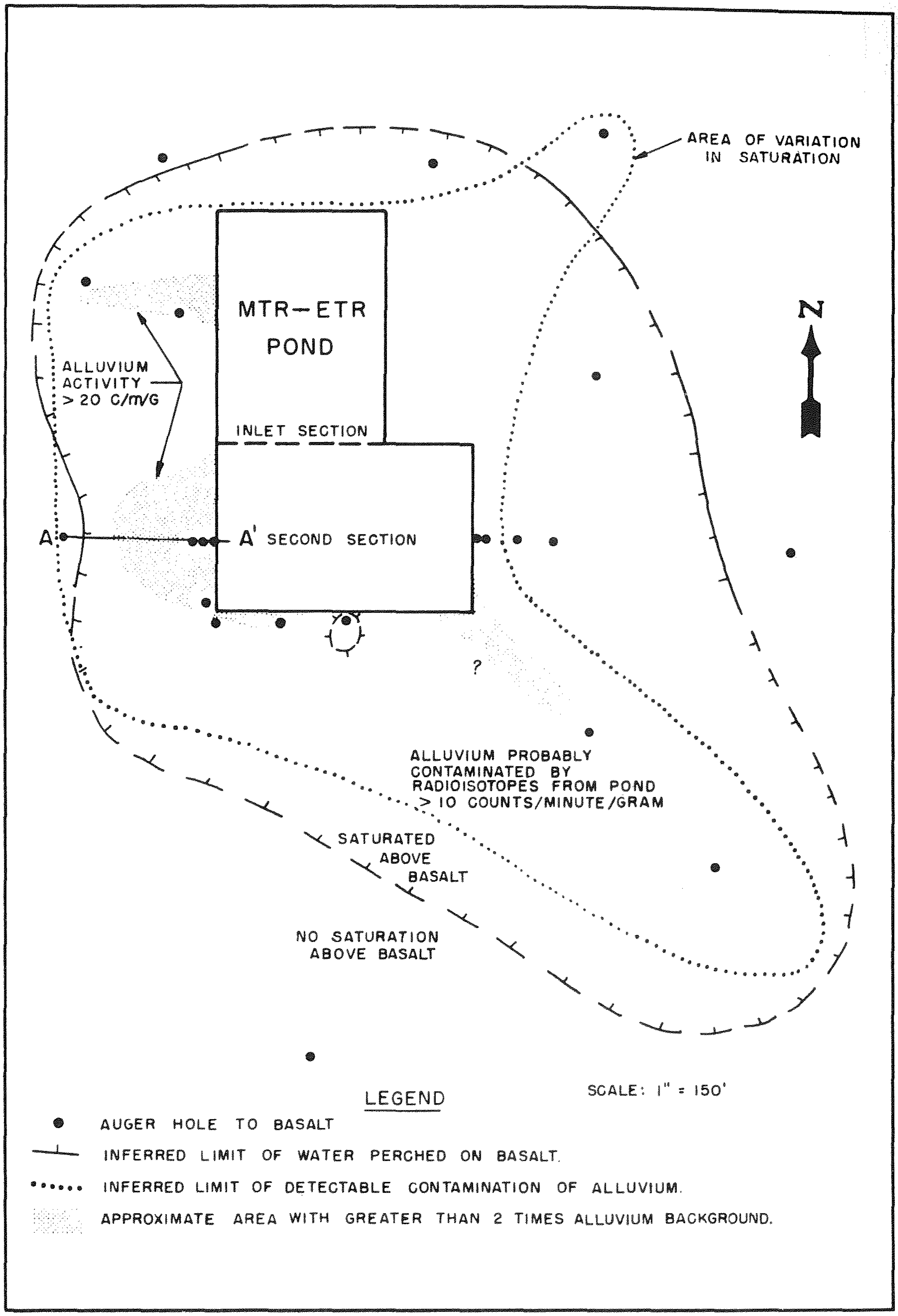


Fig. 43 Waste distribution in alluvium near MTR–ETR disposal pond.

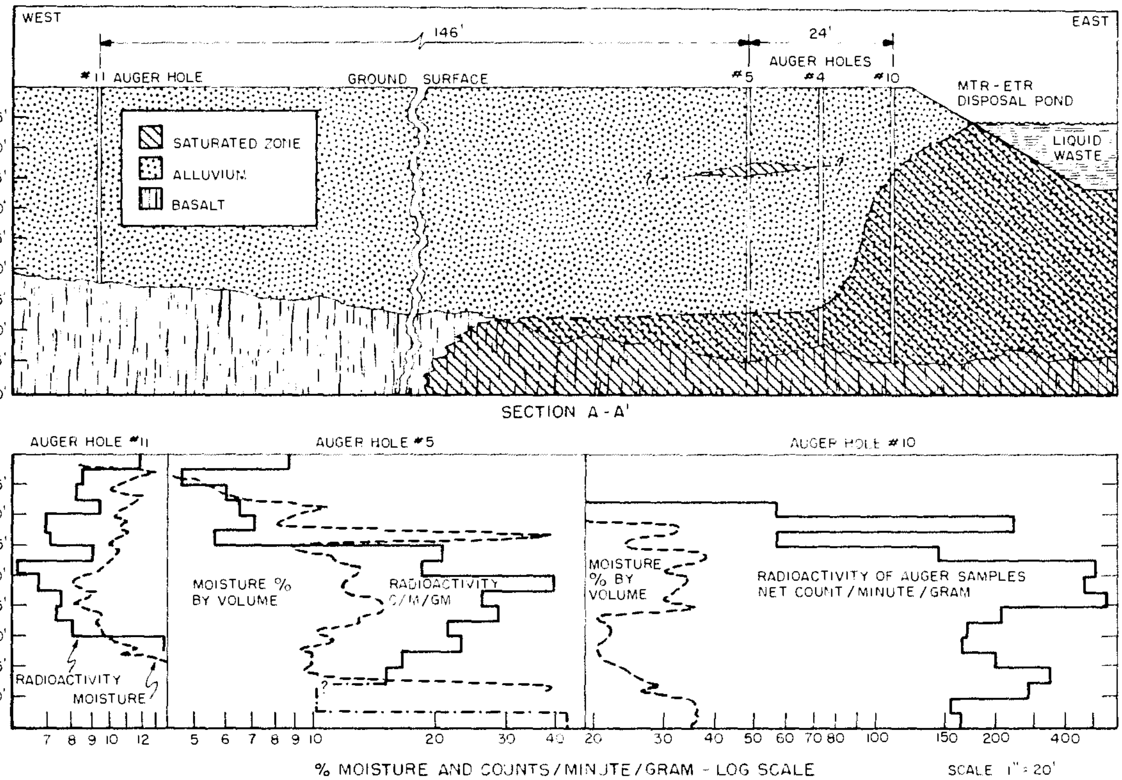


Fig. 44 Graph and profile of moisture movement in alluvium near MTR-ETR disposal pond.

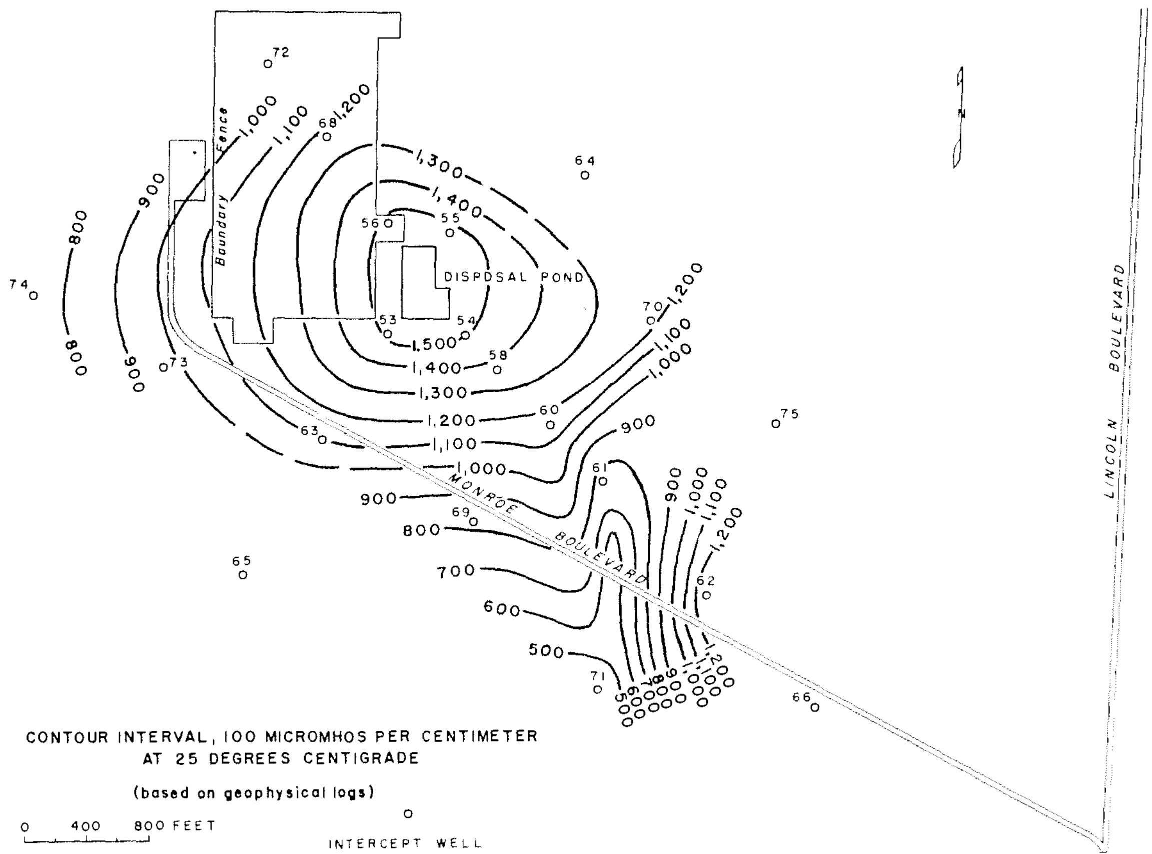


Fig. 45 Maximum specific conductance of water in MTR-ETR area. Drawing courtesy USGS.

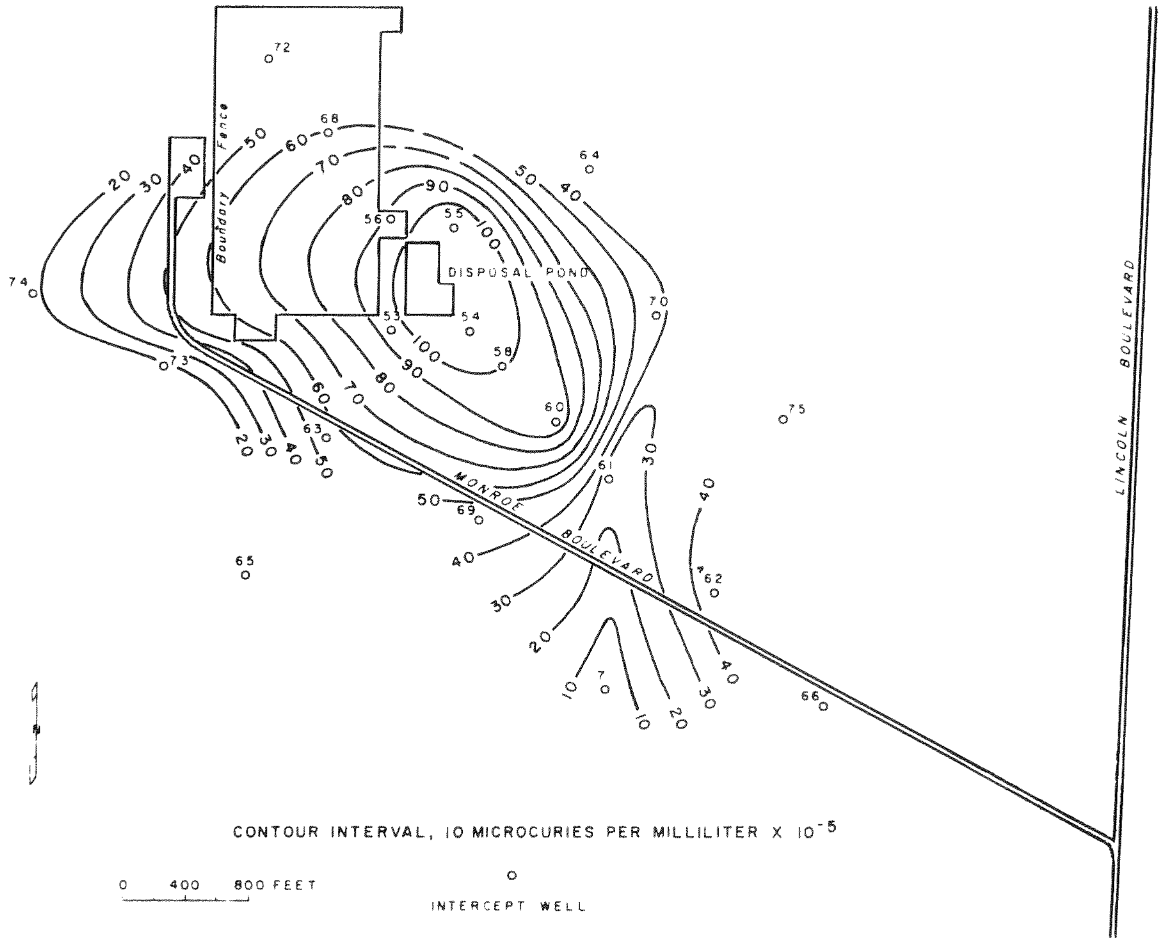


Fig. 46 Tritium content of water in MTR-ETR area. Drawing courtesy USGS.

for predicting the path and rate of movement of radioactive waste across the Snake River Plain.

ICPP operations with resulting discharge of tritium were resumed in December 1961. These releases were detectable in surrounding wells as illustrated in Figure 48 which shows the effect in two wells, Nos. 43 and 47.

Assuming that the discharge of 203 curies on December 10 was first detected in well 43 on December 17 and in well 47 on December 15, the rate of travel, based on first arrival, can be estimated as shown in Table XXXIV. These values substantiate previous determination if allowances are made for errors in determining time, distances, etc. This study was not complete as of the end of the year and is being continued to include additional wells.

Plans to conduct a deliberate tracer test under controlled hydraulic conditions were not completed. This was due to the fact that an electronic system utilizing pressure transducers to determine well water levels did not perform according to specification. The system involved central read-out equipment consisting of visual, tape printer and tape punch systems. The original specifications required an accuracy to 0.02 foot of water and a recording capability of 15 seconds. Figure 49 is a photograph of the read-out equipment.

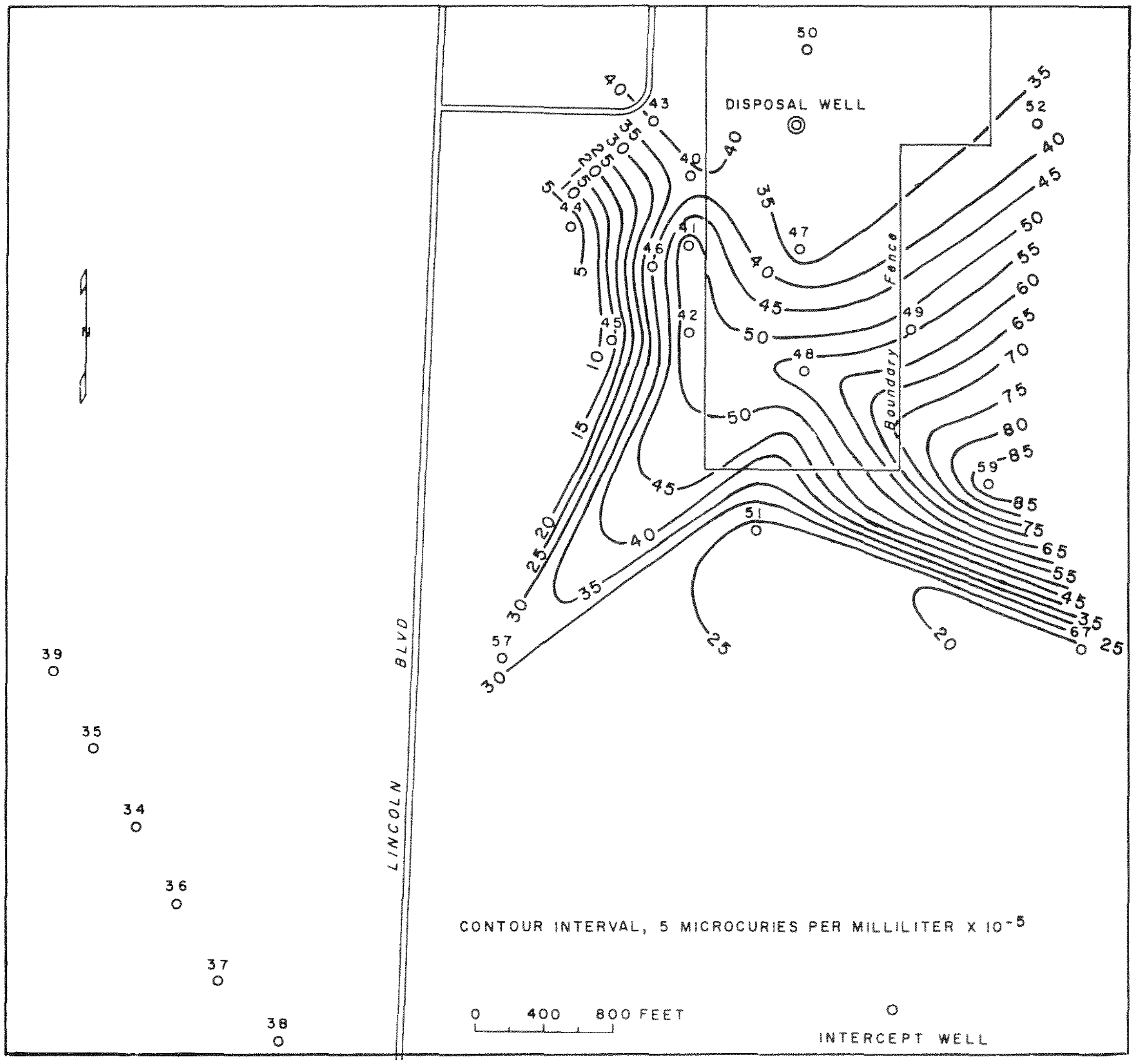


Fig. 47 Tritium content of water in ICPP observation wells, August 14, 1961.

Additional work is being carried out to eliminate the operational difficulties which developed. This system will be installed with detection transducers in as many as 14 wells. It will be used to determine the head differentials caused by discharge to individual aquifers. The transducers will be sealed in the well in order to eliminate the effects of changes in the barometric pressure which otherwise could cause water level fluctuations larger than those caused by the discharge. The sealed wells have been equipped with submersible pumps for the purpose of obtaining samples.

3.25 Investigations at the NRF. As part of a study of the distribution of radioactive material in the regolith in the vicinity of waste disposal ponds, two sets of auger holes were drilled near a dry abandoned disposal pond used by the S1W facility at NRF. Fifteen holes were drilled and sampled prior to the disposal of solutions resulting from the decontamination of the primary system of the S1W reactor. These same holes were offset, drilled and sampled after disposal to determine changes in the existing field of contamination

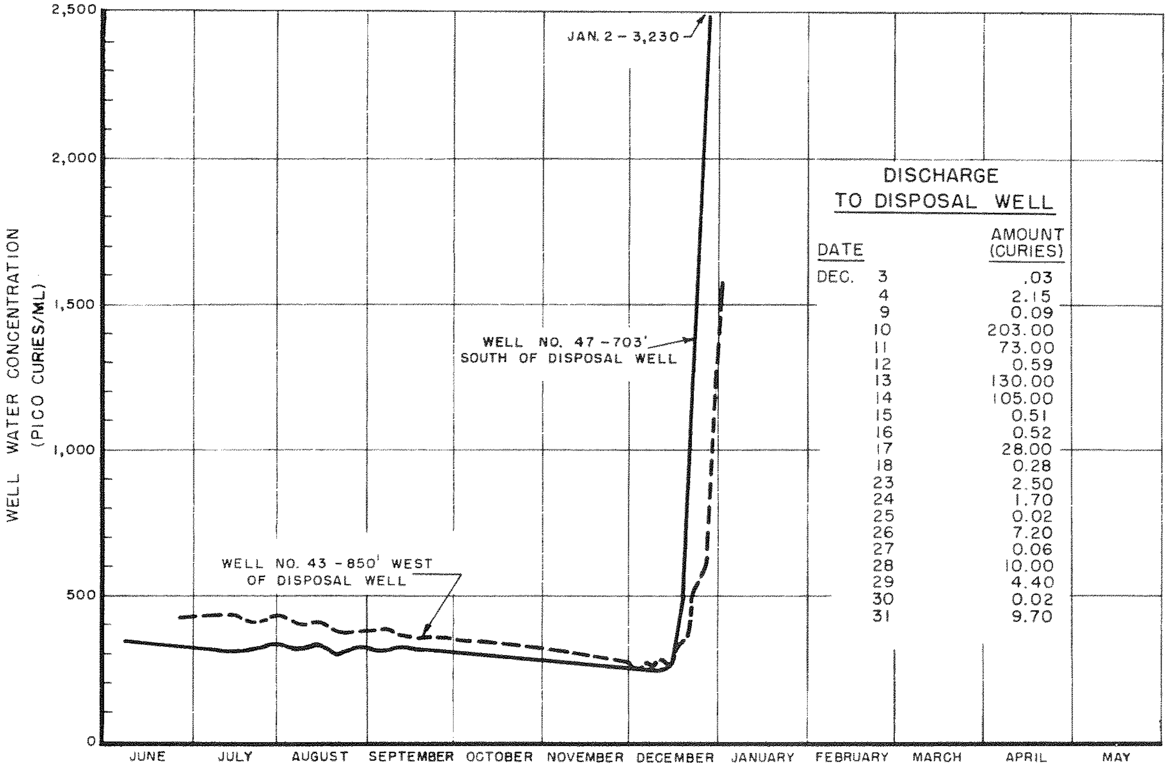


Fig. 48 Graph of concentration vs time for tritium in wells 43 and 47.

Table XXXIV

MAXIMUM RATE OF MOVEMENT OF TRACER MATERIALS FROM DISPOSAL WELL TO MONITORING WELLS 43 AND 47

Well No.	Distance From Disposal (ft)	Number of Days to Appear: Fission Products 12-9-58	Number of Days to Appear: Dye 11-21-58	Number of Days to Appear: Tritium 12-10-61	Rate of Movement (ft/day): Fission Products	Rate of Movement (ft/day): Dye	Rate of Movement (ft/day): Tritium
43	850	6[11]	6[11]	6-8	141	141	106-141
47	703	7[11]	5[11]	5	100	141	141

produced by an estimated 15 curies of waste. Gross gamma activity up to 250 times normal background (less than 10 counts/minute/gram) was found in the second set of samples.

Contamination of the alluvium around the pond showed a factor of 50 increase after the single discharge. Contamination of 20 times background was detected at a horizontal distance of 35 feet from the pond. Cobalt-60 appeared to be the primary migrating isotope and constituted 75% of the discharge. Cesium-134, -137 constituted only 1.5% of the discharge but was detected in many of the samples. Chromium-51 and manganese-54 contributed 14% and 5%, respectively, of the discharge but were not detected in the samples. The migrating radioisotopes apparently move laterally within or close to a zone of perched water produced on top of the basalt. The water moves away from the pond in an irregular pattern related to the buried topography on the youngest basalt flow and the permeability of the regolith.

3.26 Laboratory Investigations. Laboratory work was initiated to investigate characteristics of locally available natural earth materials in relation to their possible use as ion exchangers for the removal of radioisotopes from aqueous waste solutions. This work is being performed by Phillips Petroleum under contract AT(10-1)205. The work has consisted in measuring the chemical and physical characteristics of 21 samples. The work has been reported in monthly progress reports and is summarized in Table XXXV.

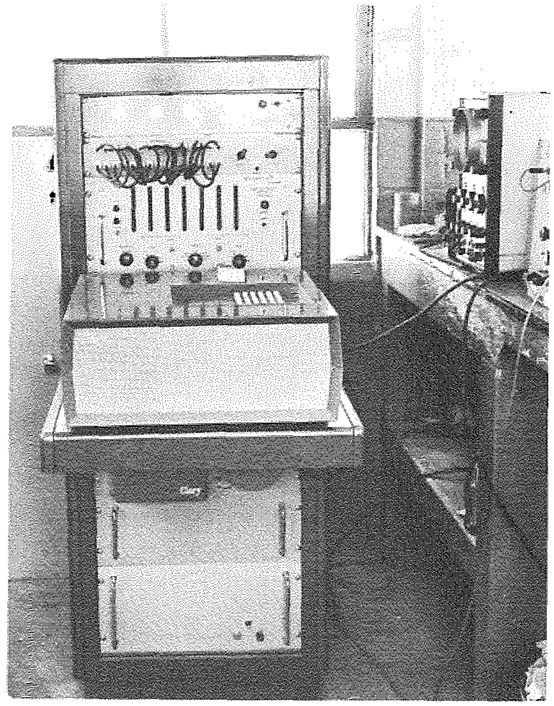


Fig. 49 Central control and read-out equipment for electronic water level equipment.

The materials represented by samples 3, 4, pc-1, pc-2, Clin-1, and Clin-2 have physical and chemical characteristics of potential value. This work is scheduled to continue with more intensive investigation of the more promising materials.

3.27 Chemical and Physical Quality of Ground Water. A detailed study of the chemical and physical quality of water in the basalt aquifers on the NRTS was completed during the year and a report is being prepared [12]. Analysis of samples of water from 88 wells, collected from depths of a few to 200 feet below the regional water table, has identified four distinct hydrochemical facies. The effects of residence in the basalt aquifers and recharge from irrigated areas and waste discharge from the NRTS are also evident.

3.28 Future Plans. The research program summarized above and planned during 1962 is of a continuing nature. It is designed for the purpose of providing information directly applicable to operational problems. The following items will receive particular consideration:

(1) Detailed laboratory work in connection with local soil materials.

(2) Detailed study of the site and plain-wide underground water quality characteristics.

Table XXXV

EXCHANGE CHARACTERISTICS OF NATURAL MATERIALS STUDIED IN CONNECTION WITH REMOVAL OF RADIONUCLIDES FROM WASTE SOLUTIONS

No.	Material Description	Exchange Capacity (meg/g)	Maximum Distribution Coefficients[a] pH	Sr	pH	Cs	Remarks
1	Lignitic material	0.10	8.7	250	—	—	Operational mine, Teton Valley, Idaho
2	Lignitic material	0.02	10.9	460	—	—	Slack pile, abandoned mine
3	Lignitic material	0.44	9.2	1300	—	—	Road cut Highway Idaho 31, good physical characteristics
4	Lignitic material	1.08	7.0	1500	5.5	800	Exposed, undeveloped vein, good physical characteristics
5	Clay	0.09	11.0	240	—	—	Clay in overlying contact with No. 4
5 + P	No. 5 plus phosphate	—	10.0	1200	—	—	No. 5 0.1 M phosphate added.
A-1	Clay deposit, Lemhi Valley, Baker, Idaho	0.76	8.0	900	6.0	1500	Bentonitic clay deposit, low permeability
A-4	Clay deposit, Lemhi Valley, Baker, Idaho	0.07	9.0	1200	6.0	2000	Bentonitic clay deposit, low permeability
ANP-1A	Silt, 0 to 5 ft	0.17	9.0	1200	6.5	3000	Samples from playa, NRTS
ANP-1B	Silty clay, 20 to 27 ft, same hole as 1A	0.15	9.5	1200	6.5	3500	Samples from playa, NRTS
ANP-2A	Silt, 0 to 5 ft	0.15	9.5	900	6.0	4000	Samples from playa, NRTS
ANP-2B	Silt, 10 to 15 ft, same hole as 2A	0.09	9.0	800	6.0	4000	Samples from playa, NRTS
GM-1	Silty clay, phosphoria formation	0.27	10.5	3000	10.8	2600	Samples from Gay Mine east of Blackfoot, Idaho, phosphate deposit
GM-2	Sandy silt, phosphoria formation	0.06	10.5	400	7.0	320	Samples from Gay Mine east of Blackfoot, Idaho, phosphate deposit
GM-3	Silty clay, phosphoria formation	0.37	8.5	3000	6.3	520	Samples from Gay Mine east of Blackfoot, Idaho, low permeability
PC-1	Phosphorite, silty clay, Swan Valley, Idaho	0.36	8.5	3000	6.0	1500	Phosphoria formation, Pritchard Creek, good physical characteristics
PC-2	Phosphorite, silty clay, Swan Valley, Idaho	0.44	8.5	2000	7.0	1100	Phosphoria formation, Pritchard Creek, good physical characteristics
SCP	Lignite	0.05	8.5	3000	6.0	540	Slack coal pile, Teton Valley, Idaho
Clin-1	Clinoptilolite, 4 to 6 mesh	0.31	8.0	6000	10.5	3400	Mink Creek, Preston, Idaho, good physical characteristics
Clin-2	Clinoptilolite, 60 to 100 mesh	0.23	8.0	8000	10.5	4000	Mink Creek, Preston, Idaho, good physical characteristics

(a) Equilibrium distribution coefficient (K_d) = Concentration of element on sample/ Concentration of element in solution.

(3) Studies for the purpose of determining the characteristics of aquifers. This will involve drilling of wells, tracer tests, geophysical logging, and hydraulic tests.

(4) A pilot field scale lysimeter for treatment of aqueous waste streams is planned.

(5) Field studies, both chemical and physical, are proposed for other plant areas.

4. APPRAISAL SECTION
(W. P. Gammill - Acting Chief)

4.1 Contractor Health Physics Appraisal

This section is responsible for conducting comprehensive appraisals of the health physics programs carried on by IDO contractors. Implementation of this phase of contractor appraisal was initiated in 1960, and efforts were accelerated in 1961 following the interruption of the program by the SL-1 accident.

In 1961 five formal appraisals were completed. These were of the Chemical Processing Plant, SPERT reactor complex and Central Facilities, operated by Phillips Petroleum; GCRE, operated by Aerojet General Nucleonics; and STPF (SUSIE), operated by General Electric. In addition, frequent appraisal was made of the health physics activities of Combustion Engineering during the early stages of its recovery and analysis efforts and, subsequently, those conducted by General Electric in the decontamination of the SL-1 reactor facilities.

Until mid-September, this function was a responsibility of the Health Physics Section, and no one was assigned full-time to its execution. Since then, two health physicists have been assigned to this new section and are supported by the part-time assistance of the branch chief.

Criteria for appraisals are taken directly from those factors listed in AEC Manual Chapter 0504. Other factors which have been added are radiological incidents, details pertaining to waste disposal, emergency procedures, adequacy of instrumentation and routine radiological control, and any special problems of a recurring nature or due to facility design limitations.

While no specific type of organizational structure is preferable, it is essential that the health physics supervisor have administrative recourse to take controversial problems directly to top management. At some of the smaller NRTS facilities, even though operations are continuous, health physics coverage is not required on all shifts. Where this is the case, a strong training and reorientation program for operations personnel is mandatory.

The detailed checklist used for the initial evaluation of a health physics program is presented in Section XII, Appendix.

Development of basic standards and minimum requirements for contractor health physics application was begun during the last quarter of 1961. These are to be integrated into the Standard Health and Safety Requirements Manual, initially issued by the Health and Safety Division in 1954.

4.2 IDO Health Physics Review

A review was made during 1961 of the activities of each branch of the Health and Safety Division which routinely uses radioactive materials or X-ray machines.

5. TALKS AND PUBLICATIONS

Branch personnel presented the following talks and papers:

(1) "Progress Report on High Volume Electrostatic Sampler" was presented by A. Western, USPHS, at the Seventh AEC Air Cleaning Seminar held at Brookhaven National Laboratory on October 10-12, 1961.

(2) "Air Monitoring Following the SL-1 Accident" was presented by G. Wehmann at the Seventh Air Cleaning Seminar.

(3) "Environmental Aspects of the SL-1 Accident" was presented by W. P. Gammill at the Sixth Annual Meeting of the Pacific Northwest Section of the American Industrial Hygiene Association, September 22, 1961, Idaho Falls, Idaho.

(4) "Liquid Waste Disposal to the Ground at the NRTS" was presented by B. L. Schmalz at the Fourth Annual Meeting of the Intermountain Section of American Water Works Association, October 5, 1961, Twin Falls, Idaho.

(5) "National Reactor Testing Station Waste Disposal Practices and Programs" was presented by B. L. Schmalz at the Second AEC Working Conference, September 1961, Chalk River, Canada.

(6) A talk entitled "Radioactive Waste Handling at the National Reactor Testing Station" was given by B. L. Schmalz at the Eighth Annual Naval Nuclear Sciences Seminar held in Idaho Falls, Idaho, August 1961.

VIII. ECOLOGY
(Z. M. Fineman - Branch Chief)

1. SCOPE

The work of the Ecology Branch consists of three inter-related phases: biological monitoring, radiobiology and ecology. The principal phase, biological monitoring, constitutes a continuous background measurement of radioactive contaminants deposited in the environment around the operational areas and extending to the perimeter and adjoining lands. Radioactivity levels of materials in food chains ultimately destined for human food products also are measured. Radiobiological studies are aimed mainly at improving the accuracy and developing new techniques of measurements in areas where direct methods cannot be employed. In this field, concentration factors and air-plant-animal activity ratios are determined and improved. Some of these relationships are so complex that preliminary studies in applied ecology must be done. They include food habits of the concentrating animals, their population composition and density, long term variations in populations of jackrabbits and coyotes, and density and current growth of plants.

2. SUMMARY OF MAJOR PROGRAMS

2.1 Biological Monitoring

2.11 Routine Programs (Zola M. Fineman)

Strontium-90 Monitoring. Environmental strontium-90 contamination since 1956 has been evaluated by the strontium-90 concentrations in the tibia and femur bones of jackrabbits. In 1960 and 1961 quarterly collection of bones were made at 33 stations in on-site, perimeter, and off-site areas (Figures 50 and 51). Two rabbits were collected, if possible, every quarter at each station. The 1960 and 1961 results are summarized in Table XXXVI.

The results for the three CPP stations (on-site areas) are reported separately. These stations are in the areas that have been slightly contaminated since 1958. The differences among stations in the other three areas were generally not significant, so that the stations within each area were combined for analysis purposes. Strontium-90 concentrations in the three CPP areas during 1961 displayed little reduction from that observed in 1960. The 1961 means for off-site, perimeter, and on-site (nine stations) areas were approximately 40% less than the 1960 means. These results indicate a decrease in environmental strontium-90 contamination levels. Strontium-90 levels in these areas, since 1956, have followed a trend attributable to worldwide fallout. The 1961 results, like those in previous years, do not indicate a contribution of NRTS operations to off-site strontium-90 contamination levels.

In the use of the jackrabbit as an indicator of environmental strontium-90 contamination, differences in age of rabbits were not taken into account as no practical or feasible method of aging jackrabbits was available. Since the fall of 1959, the dry eye lens weight method has been successfully employed to classify jackrabbits into three year-of-birth groups. An analysis of the

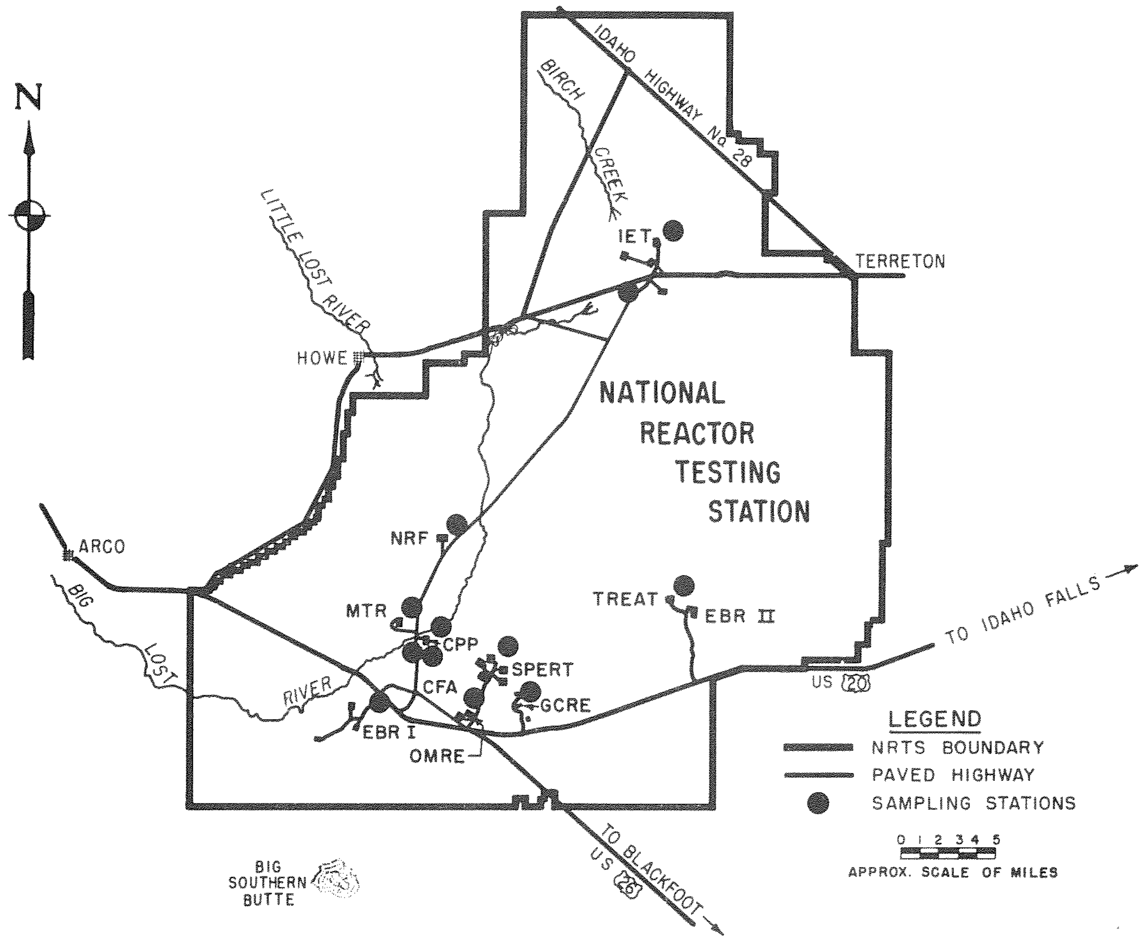


Fig. 50 On-site biological monitoring stations.

strontium-90 concentrations in jackrabbits born in different years is presented in Table XXXVII. Distinct differences in strontium-90 concentration were obtained between rabbits born in different years. Analyses of each age group from quarter to quarter indicated that the strontium-90 level in a jackrabbit is primarily that established in its first year of life. Young-of-the-year rabbits are, therefore, the most sensitive bio-indicators of the existing strontium-90 contamination level.

An assessment of the environmental strontium-90 contamination existing between November 1959 and October 1961, based solely on young-of-the-year rabbits is presented in Table XXXVIII. The strontium-90 concentrations of the 1959 young-of-the-year rabbits provide an assessment of the strontium-90 concentration levels existing from the spring of 1959 to the spring of 1960. Similarly, 1960 and 1961 young-of-the-year rabbits provide assessments for their respective first years in the field. It is evident from the yearly strontium-90 averages in Table XXXVIII, that the strontium-90 levels in on-site, perimeter, and off-site areas, were higher by at least a factor of two in 1959 than in 1960. The 1961 levels were about 20% higher than 1960 levels. These results are markedly different than the results obtained when the assessment was made by combining rabbits of all ages. The results are in better agreement with those expected from the trend in strontium-90 fallout from 1959 through 1961 than the results

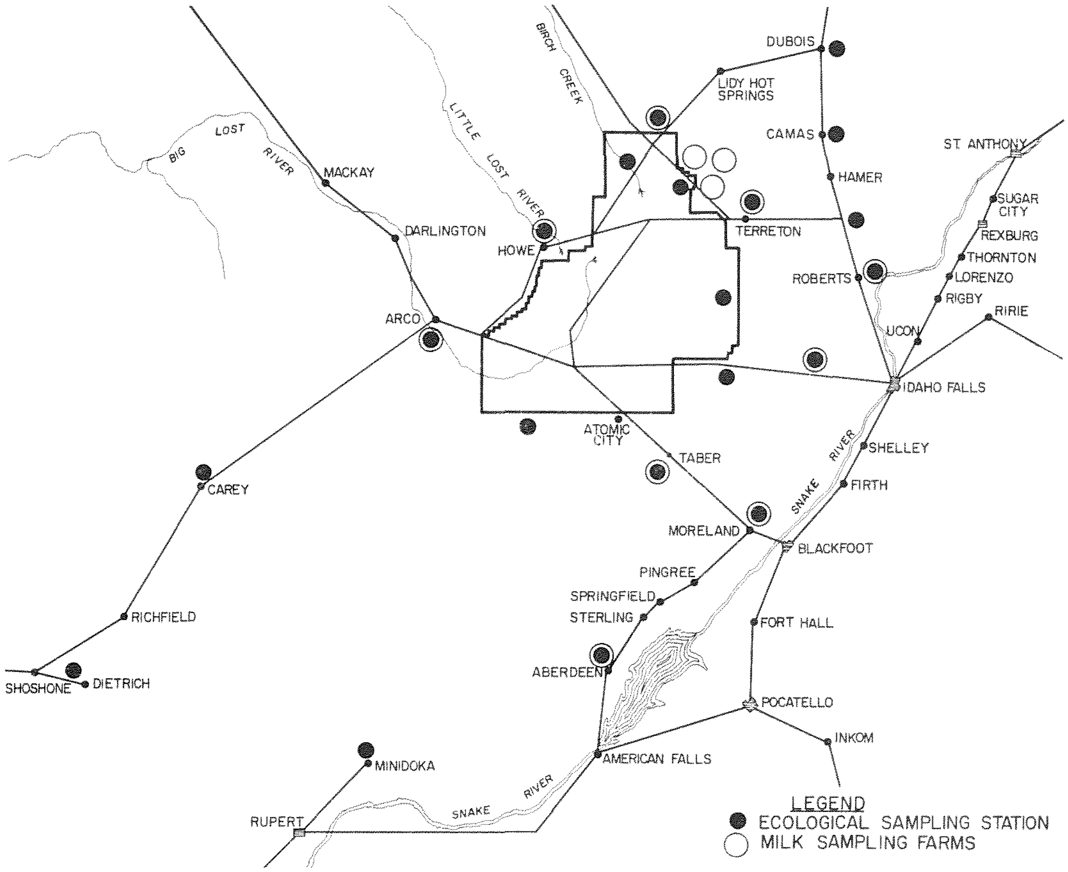


Fig. 51 Perimeter and off-site biological monitoring stations.

Table XXXVI

STRONTIUM-90 CONCENTRATIONS IN JACKRABBIT BONES IN 1960 AND 1961

		Sr-90 Concentration (pc/g calcium)			
		1960		1961	
Area	No. of Stations	Sample Size	Average	Sample Size	Average
Off-site	12	94	15.2	85	10.6
Perimeter	8	47	15.3	45	10.8
On-site	9	61	17.1	51	13.1
CPP, NE	1	7	47.0	10	51.8
CPP, SW	1	7	44.6	12	39.9
CPP, SE	1	10	185.2	10	316.6

Table XXXVII

STRONTIUM-90 CONCENTRATIONS IN BONES OF 4 AGE GROUPS OF JACKRABBITS

		Sr-90 Concentration (pc/g calcium)							
		1958[a]		1959[a]		1960[a]		1961[a]	
Area	No. of Stations	Sample Size	Avg	Sample Size	Avg	Sample Size	Avg	Sample Size	Avg
On-site	9	28	22.0	23	24.4	57	9.4	8	11.4
Perimeter	8	18	18.5	39	17.5	31	6.9	12	11.1
Off-site	12	25	19.4	57	17.6	66	9.1	35	9.4
Total	29	71	20.2	124	19.1	154	8.8	55	10.3

(a) Year of birth

Table XXXVIII

STRONTIUM-90 CONCENTRATIONS IN BONES OF YOUNG-OF-THE-YEAR JACKRABBITS

		Sr-90 Concentration (pc/g calcium)					
		1959[a]		1960[a]		1961[a]	
Location	No. of Stations	Sample Size	Avg	Sample Size	Avg	Sample Size	Avg
Off-site	12	10	19.3	52	8.5	35	9.5
Perimeter	8	7	16.2	19	7.1	12	11.1
On-site	9	5	31.9	37	8.1	8	11.3
CPP, NE	1	2	123.4	4	36.3	4	42.5
CPP, SW	1	1	70.5	4	32.2	5	27.2
CPP, SE	1	1	6305.1	5	37.8	6	430.1

(a) Young-of-year

obtained when using jackrabbits of all ages. In the future, the assessment of environmental strontium-90 contamination will be based on young-of-the-year rabbits.

The strontium-90 programs with native and domestic animal bones were initiated in 1956. With the exception of the jackrabbit, the native animal program has been maintained on a modest scale. Cattle bone sampling between 1956 and 1959 consisted of two samples per month from Roberts (twenty miles east of the NRTS) and Shelley (twenty-five miles east-southeast of the NRTS). In the fall, bones of deer, elk, and antelope were secured from different localities and different elevations. The bones were obtained from hunters and local game officials. Coyote bones were the by-product of the NRTS predatory animal control program. The average strontium-90 concentration in the bones of six species of animals during the six-year period, 1956-1961, is shown in Table XXXIX. Except for the coyote the highest strontium-90 in all species was observed in 1959. For all species, the 1957 mean was less than the 1956 mean. The peak strontium-90 concentration in 1959 was followed by an abrupt decline in 1960, and a further decline in 1961. The data in Table XXXIX, suggest an increase in fallout with altitude, as the mountain species, deer, and elk, had strontium-90 concentrations that were greater than those of animals from lower elevations. The omnivorous coyote had a lower strontium-90 concentration than the big game animals.

Jackrabbit Thyroid Iodine-131. The jackrabbit has been used as a bio-indicator of environmental iodine-131 contamination since 1955. Thyroid iodine-131 activity has been shown to vary directly with vegetation and effluent release levels. The jackrabbit thyroid iodine-131 activity means for the four quarterly surveys in four areas are shown in Table XL. The first and fourth quarter

Table XXXIX

STRONTIUM-90 CONCENTRATIONS IN NATIVE AND DOMESTIC ANIMAL BONES

	Sr-90 Concentration (pc/g calcium)									
	Cattle		Jackrabbits		Antelope		Deer and Elk		Coyotes	
Year	Sample Size	Average	Sample Size	Average	Sample Size	Average	Sample Size	Average	Sample Size	Average
1956	17	10.4 ± 1.7	100	15.4 ± 0.8	4	14.4 ± 4.9	6	23.0 ± 4.9	2	7.2 ± 0.1
1957	26	10.1 ± 1.1	43	11.8 ± 0.5	6	7.9 ± 0.8	2	11.2 ± 6.4	1	3.2
1958	37	12.1 ± 0.9	27	16.3 ± 0.9	10	9.1 ± 0.9	8	20.5 ± 2.1	20	10.0 ± 1.2
1959	37	16.8 ± 1.2	17	17.8 ± 1.7	7	31.1 ± 5.2	6	30.4 ± 4.2	16	11.0 ± 1.2
1960	8	9.9 ± 1.9	8	14.3 ± 2.4	14	13.6 ± 1.7	6	17.4 ± 4.0	8	11.2 ± 1.8
1961	4	8.6 ± 2.2	8	12.4 ± 2.1	9	8.9 ± 1.8	4	20.9 ± 0.8	5	6.0 ± 2.3

Table XL

IODINE-131 ACTIVITY IN JACKRABBIT THYROIDS IN 1961

		I-131 Activity (μc/g thyroid x 10^{-4})							
		Mar. 1-Apr. 13*		June 1-16*		August 7-17*		October 2-19*	
Area	No. of Stations	Sample Size	Avg	Sample Size	Avg	Sample Size	Avg	Sample Size	Avg
CPP, on-site	3	3	29.66	8	5.0	12	3.86	7	28.69
Other, on-site	9	19	17.92	19	0.04	14	0.35	12	22.30
Perimeter	7	12	12.68	16	0.21	12	0.01	11	49.34
Off-site	12	25	2.58	30	0.11	25	0.09	24	35.27

* Collection period

means in all areas are significantly higher than the second and third quarter means. The higher first quarter means, like those of vegetation (Table XL), resulted from iodine-131 released primarily from SL-1 and ICPP. The off-site and perimeter means during the second and third quarters indicate extremely low levels of iodine-131 contamination on vegetation. Russian weapon test fallout resulted in a drastic rise in the thyroid iodine-131 activity of jackrabbits from all areas. Except for the SL-1 release in the first quarter, bio-assessment of iodine-131 contamination in perimeter and off-site areas was indicative of very low levels of iodine-131 attributable to NRTS operations.

Vegetation Sampling. The gross gamma activity means of the sagebrush (Artemisia tridewtata) samples for four quarters and six areas are presented in Table XLI. The means of the alfalfa collected from the milk sampling farms during the summer months are also given. The first quarter samples were collected from March 21 to April 13, at a time when activity levels from the SL-1 release were much reduced. The means of the perimeter and off-site areas during the first quarter are slightly higher than the second and third quarter means, and represent background values. The gross gamma activity of sagebrush samples increased greatly in the fourth quarter. The increase was due to fallout from the Russian weapon tests. Except for the activity attributable to SL-1 effluent, the gross gamma activity of perimeter and off-site vegetation are indicative of very little contribution from NRTS operations. During the summer months the background level of gross gamma activity of the alfalfa samples was associated with the nondetection of iodine-131 in milk.

Milk Samples (Donald Adams). Milk samples were collected monthly for iodine-131 analysis from the 12 perimeter farms shown in Figure 51. Milk samples of 900 milliliters were screened for iodine-131 activity in a gamma well scintillation counter. Gamma spectrum analysis was used to confirm iodine-131 activity. Detection methods were improved during the

Table XLI

GROSS GAMMA ACTIVITY OF VEGETATION SAMPLES

			Gross Gamma Activity (c/m/g)			
Type	Location	No. of Stations	First Quarter	Second Quarter	Third Quarter	Fourth Quarter
Sagebrush	Off-site	12	4.6	2.9	2.8	141.2
Sagebrush	Perimeter	8	3.1	2.4	2.5	101.8
Sagebrush	On-site	9	11.0	2.7	4.4	98.6
Sagebrush	CPP, NE	1	13.0	6.0	10.0	147.0
Sagebrush	CPP, SW	1	12.0	4.0	6.0	155.0
Sagebrush	CPP, SE	1	—	15.0	8.0	88.0
Alfalfa	Off-site	9	—	—	1.3	63.9
Alfalfa	Perimeter	3	—	—	0.8	46.5

second half of the year which lowered the detection limit from 2.0 x 10^{-7} to 5.0 x 10^{-8} microcuries per milliliter. To lower the detection limit the counting time was increased from 10 to 50 minutes. The highest concentrations of iodine-131 observed in raw milk occurred during September in samples collected from cows on pasture. This activity is attributed to the atmospheric weapons tests being conducted by the Russians. The results of the 1961 liquid milk sampling program are reported under environmental monitoring.

Weekly dried milk samples collected at a local dairy were a composite of the Upper Snake River Valley's milk production. Samples of 500 grams were counted in a gamma well scintillation counter for iodine-131 activities. Iodine-131 concentrations are more easily detected in powdered milk than raw milk because of the concentration factor of 10 to 1. Analytical methods were improved in the last half of the year to lower the detection limit from 2.0 x 10^{-7} to 8.0 x 10^{-8} microcurie per gram. Increases of iodine-131 activities in powdered milk samples from September through December are attributed to the Russian tests.

2.12 Non-routine

SL-1 Accident (Ray McBride and Donald Adams)

(1) Introduction - The emergency biological monitoring program for the SL-1 incident followed a general plan that had been developed during the previous three years for scheduled and non-scheduled releases from NRTS operations. The plan is outlined below:

Wind direction and velocity during the release are obtained from the U. S. Weather Bureau, NRTS.

Crosswind sampling arcs are established at geometric distances downwind from the release point. The distance between sampling stations on an arc is approximately one-tenth of the downwind distance.

Samples of sagebrush are collected along these arcs in the order of their distance from the release point. Sagebrush samples weigh approximately 200 grams, and consist of the current season's leaves and flowers from 10 to 15 plants in a 100-foot square.

Sagebrush samples from the first downwind sampling arc are collected and analyzed, as rapidly as possible, for gross gamma activity to determine whether the deposition pattern agrees with meteorological predictions and whether changes in sampling techniques at further downwind distances are necessary.

Collection and analysis of milk samples in the off-site deposition area is usually started 24 to 36 hours following a release.

The iodine-131 in the jackrabbit thyroid after a single release reaches a maximum five to ten days after the initial deposition. Jackrabbit thyroids usually are collected 10 days after a release.

(2) Sagebrush Sampling for General Deposition Pattern - The U.S. Weather Bureau, NRTS, reported winds from the northeast at approximately six miles per hour during the evening of January 3 and the morning of January 4. Sagebrush sampling started at 6:55 a.m. on January 4, one mile south of SL-1 on Highway 20, and samples were collected from downwind arcs approximately one mile and four miles south of the SL-1 area on this date. All samples were gamma counted in a thallium-activated sodium iodine well counter. Gamma spectra of representative samples indicated that the activity was due to iodine-131. The plotted activity of the January 4 samples confirmed that the released material was distributed in a southerly direction with the highest activity south and southeast of SL-1. Results of vegetation samples taken on January 6, north and northeast of the SL-1 area (Figure 52)

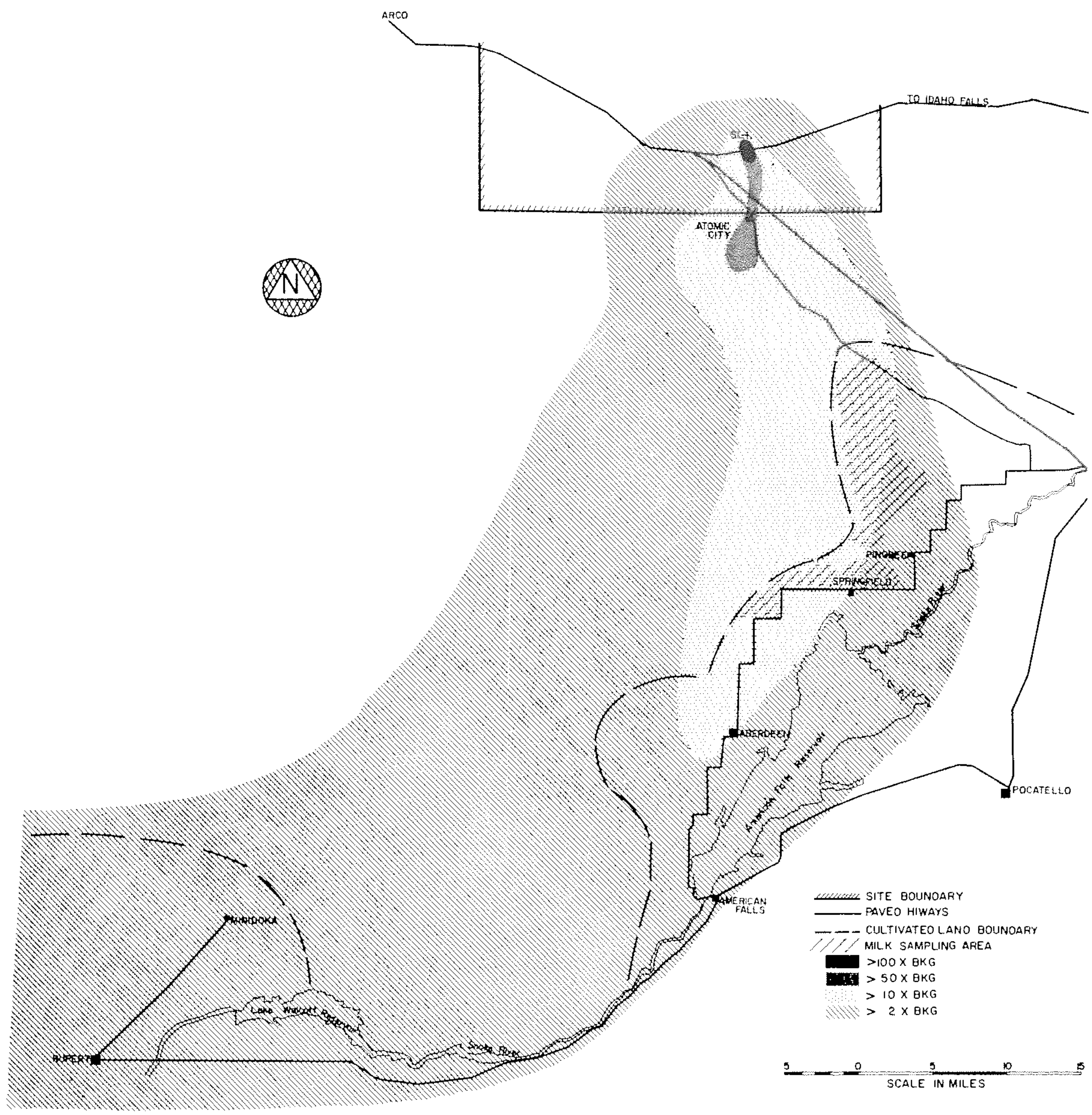


Fig. 52 Iodine-131 deposition on vegetation.

verified that the general deposition pattern was south and southeast of SL-1. Additional samples were collected on January 5 and 6 from arcs approximately 8 and 18 miles south of the SL-1 area. The maximum activity on these arcs was south-southeast of the SL-1 area. Since the results of all sampling through January 8 indicated that the effluent had been carried in a southerly direction, sagebrush samples were collected along highways south of the NRTS from Moreland to Shoshone. Vegetation samples were also collected from dairy farms in the Taber area.

Results of resampling on the one-mile arc along Highway 20, on January 9, showed increased activity over that obtained on January 4 and indicated a continuing or subsequent release from the SL-1 area following the initial deposition.

The results of resampling the eight-mile arc on January 11 indicated that the activity level had increased approximately 50% over that determined on January 5. Results from the off-site area north of Aberdeen and west of Springfield verified the activity levels found on January 9. Also on January 11, the eastern and southern boundaries of the deposition pattern were generally established by sampling along the highway from Blackfoot to Pocatello to American Falls, and to Rockland. Samples collected east of the SL-1 area on Highway 20, January 16, indicated additional radioactive material had been deposited east of the area after the January 9 survey.

From the results of sagebrush sampling from January 4 to January 11, a general deposition pattern for iodine-131 was plotted and is presented in Figure 52. The western boundary of the irrigated farming area is shown by a dotted line. Because virtually no passable roads or population were present in the area west of this line, sagebrush samples were not collected there.

After January 11, sagebrush sampling was restricted primarily to areas west, north, and east of SL-1. However, sampling in these areas and check resampling in the area south of SL-1 indicated no major change in the general deposition pattern, except for increased levels of activity. Sagebrush sampling from January 23 to February 3 in an array of 10 stations around and within a mile or two of SL-1 indicated that the gross gamma activity of the vegetation reached a peak on January 24 or 25. After January 25, there was a steady decline in the gross gamma activity of the sagebrush in the SL-1 area.

(3) Jackrabbit Sampling - The iodine-131 activities in jackrabbit thyroids before and after the SL-1 accident are presented in Table XLII. The fourth quarter survey thyroids collected in December 1960 indicate the low levels of thyroid iodine-131 activity that were present before the accident. The thyroid iodine-131 activities in Table XLII agree very well with the general deposition pattern based on sagebrush iodine-131 shown in Figure 52, and with sagebrush iodine-131 activity after January 11. The data also confirmed that the distribution of effluent was mainly

Table XLII

JACKRABBIT THYROID IODINE-131 ACTIVITY
BEFORE AND AFTER SL-1 ACCIDENT OF JANUARY 3, 1961

General Area	Location In Relation to SL-1		Date Collected	Sample Size	Iodine-131 Activity ($\mu c/g \times 10^{-2}$)
	Direction	Distance			
SL-1	Northeast	1 mi	Dec., 1960	1	00.01[a]
SL-1	SL-1 area	SL-1 area	Feb. 8, 1961	1	75.67
SL-1	SL-1 area	SL-1 area	Feb. 27, 1961	5	21.28
SL-1	North-northeast	5-6 mi	Jan. 30, 1961	3	00.94
Atomic City	South	4 mi	Jan. 12, 1961	2	12.56
Atomic City	South	4 mi	Feb. 1, 1961	1	18.43
Atomic City	South	4 mi	Feb. 28, 1961	2	4.08
Taber	South-southeast	15 mi	Dec., 1960	2	0.01[a]
Taber	South-southeast	15 mi	Jan. 13, 1961	4	6.10
Taber	South-southeast	15 mi	Jan. 27, 1961	3	6.61
Moreland	Southeast	25 mi	Dec., 1960	1	0.01[a]
Moreland	Southeast	25 mi	Jan. 14, 1961	1	0.17
Springfield	South-southeast	30 mi	Jan. 14, 1961	3	1.12
Aberdeen	South	39 mi	Dec., 1960	2	0.01[a]
Aberdeen	South	39 mi	Jan. 8, 1961	2	0.87
Aberdeen	South	39 mi	Jan. 14, 1961	2	0.75
CPP, NRTS	West-northwest	10 mi	Jan. 3, 1961	2	0.02[a]
CPP, NRTS	West-northwest	10 mi	Jan. 25, 1961	2	0.55
CPP, NRTS	West-northwest	10 mi	Feb. 2, 1961	2	0.65
CPP, NRTS	West-northwest	10 mi	Feb. 28, 1961	2	0.07
Howe	Northwest	20 mi	Jan. 23, 1961	1	0.26

(a) Background levels.

in a southerly direction. Thyroid iodine-131 activity increased until late January or early February. By the end of February thyroid iodine-131 levels were still well above background levels and did not reach background levels until the end of May.

Bio-assessment of strontium-90 contamination in the general deposition pattern area was accomplished by the collection of jackrabbits at monthly intervals. Only the jackrabbits collected within one mile of SL-1 had strontium-90 activities above background levels. Strontium-90 activities that were 20 times background levels were observed in jackrabbit bones collected in June about one-half mile southwest of SL-1. The 1961 bio-assessment for environmental strontium-90 in the SL-1 deposition pattern indicated no off-site deposition of strontium-90.

(4) Milk Sampling - Milk sampling was started on January 4. Between January 4 and 19, 28 milk samples were collected from five farms in the Taber area (Figure 52). One farm was located at Taber and the remaining four farms were eight miles south of Taber. These farms with dairy cows were located nearest to the southern boundary of the NRTS. The results of the milk-sampling program through January 19 are presented in Table XLIII. Six of the 28 samples showed gross gamma activity slightly greater than three standard deviations of the net count. The remainder of the samples showed no detectable activity under the conditions used for counting, which were capable of detecting 2×10^{-7} microcuries of iodine-131 per milliliter.

Two 50-pound powdered milk samples were obtained from an Idaho Falls dairy. One sample was of milk collected on January 4, 5, and 6 and the other of milk collected on January 7, 8, and 9. The samples were from milk collected throughout the Upper Snake River Valley. Iodine-131 was not detected in either sample at the detection limit of 2×10^{-7} microcuries per gram.

The results of milk-sampling program confirmed that any iodine-131 present in milk, as a result of the SL-1 incident,

Table XLIII

IODINE-131 ACTIVITY IN MILK FOLLOWING THE SL-1 ACCIDENT

	Iodine-131 Activity (pc/l)				
Date	Taber[a]	7.7 mi S, 1.5 mi E of Taber[a]	10 mi S, 1 mi E of Taber[a]	10 mi S of Taber[a]	10 mi S, 3 mi W of Taber[a]
Jan. 4	0	0			
Jan. 5	0	0			
Jan. 8	174 ± 54	178 ± 54	0	0	0
Jan. 9	0	0	0	0	0
Jan. 10	268 ± 54	0	0	183 ± 54	0
Jan. 11	285 ± 54		165 ± 54	0	0
Jan. 19	0	0		0	0

(a) Farm location.

was well below the Radiation Concentration Guide of 2×10^{-6} microcuries per milliliter for non-occupational exposure. Low iodine-131 levels in milk were expected because dairy cows are fed baled hay and are not on pasture during this time of the year.

(5) Sheep Thyroid Iodine-131 - A large herd of sheep was grazed one mile south of Atomic City between January 4 and March 15. On January 23, two sheep were purchased and their organs and tissues analyzed for radioisotopes. A ewe that had been killed by coyotes was obtained on February 1. The iodine-131 activity of the three sheep and the two foeti of one ewe are presented in Table XLIV. The iodine-131 activity of jackrabbit thyroids collected near Atomic City are included for comparison. The sheep fed almost exclusively on Russian thistle which had an iodine-131 activity of 1.5×10^{-4} microcuries per gram. The iodine-131 activities of sheep and jackrabbit thyroids from the Atomic City area were essentially alike. This result was expected as the jackrabbit's grazing habits are similar to those of sheep.

(6) Rodent Thyroids - Jackrabbits and deer mice were collected from a sagebrush area about four miles south of SL-1 and one mile north of Atomic City for monitoring purposes during the last two weeks of January 1961. On January 31, a 14,000-foot transect on a line from SL-1 to Atomic City was trapped for mice. Gross gamma thyroid activity, considered to be iodine-131, attenuated by two to one from the near stations to the far ones. Ratios of thyroid activity, iodine-131, from rabbits and mice in the area about one mile north of Atomic City corrected to January 17 show: jackrabbits 0.12 microcurie per gram, and deer mice 0.10 microcurie per gram of thyroid tissue.

Table XLIV

SHEEP AND JACKRABBIT THYROID IODINE-131 ACTIVITY IN THE ATOMIC CITY AREA SIX MILES SOUTH OF SL-1

	Sheep		Jackrabbit	
Type	Date	I-131 Activity ($\mu c/g \times 10^{-2}$)	Date	I-131 Activity ($\mu c/g \times 10^{-2}$)
Ewe	1-23-61	7.50		
Ewe, foetus	1-23-61	11.30	1-12-61	12.6
Ewe, foetus	1-23-61	6.90		
Ewe	1-23-61	14.70		
Ewe	2-1-61	5.67[a]	2-1-61	18.4

(a) Killed by coyotes and probably sick.

(7) Soil Sampling - The program was undertaken to determine the distribution and concentration of radioisotopes deposited on the surface soils outside the SL-1 fenced area (Figure 53). Surface soil samples to a depth of a half inch and one foot square were collected on January 25 and February 14. Thirty-eight samples were collected on eight radials at distances of 300, 600, 1200, 1800, and 2400 feet from the reactor. All samples were corrected for decay to January 25. Gamma spectrometric analyses were made on aliquots of samples. Aliquot size varied inversely with activity present. The following isotopes were detected by gamma spectrometric analysis: iodine-131, lanthanum-140, zirconium-niobium-95, cesium-137, ruthenium-106, and cerium-144. Others may have been present but were not detected. A plot of the iodine-131 activities gave the deposition pattern shown in Figure 53. This deposition pattern, like the one for sagebrush in Figure 52, extends in a southerly direction.

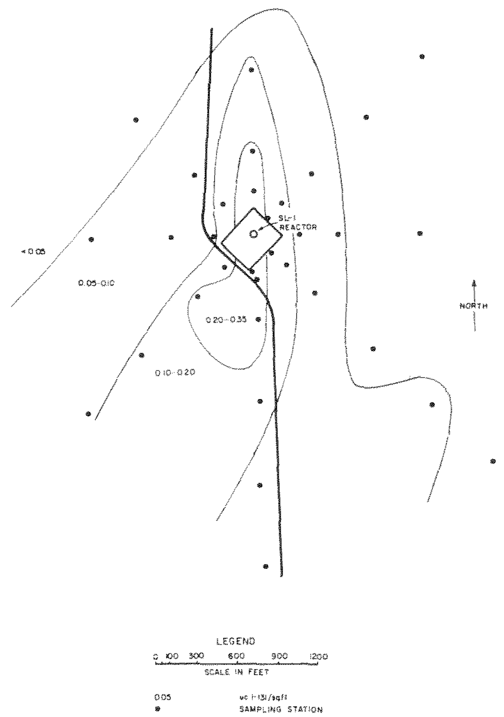


Fig. 53 Iodine-131 deposition pattern outside SL-1 fence area, January 25, 1961.

Aquatic Vegetation in Effluent Streams, OMRE-GCRE. Monthly samples were taken from the effluent streams from OMRE-GCRE during the summer of 1961. These consisted of plants found growing within the stream proper. A small soil sample was taken from the area immediately adjacent to the water in the settling pond. These samples, with the exception of a silica gel precipitate, were oven dried at 80°C and weighed. Counts were made in a well counter for gross gamma activity. Gamma scans of hot samples showed the activity to be mainly cobalt-58 and cobalt-60. Counts from OMRE samples were negligible. The highest count from GCRE was from a crustose algae with a maximum of 23,000 c/m/g. The survey was concluded in August. A statistical summary of the biological monitoring program is presented in Table XLV.

2.2 Radioecology (John B. Echo)

2.21 Radiostrontium Metabolism in Wild Jackrabbits. While scheduled releases of radioisotopes to the environment are routine in the vicinity of operational plants on the NRTS, the levels of contamination in these areas are often too low for direct measurement. The biological concentration of these contaminates in the organs and tissues of the jackrabbits living in the area offers a method of measurement if the magnitude of the concentration can be determined.

During the winter and summer months of 1960, wild jackrabbits were live-trapped, given a gelatin capsule containing strontium-85, released, and subsequently retrapped and examined. Only skeletal components were radiologically assayed.

Table XLV

SUMMARY OF BIOLOGICAL MONITORING SAMPLES
COLLECTED AND ANALYZED DURING 1961

		Isotopic				Gross Gamma		
Types of Samples	Collected	Spectro-metric Analysis	I-131 Thyroid	Sr-90 Bone	Cs-137 Muscle	Indi-vidual Organs	Whole Body	Total
Jackrabbit	413	17	408	236	51	49	—	761
Predator	16	—	16	6	—	—	—	22
Small rodents	22	—	13	—	—	—	16	29
Cow & sheep	7	7	5	4	2	10	—	28
Birds	3	2	1	1	—	—	2	6
Deer & antelope	14	—	14	13	—	—	—	27
Soil	180	50	—	—	—	—	180	230
Milk & milk products	431	19	—	—	—	—	431	450
Snow & water	18	5	—	—	—	—	18	23
Vegetation	777	46	—	—	—	—	777	823
Total	1881	146	457	260	53	59	1424	2399

With data from the 1960 annual report [4] and a concurrent jackrabbit food habit study, an attempt was made to correlate strontium-90 in the jackrabbit skeleton and environmental strontium-90 contamination levels. The sample jackrabbit bone is analyzed for radio strontium in picocuries (Qt). Estimation of food contamination (Q_o) in picocuries is found from the expression

$$Q_o = \frac{Qt\ (1-n)\ 0.37}{t^{(1-n)} - 1}$$

The n is the decay slope (avg. 0.3) and t is the number of days on contaminated food. The number 0.37 is an experimental factor relating the amount of food eaten per day to the amount of skeletal calcium. In an experiment relating the strontium-90 activity of samples of rabbit food and the rabbits collected in the same area, agreement was within 20%.

2.22 Radiocesium Metabolism in NRTS Jackrabbits. During the summer of 1961 wild jackrabbits were live-trapped, given a gelatin capsule containing 0.48 microcurie of cesium-134, released, and subsequently retrapped and examined. Thirty rabbits were recovered for analysis. Cesium-134 was deposited mainly in muscle tissues. This tissue was assayed by gamma counting to determine uptake and release of cesium-134.

After analysis the activity per gram of muscle tissue was calculated and plotted on semi-log paper. The activity on any day (A_t) for any day (t) can be calculated from the expression $A_t = A_o e^{-0.11t}$.

Laboratory rabbits of the "Dutch" variety were used in conjunction with the wild jackrabbit studies. They were used to test relationships not readily amenable to study in the wild.

The age of the sample jackrabbits were determined by the dry lens method. There was no significant discernible difference due to age at the 95% confidence level. However, two Dutch rabbits, two months and one year of age, were given oral doses of one microcurie cesium-134, and counted alive in a gamma spectrometer every day for 36 days. At the end of this time there was a small significant difference in their body burdens of cesium-134.

A mature female Dutch rabbit was given one microcurie of cesium-134 orally, and immediately bred. After 33 days, she had retained 5.6% of the initial dose and each of eight young had 6% of the mother's body burden after parturition.

2.23 Biology of Settling Ponds at MTR-ETR. The objective of this study is to determine the influence, if any, of settling pond biota on radioactive waste disposal to the environment, particularly in the modification of the composition of the biological material present.

A 9- x 9-foot sampling raft was made for each pond. Samples were taken through a two-foot-square hole in the raft center. A Kemmerer water sampler was used for liquid samples and an Ekman dredge was used for bottom samples. Microorganisms were collected with a number 20 silk plankton net. Samples of sludge, water, and plankton were taken monthly over the summer.

Shortly after the study began the pH of the pond water dropped to around 2.9 and remained in this range. Planktonic microorganisms were very scarce and algal growth was negligible. Analysis of the bottom sludge in the Analysis Branch laboratories showed this to be composed mainly of silica gel. These deposits approach 50% coverage of the basin and are more than six inches thick in some places. Laboratory cultures of algae from these ponds will be tested for selective adsorption of isotopes.

2.24 Aging Jackrabbits from their Dry Eye Lens Weights (Zola M. Fineman) The strontium-90 content of animal bones varies with age, as uptake and retention decrease with age. In order to determine the effect of age on the strontium-90 content of jackrabbit bones, a method of aging rabbits was needed. In 1959 Lord's method of aging cottontail rabbits from their dry eye lens weights was adopted for use with wild jackrabbits. Between November 1959 and October 1961, the dry eye lens weights of 780 rabbits were determined. Young-of-the-year rabbits were collected for the first time in June. The frequency distributions for the young rabbits are distinct from those of the older rabbits until March when they start to merge. Complete merging of the frequency distributions of young and old rabbits is accomplished by October. The distinct breaks between the frequency distributions of young and old rabbits for nearly a year, provide a method of dividing collections of rabbits into two age groups: (a) young-of-the-year and (b) older rabbits. The 1961 results were similar to those obtained in 1960. The combined data will be analyzed statistically to obtain a growth rate curve and an estimate of the variation in dry lens weight among rabbits of the same age. The analysis will be restricted to a truncated portion of the distribution frequencies which contain only rabbits of known age.

2.25 Jackrabbit Food Habits (William E. Saul). A reference collection of a wide variety of short-lived green annuals as well as perennial forbes was made during the 1960 growing season. A year-round collection of stomach samples also was made. During the summer of 1961 an effort was made to analyze the stomach contents from current and reference collections of jackrabbits. It was found that jackrabbit food plants could be identified by microscopic examination and that relative abudance could be determined in nearly all cases. Several schemes of analysis were tested and analysis time reduced to about two hours per stomach sample. In late August a study area of 110 acres was selected and extensive vegetation surveys made of the available plants. Sixteen jackrabbits were collected at the same time in this area and their stomach contents analyzed.

Big sagebrush is the dominant plant in the area. Grass and prickly pear are available but widely scattered. Rabbit and horse brush are present in trace amounts only. Russian thistle is available in small quantities along the edge of part of the area. Analysis showed Russian thistle and prickly pear to be the major items of food with lesser amounts of grass and rabbit brush. Very little sage was eaten. This study continues, to develop a year-round relationship between the plant material available and those selected for food by the jackrabbit. In this way correlations can be made between levels of radioactivity in the sample jackrabbit and those of the contaminated food plants in his environment.

2.26 Vegetation Studies (Ray McBride). Vegetation coverage of the NRTS area varies in both species composition and density within species. To better evaluate various situations of biological monitoring and long range ecological studies, a three-species type inventory is desirable. The basic work on the 1954 aerial photos and the necessary field surveys have been completed. Location of the type lines on the area base map is now 75% complete. The 1957 line transect data have been tabulated and are being used as a refinement and addition to the original 1950 preoperational ecological survey.

Nine different species of plants were surveyed on seven different plots during June and July of 1961. In general, cover due to current season's growth was about 15% less than in 1960, with grasses making less growth than the broadleaf plants.

2.3 Predatory Animal Control (Ray McBride)

During 1961, under contract AT(10-1)1039, with the U. S. Department of the Interior, Fish and Wildlife Service, and Bureau of Sport Fisheries and Wildlife, the following work was carried out: A fulltime employee maintained 450 coyote getters (cyanide guns), 40 poison-bait (1080) stations, and about 110 steel traps inside the NRTS boundary. A total of 175 coyotes and 18 bobcats was taken by the above methods. Records were kept of the date and location of kill and the sex and age of each animal. During the year 17 mature plus 69 immature females, and 20 mature plus 71 immature male coyotes, were taken. Of the bobcats, 11 were females and 7 were males. Two aircraft flights over the site in May resulted in shooting of eight mature coyotes. A total of 183 coyotes and 18 bobcats was killed under this contract. The Ecology Branch personnel recovered eight coyotes and five bobcats that had been either shot by Security Guards or were killed accidently by automobiles.

2.4 Noxious Weed Control (Ray McBride)

Control measures for the year consisted mainly of the reseeding of disturbed areas, both old and new, to crested wheatgrass (agropyron disertorum). The use of soil sterilizer was kept to a minimum and was used only within the fenced areas around buildings, parking lots, and heavily gravelled areas. Excessive weed growth along roadways was removed by mowing. The Ecology Branch personnel gave technical assistance for all work. Reseeding was done on 30 acres along the new road from SPERT to GCRE, 95 acres along East Portland Avenue, 180 acres along Highway 20 from the junction to EBR-II, 215 acres along Lincoln Boulevard, and 34 acres along the Central Monument road.

3. FUTURE PROGRAMS 1962

3.1 Biological Monitoring

The contribution of NRTS effluent to background levels of radioactivity, on-site and off-site, will be quantitatively evaluated by a comprehensive program of sampling at perimeter agroecological, off-site agricultural, and on-site ecological stations. A maximum of correlatable data will be gained by sampling at agroecological stations where native and domestic animals, plants, and milk are available in close proximity. Simultaneous sampling in on-site and off-site areas will permit cross comparisons of areas not containing the same types of biological samples. The program will provide data on two important food chains: vegetation strontium-90 to milk strontium-90 and vegetation strontium-90 to jackrabbit strontium-90.

3.2 Biological Availability of Radioisotopes in Calcined Wastes

The waste calciner at ICPP transforms fission products in solution by rapid evaporation into dust size particles of dry matter. The isotopes, strontium-90, cesium-137, and others, will be imbedded in the matrix of the particles. If any of these particles should escape from the calciner, they will be deposited eventually on plants and soil. They may enter the food chain through absorption by the roots and leaves of plants or by direct ingestion from plant tissues by animals. The metabolic availability of waste calcine strontium-90, cesium-137, and others, will be proportional to the amount made available by the digestive processes. Similarly, the absorption by plants will depend on their availability through soil chemistry and biological action. The potential health hazard of waste calcine radioisotopes will, therefore, depend to a great extent on their biological availability. An attempt will be made to determine this availability through laboratory and field experiments with plants and animals.

3.3 Monitoring With Small Mammals

Deer mice and chipmunks make their home in the sagebrush habitats which cover most of the NRTS. These with the jackrabbit and coyote represent the major animal residents on the Snake River Plain. These animals concentrate in their body tissues radioisotopes from their diet. The best is the jackrabbit and in most cases it is the animal used to determine levels of radiocontamination too low to measure directly. However, sample rabbits are not always available where and when they are needed. Also, some areas of contamination are very small (less than an acre) and since jackrabbits range over areas considerably larger, their body burden of radioactivity does not represent accurately the radioactivity in these small areas. In these cases other sampling animals are needed. Small rodents have the advantages of reliable availability and small range. Experiments will be run to determine the amount, kind, and location of radioisotopes in rodents living in contaminated areas, and to correlate the levels of radioactivity in the animals to those in their environment.

4. TALKS AND PUBLICATIONS

The following talks or papers were presented during 1961:

(1) A Program on Monitoring the Physical and Biological Environment for Radiation and Radioactive Contamination was presented to ten Agricultural Extension Agents of Southeastern Idaho at the NRTS, June 23, 1961. The following talks were given at this meeting:

(a) "Monitoring the Biological Environment" by Zola M. Fineman.

(b) "Radioecological and Ecological Studies" by John B. Echo.

(2) Health and Safety Division Seminar held August 9, 1961:

(a) "Metabolism of Strontium-85 in Wild Jackrabbits" by John B. Echo.

(b) "Strontium-90 Activities in Jackrabbits, Cattle, and Native Animals" by Ray McBride.

(c) "Variations in Strontium-90 Activity in Jackrabbits of Different Ages" by Zola M. Fineman.

(3) "Noxious Weed Control on the NRTS" by Ray McBride at the Annual Meeting of the Idaho Noxious Weed Control Association held in Blackfoot, Idaho, August 1-3, 1961.

(4) "Use of the Jackrabbit for the Biological Monitoring of Strontium-90" by Zola M. Fineman, Ray McBride, and Jack Detmer was presented by Ray McBride at the First Symposium on Radioecology, held at Ft. Collins, September 11-15, 1961.

(5) "Botanical Microtechnique for Analyzing the Food Habits of Black-tailed Jackrabbit" by William E. Saul at the Annual Meeting of the Idaho Academy of Science, Twin Falls, Idaho, April 15, 1961.

(6) "Reproduction and Longevity of the Black-tailed Jackrabbit in Idaho" by N. R. French, R. McBride, and J. Detmer at the 42nd Annual Meeting of the Pacific Division of the American Association for the Advancement of Science held at Davis, California, June 19-23, 1961.

IX. U. S. WEATHER BUREAU

(Norman F. Islitzer - Meteorologist in Charge)

1. SCOPE

The Weather Bureau, under the auspices of the AEC, maintains an operational and research type weather station at the NRTS. Diffusion weather forecasts, required by the Health and Safety Division and the various contractors of the AEC for the safe conduct of reactor experiments, are supplied along with meteorological observations during the course of the experiments. The Weather Bureau also has the responsibility of conducting an extensive observational program in order to provide the necessary climatological statistics for reactor siting and planning purposes.

To increase the understanding of aspects of atmospheric diffusion and transport at the NRTS that are important to problems encountered in the safe disposal of radioactive material in the atmosphere, an extensive research program is conducted. Studies of diffusion, utilizing radioactive material released from reactor operations and also fluorescent tracers, are carried out. Various turbulence properties of the lower atmosphere are measured for correlation to measured diffusion. Wind forecast studies also are carried out to improve this aspect of the operational program.

2. SUMMARY OF MAJOR PROGRAMS

2.1 Meteorological Control of Reactor Operations

Diffusion weather forecasts and vectoring of mobile and aerial monitoring crews were supplied for a variety of reactor experiments and special tests. These diffusion forecasts were given for the monthly Radioactive Lanthanum Process (RaLa) in the Chemical Processing Plant (CPP) and the experiments in the Transient Reactor Test Facility (TREAT). Tests in the Initial Engine Test Facility (IET) were terminated early in 1961. As a result of the ANP program termination, there was very little testing in the Materials Testing Reactor and Engineering Test Reactor (MTR-ETR) that required meteorological support services from the Weather Bureau. Some diffusion forecasts were given for the Special Power Excursion Reactor Tests (SPERT).

The RaLa operating plan requires good atmospheric mixing and monitoring conditions so that the forecast specifically was required to prevent significant releases of effluent during protracted periods of calm, excessive precipitation, and very light and variable winds. The experiments in TREAT were suspended or delayed if the wind direction for the test period was anticipated to be from the northwest, thereby carrying any radioactive material that might have been released over the EBR-II area. Some of the SPERT experiments require southwest winds of appreciable velocity, so that a one-to-two-hour period of prevailing southwesterly winds can be anticipated during and following the tests. These winds would carry any radioactive material out over the uninhabited area of the NRTS.

A series of four meltdown tests of TORY II-A fuel elements were performed during the summer on grid 3 by Convair Aircraft, Division of General Dynamics Corp. There were three contained releases and one open release during daytime temperature lapse conditions. The Weather Bureau provided the necessary weather forecasts of the specified meteorological conditions for the tests and also a mobile micrometeorological laboratory to house the various recorders and control systems for the meteorological measuring instruments on the 150-foot tower. Most of the meteorological instruments were supplied by the Weather Bureau.

2.2 SL-1 Accident, January 3, 1961

Considerable meteorological support and evaluation of radiation data collected in the field were supplied to the Health and Safety Division following the accident in the SL-1. Some of this information has already been presented in reports concerning this accident, and a rather complete discussion of the meteorological conditions and support activities for the SL-1 will be presented in a future report [13]. The Weather Bureau was alerted shortly after the accident and supplied the director of the Health and Safety Division and field crews with the most likely trajectories of any released material, and likely areas of contamination from any major subsequent release. Following the first few hours after the accident, the collected radiation field data involving both deposition of iodine-131 on the vegetation and air concentration of iodine-131 was evaluated with the meteorological conditions for back calculations to a release term. This provided a daily estimate of release of iodine-131 from the SL-1 area. In addition to determining source figures, some estimates of the deposition velocity of iodine-131 on sagebrush were obtained. From the sagebrush activity and air concentration data, a deposition velocity of 0.2 cm/sec was computed. This figures was about four times the deposition velocity estimated over both soil and snow samples, which were collected by the Ecology Branch. The deposition velocity 0.2 cm sec^{-1} compares fairly well with the deposition velocity of 0.15 cm sec^{-1} obtained by General Electric for the LIME [14] meltdown test of 1960. This slight difference can be attributed to the somewhat different density of sagebrush between the sites for the LIME test and the SL-1 accident.

The general meteorological conditions following the SL-1 were marked by extremely deep inversions through the night burning off in the daytime to a shallow layer some 1500 to 2000 feet above the ground. A capping inversion would persist throughout the entire day, and the surface inversion would quickly re-form after sunset. The prevailing winds through this period were from the northeast with light-to-moderate speeds such that the effluent from the SL-1 traveled in a south-to-southwest direction down the Snake River Plain. Analyses of wind records at various stations throughout the Snake River Plain indicated that a general movement of material along the axis of the plain towards the Boise region could be anticipated through the month of January. By the end of January there was a breakdown in the general anticyclonic weather regime with a consequent reduction in inversion strength and number of inversion hours. The prevailing winds then shifted to westerly with periods of excessive wind speeds. This was marked by a reduction in air concentration levels at sampling stations just south of the SL-1. There was also some indication from a U. S. Public Health Service air sampling station in Boise that a definite rise of general radioactivity about the week ending January 7 and a consequent drop about January 28 could be attributed to the wind reversal.

Release estimates of iodine-131 made from the radiation data indicate that less than 80 curies of iodine-131 came out in the first 30-day period after the accident. The release rates had dropped by a factor of 10 by this time and were estimated to be less than one curie per day. The computed mean air concentration isopleths around the SL-1 region are shown in Figure 54 for the period of January 3 to February 12, 1961. These isopleths were computed from the observed meteorological conditions and the usual diffusion equations, with the daily source term estimated from radiation field data. The prevailing winds during the accident measured on the meteorological tower some six miles west of the SL-1 indicated a southwesterly movement of effluent would be anticipated at the 250-foot level. Surface winds during the strong nocturnal inversion were essentially calm. The forecast trajectory to the southwest was off about 30 degrees from the measured movement of radioactive material. Deposition surveys showed that the radioactive material initially went towards the south-southeast and then curved back towards the southwest along the Snake River. Apparently the effluent was emitted from the SL-1 area near the ground and drifted slowly down the elevation contours strongly channeled by nearby terrain features. The meandering nature of this type wind was revealed by smoke photographs taken after the accident under similar strong inversion conditions. Accurate trajectory computations during such meteorological conditions would require an extremely dense network of wind stations supplemented perhaps by visible tracers.

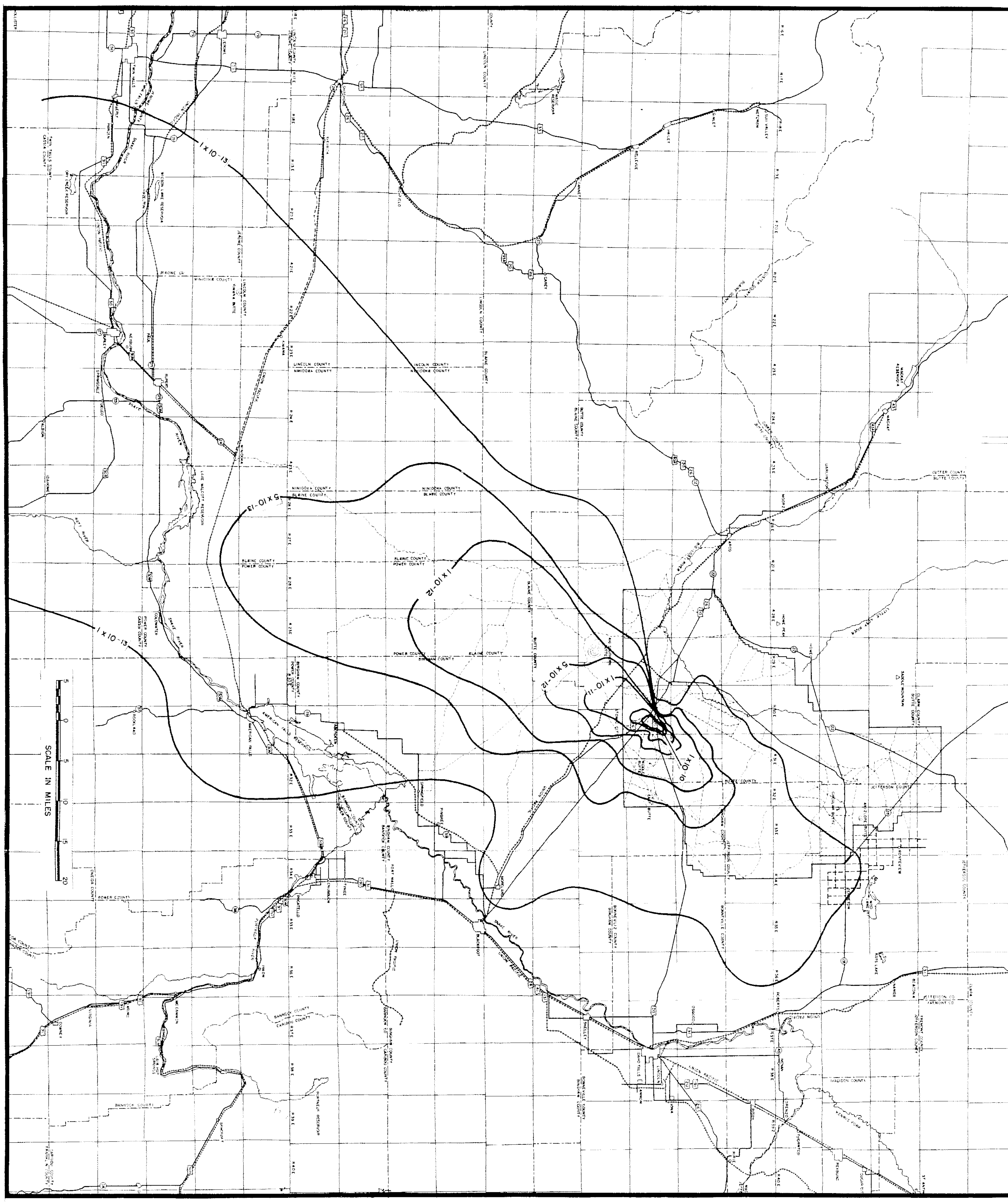
2.3 Chemical Processing Plant Criticality Accident, January 25, 1961

A release of radioactive material occurred at the Chemical Processing Plant on January 25 at 9:50 a.m. The material was released at the top of the 250-foot stack and was transported with northeast winds towards the southwestern region of the NRTS. The Weather Bureau provided rapid calculations of cloud trajectory and movement for the mobile monitoring teams and the aerial monitoring crews. Speed was necessary since the Central Facilities area and the EBR-I area inhabited by 700 people were within one hour's travel time of the radioactive material from the release point. The cloud traveled as expected over the Central Facilities area and headed towards Big Southern Butte. Tracking by both mobile and aerial monitoring crews was extremely successful. The capability of rapid coordinated action between monitoring teams and the Weather Bureau during emergencies was shown. It developed that only about 30 minutes time elapsed between the notification of the alert and the detection of radiation in the Central Facilities area. If evacuation had been necessary, extremely rapid and organized action would have been essential to successfully escape the radioactive cloud. This, plus some uncertainties in rapid meteorological calculations of precise arrival times of radioactive material, seemed to warrant a decision to remain under cover in the buildings.

2.4 Civil Defense Exercise Opal 61

Personnel from the Weather Bureau were actively engaged in the exercises carried out by Idaho Operations Office for Operation Alert 1961. Streamlines and fallout patterns from the reported nuclear detonations were plotted upon maps along with anticipated future movement. General weather briefings and the interpretation of these analyses were given to the IDO control groups.

Fig. 54 Computed isopleths of air concentration around SL-1, January 3 - February 12, 1961.



2.5 Special Forecasts

Special forecasts needed for construction and engineering activities were given to appropriate officials. Severe weather advisories also were given during months of inclement weather. The distribution of weather forecasts has been greatly facilitated by a dual automatic answering system. Two forecasts are recorded each day, averaging about 90 seconds in length, and including a diffusion weather forecast. This diffusion forecast specifies significant wind direction reversals, anticipated times of fumigation, lapse and inversion conditions, and overall wind speeds. A counter on the automatic answering system shows that about 200 calls per day are received.

2.6 MTR-ETR Study

In order to evaluate the meteorological requirements in the immediate vicinity of MTR-ETR to obtain optimum information for plant protection, a study was made of several months of air concentration data collected by the contractor. These air concentration data were collected at several points throughout the MTR-ETR area within several hundred yards of the 250-foot ETR and MTR stacks. An anemometer was in operation on a 20-foot mast on the roof of the MTR building, some 80 feet high, during the data collection period. The radiation data were analyzed with respect to the observed winds and temperatures on the 150-foot meteorological tower at grid 3, about one mile east of MTR-ETR, and to the wind measurements on the MTR building. The study is continuing, but the following preliminary results can be cited:

(1) There is good agreement between the wind direction measured on the MTR roof and the 150-foot level at grid 3, despite possible influences of the buildings on the MTR wind. The wind directions agreed to within 22-1/2 degrees 85% of the time, and to within 45 degrees 96% of the time. The correlation of wind direction between the 150-foot level at grid 3 and the 250-foot level at Central Facilities, three miles to the south, was only slightly less for this period. It appears that the meteorological tower at grid 3 can be considered as satisfactory for supplying the meteorological information required for the MTR-ETR as well as the Chemical Processing Plant and the Waste Calcination Plant, about one mile south of grid 3. Differences between these various locations are of short period duration and occur less than 10% of the time.

(2) The collected air concentration data show no consistent correlation with the observed meteorological conditions. This is interpreted to mean that dilution found around a structure such as the MTR-ETR complex includes aerodynamic effects which are unknown. Such phenomena as no marked variation of levels of relative air concentration with the change from strong temperature lapse to strong inversion and vice versa through a 24-hour period, no strong relation between the observed wind direction and the sampling station showing the highest relative air concentration, and no marked change in air concentration at a station with wind direction shifts of 90 to 180 degrees were the rule rather than the exception and impossible to interpret.

(3) A tendency for maximum relative air concentrations to occur during extended periods of calm regardless of the temperature lapse rate was evident but not consistent.

It appears from this study, if it can be assumed that the 250-foot MTR and ETR stacks were the principal sources of radiation, that conventional meteorological measurements around a complex such as the MTR-ETR may be of limited value. A more definitive study may require the use of a special tracer released from the MTR or ETR stacks under a variety of meteorological conditions such that no doubt is possible as to the source of air concentration levels.

2.7 Hazard Report Reviews

The following hazard reports were reviewed for the Health and Safety Division:

Experimental Beryllium Oxide Reactor

Experimental Organic Cooled Reactor

Mobile Low Power Reactor - I

Plutonium Release from Meltdown of SNAP II Fuel Capsules

Design and Hazards Summary Report Boiling Reactor Experiment V (BORAX V)

Advanced Test Reactor (in preparation)

Reactor Siting Criteria

2.8 Climatological Observations

The extensive meteorological observational network has continued in operation for the past year with no major changes. The recorded observations are punched on IBM cards for later periodic machine tabulations of importance to health and safety problems and engineering and construction problems. The wind rose tabulations and other climatological statistics, which were compiled for the period ending in 1956 for previous reports, are being brought up to date.

3. SPECIAL ACTIVITIES

3.1 Diffusion and Deposition Measurements

The diffusion-deposition measurements for a ground-level source to 800-meter distance on grid 3, discussed in the previous annual report [4], have been extended to 3200 meters. About 20 releases of fluorescent tracer for 1-hour periods were carried out during both lapse and inversion conditions to this greater distance. All the data from the total 35 releases have been processed and summarized with the assistance of the Health and Safety Division's IBM 1620 computer. The measured air concentration for lapse and inversion cases along the axis of the plume are shown in Figures 55 and 56, compared to predicted values from meteorological data. The measured and predicted values are represented by regression lines computed by least squares. The model used for predicting air concentration shown in Figures 55 and 56 assumes that no deposition is occurring, and that the vertical and horizontal dispersion of the tracer is explained by the corresponding variances of the time-averaged bivane signal near the source. As can be seen, the meteorological models all over-predict air concentrations. If the customary exponential depletion term due to deposition is applied to the ratio of measured-to-predicted air concentrations, appropriate deposition velocities to make the two compatible can be computed. These deposition velocities are shown in Table XLVI for lapse condition for each arc.

The mean computed deposition velocity for 39 inversion cases, covering a wide range of inversion intensity, was 1.5 cm sec^{-1}.

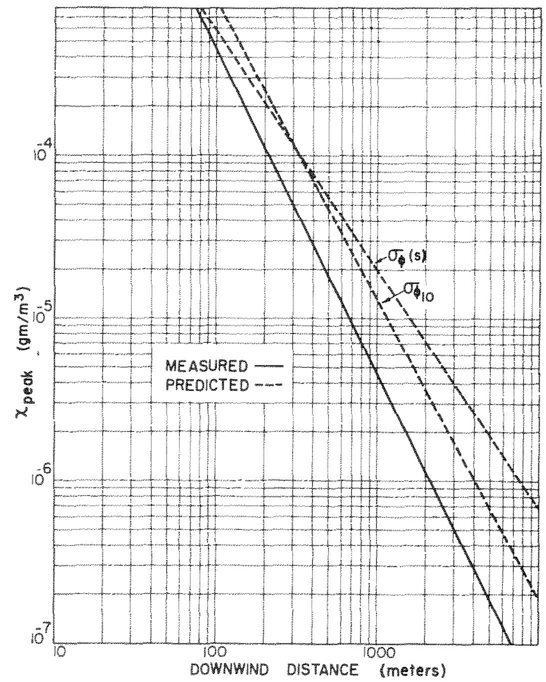


Fig. 55 Axial concentration vs distance for lapse conditions.

Independent measurements of deposition velocity, V_g, were obtained by measuring the vertically integrated air concentration at the 400-meter arc with a row of five sampling towers, each 90 feet high, and subtracting this from the total released tracer at the source. The deposited material and deposition velocities are shown in Table XLVII, along with other meteorological variables. It can be seen that the deposition velocities are of the same magnitude as computed from plume-center air concentrations shown in Table XLVI. The variation with stability is also quite marked, the two strong inversion tests O and Q having the low values of 0.2 cm sec^{-1}. It is of interest to note that this value is similar to that found for the deposition of iodine-131 from the SL-1 accident and also from the LIME test, especially since the latter two sets of data came from measurements of deposition per unit mass of vegetation rather than per unit area of surface. More such experiments under inversion conditions are needed to confirm these preliminary findings. The agreement between measured and predicted vertical particle dispersion, σ_z, is fairly good as shown in Table XLVII. The vertical particle dispersion was

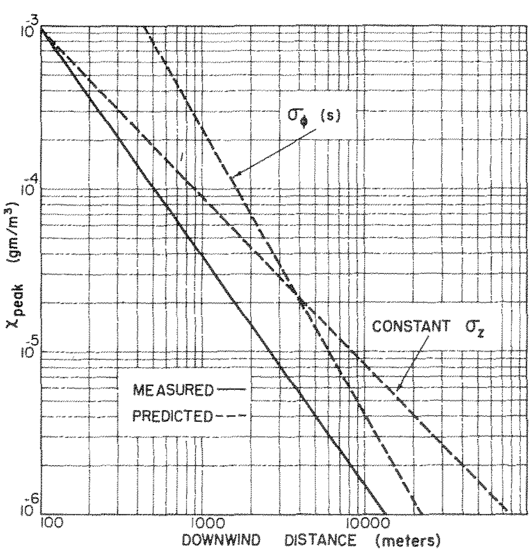


Fig. 56 Axial concentration vs distance for inversion conditions.

Table XLVI

DEPOSITION VELOCITIES FOR LAPSE CONDITIONS
COMPUTED FROM MEASURED AXIAL AIR CONCENTRATIONS

	Deposition Velocities ($cm\ sec^{-1}$)					
	100[a]	200[a]	400[a]	800[a]	1600[a]	3200[a]
Mean	6.4	5.3	4.0	4.5	5.2	5.6
Standard deviation	3.3	2.9	2.4	1.6	1.5	1.8
No. of observations	13	24	13	20	14	14

Grand mean: 5.2 ± 2.4

(a) Distance in meters.

Table XLVII

TRACER MATERIAL BALANCE MEASUREMENTS

Test	$\bar{U}_{4m}$ (m/sec^{-1})	ΔT 16m-4m (°F)	Travel Distance (meters)	Amount Deposited (%)	σ_z[a] Measured (meters)	σ_z[b] Predicted (meters)	V_g (cm/sec^{-1})
C	6.3	- 0.3	400	54	14.6	10.8	9.2
D	4.9	+ 0.5	400	35	9.5	8.6	2.3
E	6.0	- 2.4	200	32	13.5	13.0	8.0
F	4.7	- 1.1	200	24	13.2	12.6	4.4
G	6.2	- 1.9	200	22	13.7	8.1	5.4
I	6.0	- 1.6	400	48	13.4	15.5	6.8
M	3.9	- 0.7	400	32	12.2	13.3	2.4
N	4.7	+ 0.7	400	38	10.0	9.8	2.6
O	2.6	+ 3.4	400	10	5.0	4.7	0.2
Q	2.5	+ 4.1	400	14	5.5	3.5	0.2
S	8.4	- 2.3	400	37	17.8	14.0	8.9

(a) σ_z measured at travel distance

(b) σ_z predicted from $\sigma_\phi(s)$, $\beta = 5.2$

predicted from the vertical wind direction standard deviation, $\sigma_\phi(s)$, after first averaging the bivane signal for time, s, with a lagrangian-eulerian time factor, β, of 5.2.

The excellent agreement between predicted and measured crosswind particle dispersion is shown in Figures 57 and 58 for lapse and inversion conditions respectively. The dispersion was predicted from the horizontal swings of the bivane near the source, smoothing the bivane signal with a variable averaging time dependent upon the travel distance for lapse cases and a 10-second mean for inversion cases before variance computations.

The details of this study will be presented more completely in a future publication on atmospheric diffusion deposition studies over flat terrain.

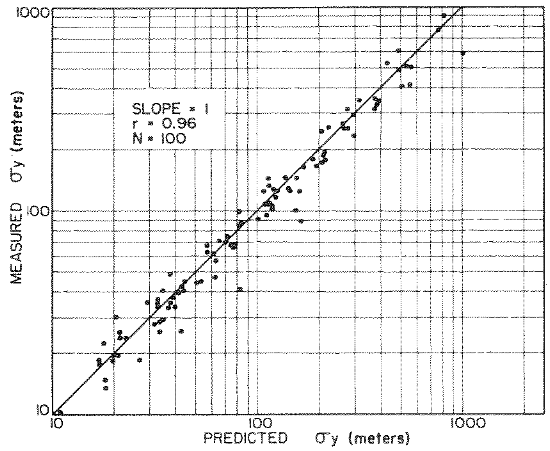


Fig. 57 Measured crosswind particle standard deviation, σ_y, vs values predicted from horizontal wind direction standard deviations ($\beta = 5.2$).

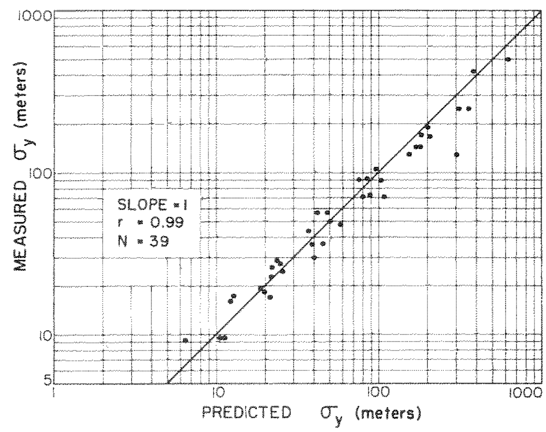


Fig. 58 Measured vs predicted lateral particle standard deviation for inversion cases.

3.2 Meteorological Digital Data System

The Weather Bureau digital data system was delivered by the manufacturer, United Electrodynamics, Pasadena, Calif., in March and placed into operation by company representatives. This system was designed to replace analog data display from the various meteorological instruments in the Central Facilities area with a digital read-out on electric typewriter and punched paper tape. The system has a capacity to integrate the various inputs such as winds in component form, with subsequent recombination into a vector of direction and speed, ambient air temperatures and temperature differences on the 250-foot meteorological tower, solar and terrestrial radiation and dew point. Averaging times from two minutes to 60 minutes can be selected, as well as instantaneous read-out of any desired parameter. Provision was also made to list out on the typewriter and punched paper tape six inputs at high speed, usually the horizontal and vertical wind directions from the bivanes. The data system is shown in Figure 59. The scope and design of the system was made with three objectives in mind: (a) obtain the information both for climatological and operational needs for immediate use by the forecaster, (b) make the system sufficiently reliable to be essentially operational on a round-the-clock basis, and (c) reduce the excessive demands on manpower to process the data manually and to eliminate some of the errors that are inherent with such manual type data reduction. These objectives have been only partially realized.

The operational amplifiers used for integration have performed well. Very little down-time was experienced and checks of calibration signals for various periods of time showed that integration was well within that required in the specifications, plus or minus 2% accuracy. This accuracy of the integration

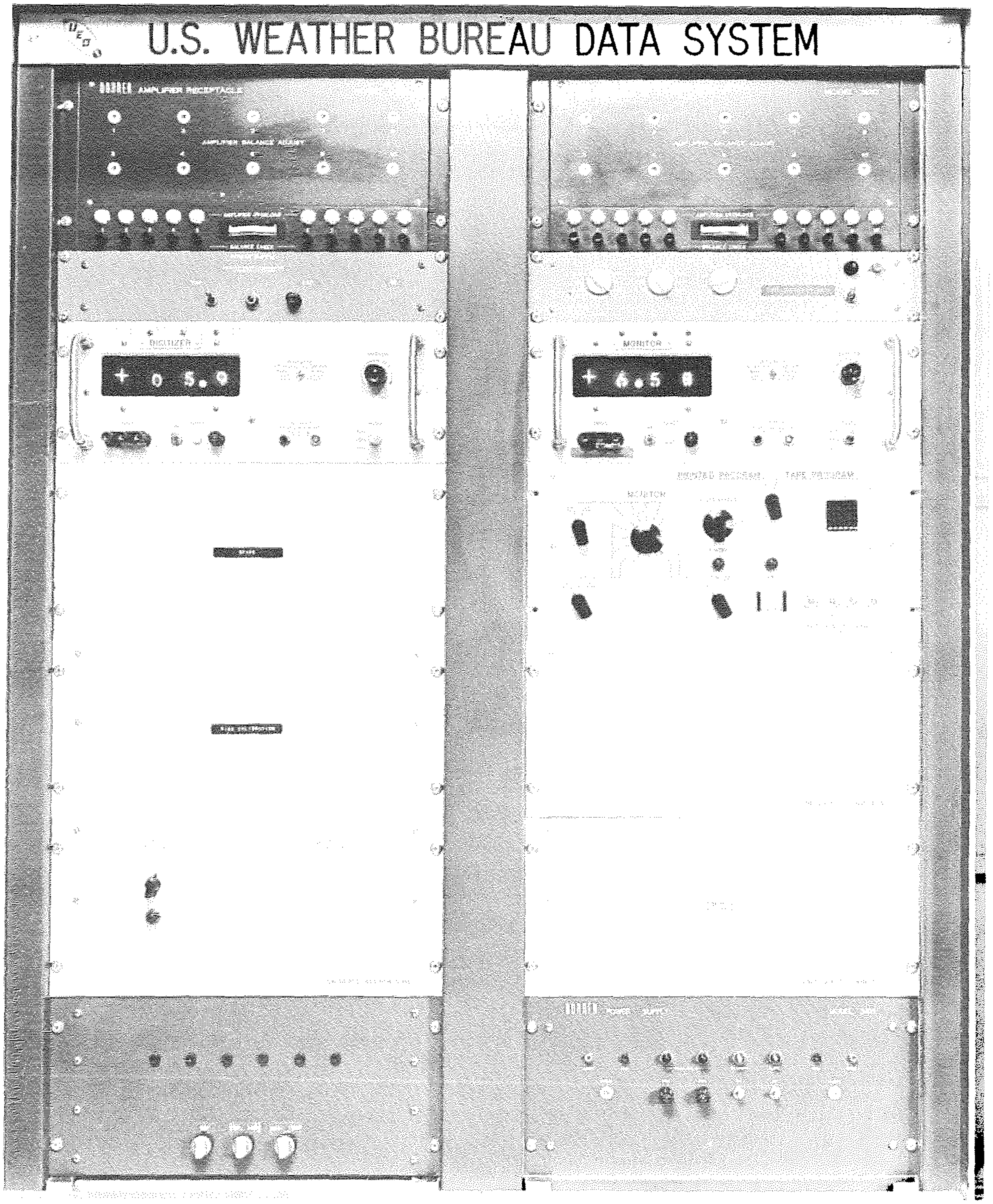


Fig. 59 Meteorological digital data system.

did not deteriorate markedly even for the longer averaging times approaching one hour. Since many of the meteorological variables that are required have such rapid time variations, averages are required for any sort of meaningful presentation. The Friden Flexowriter initially required a considerable amount of debugging and adjustment to place it into complete synchronization with the digital system. It has worked satisfactorily and appears to be holding up well, although it is not certain that the need for fairly frequent maintenance and adjustment has been eliminated.

The performance of the Hewlett-Packard digital voltmeter has been discouraging. Although apparently suitable in principle, it has not been holding up under the demand of continuous operation. Following a period of several weeks of satisfactory operation, periods of malfunction became more frequent requiring considerable debugging and maintenance work, until finally it was no longer operational. After considerable efforts to improve the performance of the voltmeter, and after also trying two replacement voltmeters, it was concluded that a more sophisticated type voltmeter is required. Negotiations are currently taking place as to the cost and details of placing the system into virtual round-the-clock reliability.

Outside of the component defect of the voltmeter, the entire system appears to be suitable in principle and design and has yielded some interesting information to evaluate the accuracy of a digital vs analog system. With the analog system, wind data are recorded and integrated as a direction and speed separately. This is not mathematically correct, since wind is a vector quantity. This may be particularly serious during periods of light winds in which the direction can vary as much as 180 degrees during the averaging period, usually one hour. Other type signals where the information is recorded as an extremely erratic trace on the chart, such as solar and terrestrial radiation during intermittent cloud cover, also will present difficulties. The old analog system was run in parallel with the new digital display for various periods to compare accuracy of the reduced data, digital vs manual. The results of a number of hours of wind studies with light and variable wind conditions show that the difference in wind speed or direction could be as much as 20%. The analog integration was shown to be in error after an extremely detailed and minute point-by-point examination of the record. The analog radiation integrations also were found to be considerably in error at times during periods of rapidly varying sunshine because of intermittent clouds. Errors in hourly averages on the order of 30% were encountered. From such studies as these it has been concluded that the improvement in accuracy due to the proper integration of signals and also the elimination of natural human error has vindicated the digital system.

Another feature which has proven itself to be quite valuable is the tendency to eliminate some errors that may occur in reading meteorological instruments during the tension of an emergency. The system has the capacity to switch to any desired variable and display this on a monitoring voltmeter in digital form. Thus, if a certain element such as wind speed and direction or a vertical temperature difference is needed quickly to evaluate the effect of a radioactive release, this input can be selected for immediate digital display. The analyst then will not make errors in reading off analog charts due to various scales, calibration factors, etc.

With proper operation of the digital system, two man-years presently needed for data reduction will be eliminated. Various calibration and debugging features should not require more than from one to two man-days per week, and this cannot be considered completely as an additional burden since the analog systems also required a certain amount of maintenance and debugging. With proper operating digital systems, it appears that the saving in manpower can be considerable and will justify the initial expenditure.

3.3 Trajectory Studies Using Radar

With the successful testing of the transponder for basic principle and design with the APS-3 radar, field studies ceased pending the procurement of a more operational type radar. The APS-3 is an obsolete, low-power radar which has limited range and usefulness for operational problems. A surplus M-33 radar has been obtained from the Army and transported to the Weather Bureau Research Station at Las Vegas, Nevada, for reconditioning and testing before transport to the NRTS. The M-33 is a more recent and powerful radar than the APS-3 and has been used successfully at the Nevada test site for tracking constant level targets.

3.4 Meso-scale Wind and Stability Studies

The study of the three-dimensional wind field and its variation through the night over the NRTS and environment continued with three sets of observations from the multiple pibal network. Two more theodolites were obtained increasing the number of upper wind stations to six which with the normal Pocatello pilot balloon station gave seven stations for the streamline analyses. The observations are started in late afternoon at the time that the gradient winds have exercised their maximum effect upon surface winds, and continue throughout the night until daybreak. These observations revealed once again the formation of a closed-type circulation or a definite trough over the NRTS. In addition to the closed circulation or trough, the progression of the shift of surface winds down the valley is well delineated. It appears that the nose of the topographically induced trough is oriented generally towards higher pressure, which is typical of flow over a barrier such as is experienced with Foehn winds. All of the three runs were made during fairly clear nights permitting strong inversion development. A number of additional runs are contemplated, before a complete digest of the data is made to detect trends and typical cases for assistance in operational forecasts. Streamline analysis from the undisturbed gradient level to successively lower layers is of considerable assistance, since some subjectivity in the analysis is required. This is due to the sparse location of stations and to the rapid variation of winds over short distances frequently experienced during the nocturnal period.

During the colder months, the T-Sonde program also has been continued. These temperature soundings are taken shortly after daybreak during periods of maximum nocturnal development of the inversion and are continued through the day. The soundings are continued until the inversion has been eliminated and gradient winds have pretty well exerted their maximum influence upon surface winds. In January following the SL-1 accident, T-Sonde measurements showed ground-based inversions extending to 5400 feet above the surface with the air temperature increasing 30°F between the ground and the top of the inversion. From these multiple pilot balloon and T-Sonde experiments, a more extended meso-climatology of the winds and stability features over the NRTS will be developed for operational forecast purposes.

4. FUTURE PROGRAMS

4.1 Meteorological Control of Reactor Operations

It is anticipated that there will be a continuing demand for reactor operational forecasts and weather monitoring in the coming year. Best present estimates indicate that demands for Weather Bureau services will be particularly heavy for destructive type testing in the SPERT reactors, for the startup of the Waste Calcination Plant, and possibly for some experiments in the MTR-ETR. Significant releases of radioactive material from some of these experiments are possible, requiring close liaison between the contractor, the field monitoring crews of the Health and Safety Division, and the Weather Bureau. Forecasts for the RaLa in the ICPP and transient tests in the TREAT facilities will be of a more routine nature. Special tests involving the meltdown of reactor fuel elements are also a strong possibility for the coming year.

4.2 Fluorescent Tracer Studies

As mentioned in section 3.1, there is a need for additional diffusion tests on grid 3 during inversion conditions. If equipment and manpower are available, it is planned to conduct a series of 10 to 15 releases of fluorescent tracer during inversion conditions starting in the late spring of the coming year.

4.3 Radar-Tetroon Trajectory Study

If a suitable tracking radar can be made operational at the Nevada test site, it is planned to relocate this radar at the NRTS. A major emphasis will then be placed upon long-range trajectory studies (10 to 50 miles) using both the constant level balloons (tetroon) and also transponders.

4.4 Meteorological Digital Data System

The necessary modifications to place the Weather Bureau digital data system into essentially continuous reliability will be performed. The major change will be a new analog-digital converter, specifically a digital voltmeter, with the necessary modification to incorporate it into the system.

4.5 MTR-ETR Study

The wind patterns and increased atmospheric dispersion due to the structures in the MTR-ETR area will be studied. Bivanes and anemometers will be placed upwind and downwind of the main reactor buildings to compare turbulence in the wake of the buildings to the turbulence over the flat terrain. Smoke and fluorescent tracer releases near the buildings may be feasible.

5. TALKS AND PUBLICATIONS

(1) "Short-Range Atmospheric Dispersion Measurements from an Elevated Source", Norman F. Islitzer, Journal of Meteorology, Vol. 18, No. 4, August 1961.

(2) "Meteorological Problems in the Location and Operation of Reactors" presented by Norman F. Islitzer at the <u>8th Annual Nuclear Sciences Seminar</u> held at Idaho Falls, Idaho, August 1961.

(3) "A Radar Transponder for Determining Meteorological Trajectories" presented by C. R. Dickson at the <u>American Meteorological Society Meeting</u>, Kansas City, Missouri, October 1961.

X. INSTRUMENT AND DEVELOPMENT
(M. Wilhelmsen - Branch Chief)

1. SCOPE

The Instrument and Development Branch:

(1) Maintains and operates a laboratory for the maintenance, repair and calibration of all types of nuclear radiation detection equipment and their associated components.

(2) Is responsible for the adequate availability and supply of portable detection equipment to the various government and private contractor personnel doing research at the NRTS.

(3) Supplies professional consultation service on matters pertaining to the techniques and instrumentation available to cope with radiation detection and measuring problems.

(4) Does calibration on instrumentation, film, radioactive sources and other sensitive devices at the request of government agencies and operating contractors where these services, or the techniques and equipment, are otherwise unavailable.

(5) Directs and advises in budgeting, ordering and inventory of all electronic and laboratory instrumentation used by the Health and Safety Division.

(6) Conducts a development program for new and improved techniques and instrumentation pertinent to the overall program of Health and Safety at the NRTS.

2. MAINTENANCE SECTION
(R. Purcell)

2.1 Function

The diversified and complex health physics requirements of the operating contractors doing research at the NRTS places the maintenance section in an important role as it fulfills the requests for its services. These services consist in the main of supplying portable radiation detection devices as well as calibration, maintenance, and consultation services. Those organizations utilizing one or more of these available services during the year are:

2.11 Idaho Operations Office

(1) Health and Safety Division consisting of the following branches:

(a) Instrument and Development

(b) Analysis

(c) Ecology

(d) Site Survey

(e) Medical Services

(f) Hazards Control

(g) Personnel Metering

(2) Licensee Compliance Division

(3) Security Division

2.12 Government Agencies

(1) U. S. Public Health Service

(2) U. S. Weather Bureau

(3) U. S. Geological Survey

(4) U. S. Navy (NRF)

(5) U. S. Army (SL-1)

2.13 Operating Contractors at the NRTS

(1) Phillips Petroleum Co.

(2) Westinghouse Electric Corp.

(3) General Electric Co.

(4) Argonne National Laboratories

(5) Atomics International

(6) Combustion Engineers

(7) Aerojet General Corp.

2.2 Equipment Accountability

As custodian of essentially all electronic equipment used by the Health and Safety Division, the total item inventory at the close of the year reached a new high as did the total dollar value. Equipment and instrument items now stand at 1971 units with a value of $1,150,000. This closing inventory is only 112 items greater than the previous year as a concentrated effort was made to excess worn-out and obsolete items. The addition of a new telemetering system accounts for the large dollar increase.

A review of the data on page 159 indicates that portable radiation monitoring and sampling equipment make up approximately 62% of the total item inventory and account for approximately 87% of the service calls. However, this is not indicative of the total time of the maintenance section personnel spent

Portable Instruments	Inventory	Number Serviced
"Cutie Pie"	159	770
Juno	195	871
Geiger counter	223	815
Radector & Minirad	79	214
Slow neutron det.	34	73
Fast neutron det.	36	70
Air samplers	361	194
Alpha counters	79	139
Long probe det.	19	41
Charger-readers	43	51
	1228	3238
Other instruments	743	596
Total	1971	3734

on these items. The repair, maintenance and calibration of these items require the services of three persons full time. In addition, one person devotes full time to the maintenance of Analysis Branch counting room equipment, and one person devotes full time to the installation and maintenance of the telemetering equipment.

2.3 Equipment Usage

Following is a summary of the data available from the historical file on repaired and calibrated instruments showing the areas of demand and the percentage of effort devoted to specific organizations.

		Percentage
(1) Atomic Energy Commission		
(a) Health and Safety Division (Excluding Site Survey)		6
(b) Site Survey Branch		13
(c) Security Division		4
(d) Compliance Division		1
	Total	24
(2) Phillips Petroleum Co.		
(a) Central Facility and Laundry		2
(b) MTR		11

		Percentage
(c) ETR		11
(d) CPP		12
(e) SPERT and AREA		2
	Total	38
(3) Argonne National Laboratory		
(a) EBR-I		4
(b) EBR-II		1
(c) TREAT		2
	Total	7
(4) General Electric Co.		
(a) ANP		5
(b) SL-1		6
	Total	11
(5) Aerojet General		
(a) GCRE		3
(b) ML-1		1
	Total	4
(6) Atomics International		
(a) OMRE		3
(7) Westinghouse Electric Corp.		
(a) NRF		1
(8) All other users		13

A review of the preceding table shows the Site Survey Branch as the largest single user of the services of the maintenance section, although Phillips Petroleum with its various plants and service areas utilizes the greatest percentage of the total instruments offered and serviced during 1961.

2.4 Calibration Facilities

One additional well for high-level gamma calibration was completed with automatic motor driven control (Figure 60). A 225-curie cesium-127 source was installed and calibrated, giving a calibration capability of 50 to 100 times greater than previously available. Additional cobalt-60 sources have been ordered to raise this capability by an additional factor of three. With these additional sources, calibration of instruments reading in excess of 1000 r/hr will be possible.

2.5 Training Programs

Eight AEC Radiological Fellowship students received a total of three weeks training and instruction devoted to instrument theory, instrument maintenance and calibration, instrument operation techniques, source standardization, and film calibration.

Primary emphasis was placed on imparting fundamental principles and techniques which might be helpful to these persons as they take positions in various Atomic Energy laboratories and facilities.

2.6 Tests Performed on New Items

With the increased interest of the past year in solid state radiation detectors, the section has tested several different types of preamplifiers and power supplies for use with these units. This work was conducted in cooperation with the Analysis Branch. Due to the rigid input requirements of the new type multichannel analyzers as regards pulse shape and size, the standard type preamplifiers do not lend themselves readily to this new pulse source. Shop-made transistorized units have been adapted for this use as well as tube types of standard design supplied on loan by electronic equipment manufacturers. This coming year should see the results of these tests and the greater use of solid state devices as radiation detectors within the analytical laboratories of the division.

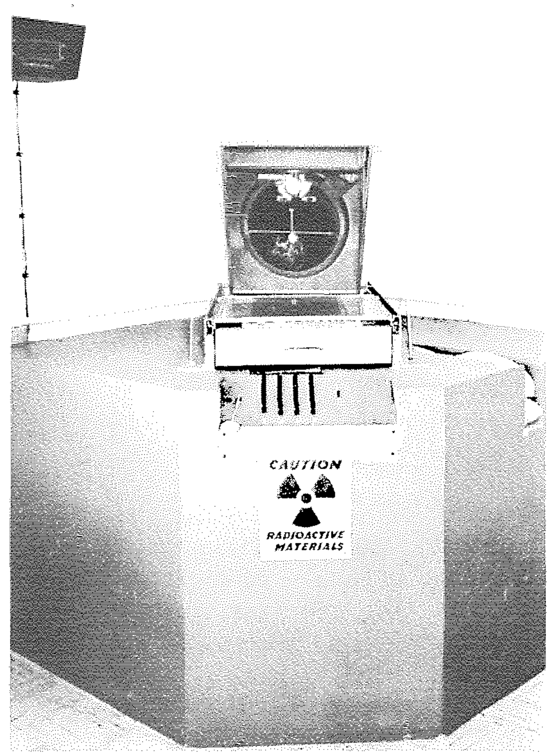


Fig. 60 Calibration well.

With the resumption of nuclear weapons testing, the general public as well as Health Physics personnel have shown an increased interest in the problems of fallout and adequate detection meters. The section has tested some of the more popular devices being marketed for this use. This has included not only pocket dosimeters and personnel type monitors, but also survey type instruments. Of those reviewed and tested, the Victoreen Model 61720 fallout meter being produced under Civil Defense contracts is a very satisfactory instrument from the standpoint of economy and operational characteristics of accuracy and linearity when calibrated to 500 r/hr using cesium-137 gammas. The branch has procured 12 units for emergency use.

Among the lessons learned from the SL-1 reactor incident was that gamma survey instruments reading in excess of 500 r/hr are necessary for early recovery and investigation work associated with similar events.

Two types of instruments reading to 5000 r/hr have been procured and tested for such emergency work. One of these is an air ionization "Cutie Pie" pistol-grip type, manufactured by Technical Associates and known as their model CP-TP-1B. The instrument features the ability to attach a 40-inch extension for extending the chamber away from the user. It was the opinion of the testing group that for emergency monitoring, the necessary use of both hands to hold and operate the device would limit its use in close places and wreckage. With the chamber and electrometer tube assembly on the end of this extension there is increased probability of damage by impact. For high-level monitoring in laboratory or under "routine" conditions there would be some application.

The second instrument was one manufactured by the Eberline Instrument Co. , their Model GADORA 1B (Figure 61). This is a scintillation type, utilizing a plastic phosphor and reads photo-multiplier tube current direct without the use of electronic amplifiers. The unit is small, lightweight, and easily operated by one hand. With selection of the proper battery pack, the instrument can be used in extremely cold weather. Ten units of this type have been obtained for emergency monitoring use.

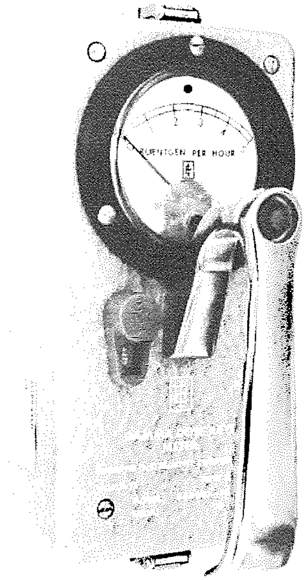


Fig. 61 High range gamma instrument.

The continued effort to upgrade the level of service being offered by the various branches of the division resulted in the procurement and installation of several new systems in the Analysis Branch counting room. Two new 400-channel transistorized pulse-height analyzers were ordered, with one being delivered during 1961. This unit has been installed for use in the whole-body counting program and features punch-paper tape, IBM typewriter, and plotted curve read-outs. It also features the capability of data "read-in" which will add significantly to its versatility in the whole-body counting system.

Another large iron vault was fabricated and installed. These two units of similar size and characteristics, fitted with comparable 3- x 3-inch stainless-steel canned scintillation crystal detectors, make a functional working pair to handle the work load of the Analysis Branch.

3. AERIAL MONITORING PROGRAM

Aerial radiation monitoring during the year resulted in eight flights, six of which were in support of non-scheduled releases at the SL-1 and CPP; one for the purpose of monitoring a scheduled release at CPP, and one flight for training purposes. The chartered aircraft used in all cases was a four-place single engine Cessna. Eight persons constitute the aerial monitoring teams and each received experience in serving as equipment operator as well as navigator-observer.

The aerial monitoring kit consists of:

(1) Aerial survey analyzer using a 3- x 3-inch NaI (Tl) crystal (Figure 62)

(2) Spring-driven strip chart recorder

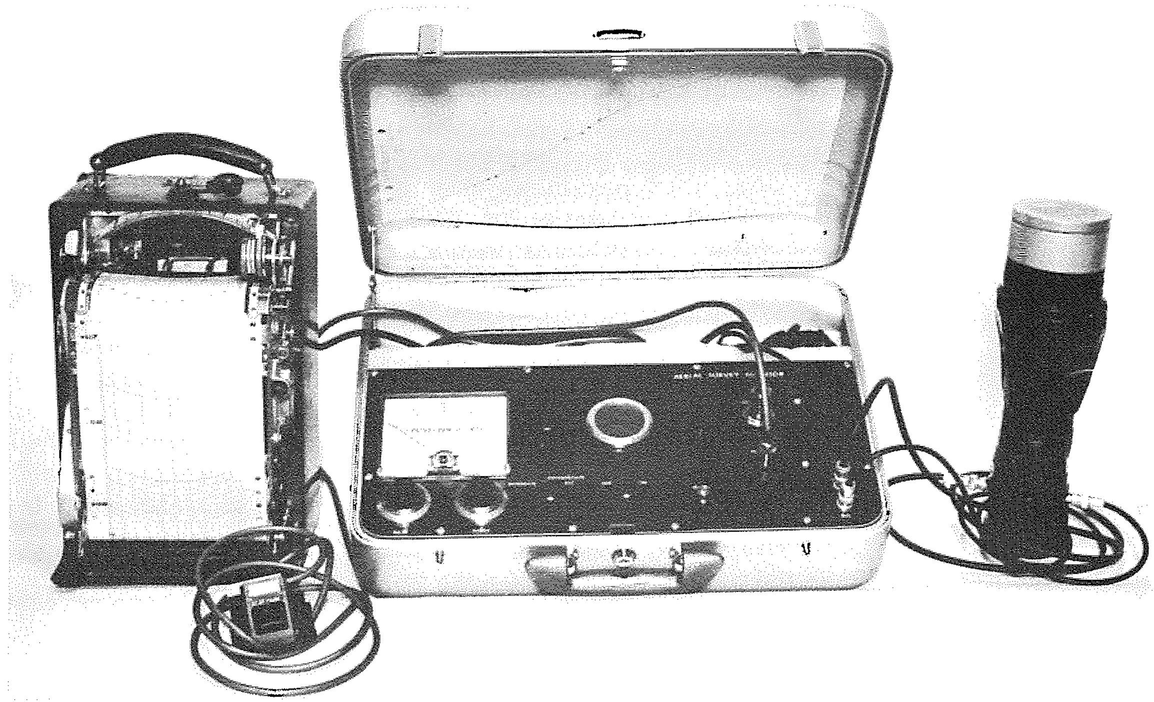


Fig. 62 Aerial survey analyzer.

(3) Handi-talkie radio with external antenna

(4) Suitable maps and accessory items

To overcome some of the weaknesses of the earlier equipment used, the aerial survey monitor was redesigned and packaged with the additional capability for strip chart recording and time-marking of the recorder chart. The entire survey analyzer together with radio and associated equipment is contained within a single carrier box for rapid transport from storage to the aircraft.

Certain difficulties still remain. Chief among these are:

(1) Positive identification of aircraft location and altitude over the terrain being monitored.

(2) Unreliable radio communications with ground personnel, resulting from distance and aircraft position with respect to radio relay equipment.

(3) The need of a technique yielding more complete and accurate logging of pertinent information acquired during the flight.

These improvements would result in more accurate radiation data.

4. DEVELOPMENT SECTION

4.1 Function

The development section plays a vital role in promoting the further advancement of concepts and design of instrumentation and apparatus for the acquisition, study and analysis of pertinent data of interest in the health and safety field. The facilities and personnel of the section are available to all branches of the Health and Safety Division as well as other government agencies and operating contractors who may seek consultation or design and fabrication of needed apparatus for the furtherance of their individual projects.

Aside from the electronic engineers and technicians, and the necessary laboratory test equipment, the section maintains a small but versatile machine shop for performing the many necessary fabrications and modifications required by the Instrument and Development Branch as well as other branches, where in the interest of time and economy, it is more desirable that the work be done locally.

All major development projects are analyzed by a divisional review committee under the chairmanship of the deputy director.

4.2 Summary of Major Developmental Projects

The major efforts of the development section were devoted to the automatic film reading system. This system is designed for the purpose of providing a means whereby film densities resulting from the exposure of film to nuclear radiation, together with a digital number in binary form, preassigned for a particular piece of film, may be read and this information recorded on punched paper tape for further analysis by computer techniques. Circuitry design is composed of transistorized, plug-in modules and, except for certain areas of power switching, all switching and logic is solid state. The complete operation is controlled and monitored by an operator at a console where equipment conditions and all data are displayed. Certain test functions as well as numerical data may be inserted manually at the option of the operator.

The prime responsibilities of the development section toward this project have been to:

(1) Develop the concept and format for the punched lead insert.

(2) Design and fabricate the lead insert punch.

(3) Redesign and modify existing mobile badge contamination monitor and X-ray.

(4) Design film handling tray for developing and reading of film.

(5) Design and fabricate a loader apparatus for the loading of film into trays in the darkroom.

(6) Design and fabricate an automatic film reader to provide data read-out in a format compatible to the input requirements of an IBM 1620 computer.

For a complex system of this magnitude to be fully functional and acceptable, certain basic concepts have been promoted in the engineering and design. The film reader will be processing information which is of prime concern to Health Physics personnel at the present time and will constitute a part of the legal record as pertains to a particular individual and his exposure record for possible future use. Odd-bit parity is used throughout the system for the purpose of decreasing the probability that invalid number identification will be made and recorded. Four density fields are read on each film, making possible better determination of various types and energies of radiation by computer analysis. A single digital voltmeter, capable of three readings per second, measures the light transmission characteristics of the film by scanning the outputs of the four separate detectors which are observing the light passage through the four density fields of the film. Differential amplifiers are used on the detector outputs which makes possible compensation for variances in the illuminating light intensity.

Zero drift as well as drift due to temperature changes in the reader head are reduced by the use of a light absorber, approximately equal in density to a blank film. The absorber is automatically inserted between the illuminating lamp and the detecting photo diodes when a film is not actually being read. This allows the photo-diode dark current to stabilize under conditions similar to those actually present when film is being read. Additional built-in National Bureau of Standards calibrated absorbers will make possible accurate calibration of the amplifiers and voltmeter. The film reading, analysis, and recording cycle requires approximately three seconds per film.

Fabrication is now nearly complete and the system check-out and testing remains to be conducted.

4.3 Radiation Monitoring Telemetering System

The summer and fall of 1961 saw the major installation work completed on an improved radiation monitoring telemetering system for the NRTS and the surrounding area of Southeastern Idaho. Four detectors measure nuclear radiation at each of 17 locations, and two sensors measure wind information at each of two locations, to comprise the remote monitoring equipment. This data is radio-telemetered to Central Facilities Area.

The complete system encompasses 24 major instrumentation groups plus alarm stations located at Central Facilities Security and the Site Survey Branch buildings. The 24 instrumentation groups are subdivided as follows:

(1) One central control base station

(2) Two remote data read-out stations

(3) Two radio frequency transmission repeater stations

(4) Seventeen remote radiation monitoring stations

(5) Two remote wind monitoring stations

The central control base station (Figure 63) consists of a control console, punched paper tape and typewriter read-out, and radio transmitting and receiving station.

The two remote data read-out stations consist of Flexowriter punched paper tape and typewriter units located at the U. S. Weather Bureau and at the Site Survey Branch. The Weather Bureau read-out is sensitive to weather data only, while the other read-out stations are sensitive to all incoming data. Associated with these remote read-out stations are the necessary alarm devices to alert personnel of abnormal radiation levels.

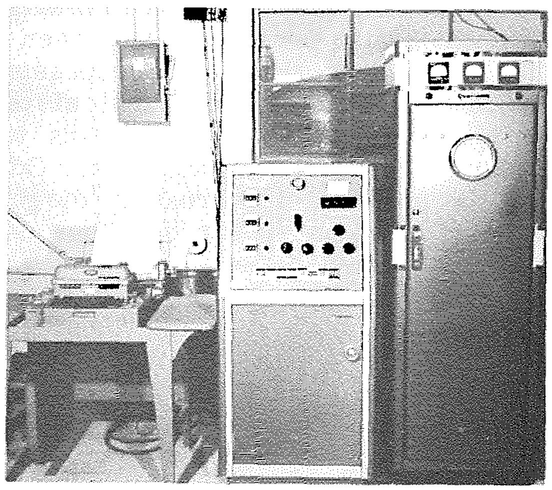


Fig. 63 Central control base station.

Under the present operational plan, two RF transmission repeater locations are used, one as a primary repeater located on the East Butte and the second being a slave station at the Kimama Butte, located south of the NRTS. This slave station is required because of the elevated terrain over which propagation must be made from the southwest area remote monitors.

Two remote wind monitoring stations and 17 remote radiation monitoring stations (Figure 64) are housed in conventional 2-wheeled trailer houses for protection of the equipment from extreme atmospheric conditions. Wall-mounted cooling fans move air through dust filters, introducing air circulation for summer conditions as well as providing a slight positive pressure on the interior to help retard dust infiltration. Liquid gas heaters keep the interior temperature at safe levels during the winter. The U. S. Weather Bureau has recorded temperatures as low as 43°F below zero within the NRTS.

The remote radiation monitoring stations consist essentially of two racks of equipment with auxilliary components (Figures 65 and 66). One rack houses

Fig. 64 Typical remote radiation monitoring station.

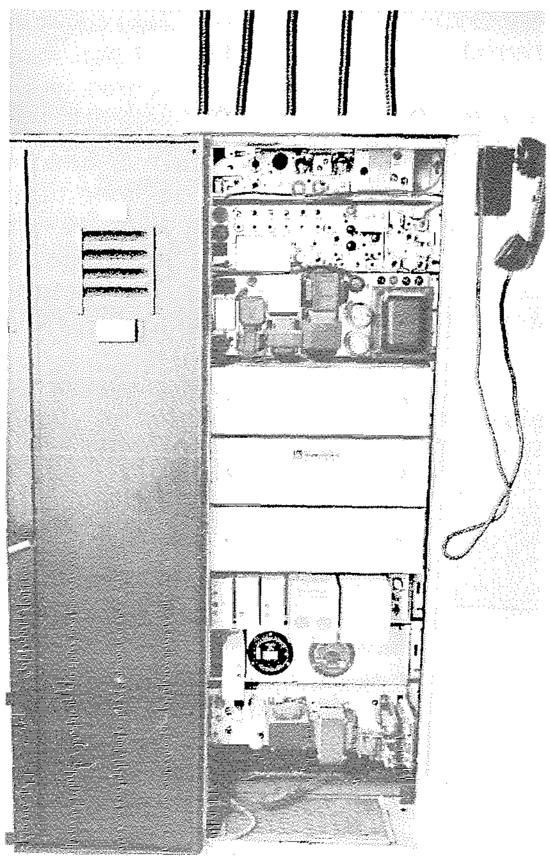


Fig. 65 Interior equipment components.

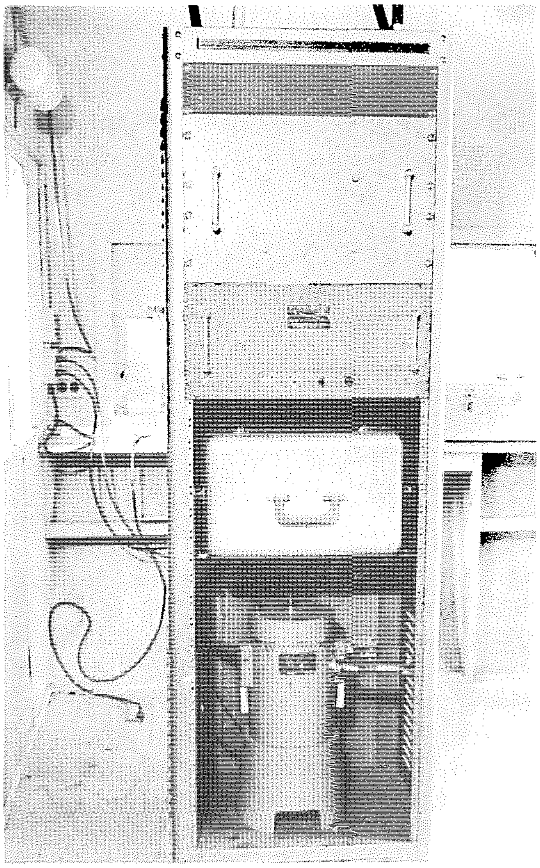


Fig. 66 Interior equipment components.

all RF receiving and transmitting gear together with digital processing equipment and the necessary power supplies and amplifiers. The second rack is comprised of air sampling and radiation detecting components together with the necessary switching components and voltage regulating units. The ionization chamber for monitoring gamma radiation in the open atmosphere is wall-mounted to the side of the trailer house. Figure 67 shows four types of detectors used for radiation monitoring. Figure 68 shows a scintillation insert and filter.

An additional feature of the telemetering system is the capability to manually or automatically control supervisory functions at the remote monitoring locations. Presently one of the controls is used to control the operation of high-volume air sampling equipment (Figure 69) mounted at openings in the sides of the trailer house. Since these air samplers could remain unused for long periods of time, the interior mounting gives protection from the atmosphere and greater operating life.

Performance tests performed on the telemetering system indicate that the equipment is capable of acceptable accuracy and consistent operation providing RF transmission can be free from interference. The recent construction of a 325-kilowatt commercial television transmitter in close proximity to the repeater station on East Butte has resulted in RF field strengths of such magnitude as to cause unacceptable interference signals in the repeater equipment. The result is inaccurate or false data reports. A change to increase the reliability for the repeater stations is anticipated in the near future.

Fig. 67 Four types of detectors used for radiation monitoring.

The radiation and weather data telemetering system gives coverage of greater than 6000 square miles in Southeastern Idaho.

A moving tape sequential air sampler was designed for use in the radiation and weather data telemetering

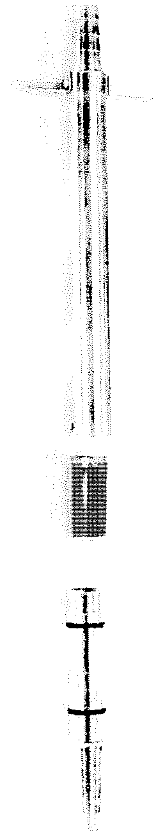


Fig. 68 Scintillation crystal insert and carbon cartridge filter.

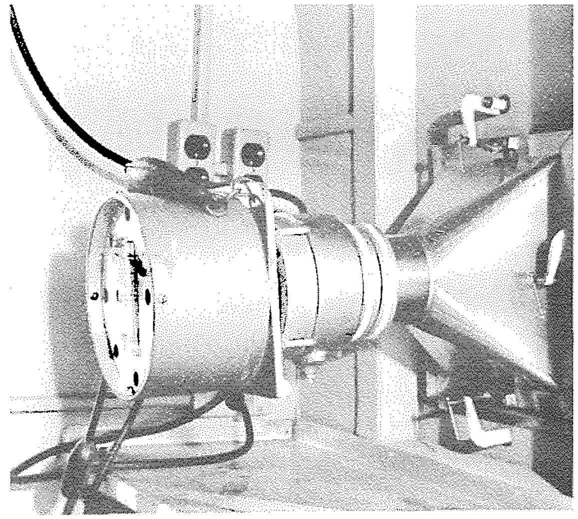


Fig. 69 Interior mounted high-volume air sampler.

system, and provides additional information regarding radioactive particulate matter in the air. Air is pulled through a paper tape filter wherein there is a buildup of particulate material. This buildup is continually monitored by a thin-wall GM counter tube. At the end of each 24-hour sampling period a motor-drive mechanism is energized and the tape is moved a pre-determined distance to place the sample deposit under an additional pancake-type thin-window GM counter. During each 24-hour period, one sample is being collected and monitored while the previous sample is being observed for the decay of short half-life products. This provides valuable information concerning the characteristics and identity of the particulate material being observed.

Low-voltage switching circuits are used and during the time interval of tape movement, the air pump is de-energized for easier movement of the filter tape. To reduce effects of air leakage around the filter, the whole assembly is housed in an air tight container. Although the major emphasis of the section was directed toward the automatic film reading system, a number of other projects were engaged in for the benefit of associated branches.

4.4 Application of Solid-State Detectors

The use of solid-state radiation detectors was further investigated in cooperation with the Analysis Branch and several designs performed. An example of this is the preamplifier assembly shown in Figure 70, utilizing detectors of the type shown in Figure 71. These particular types are used in alpha spectroscopy. This assembly was made to be completely interchangeable with the standard pre-amplifier of the Frisch grid chamber and provides an output entirely compatible with the input requirements of the multichannel analyzers.

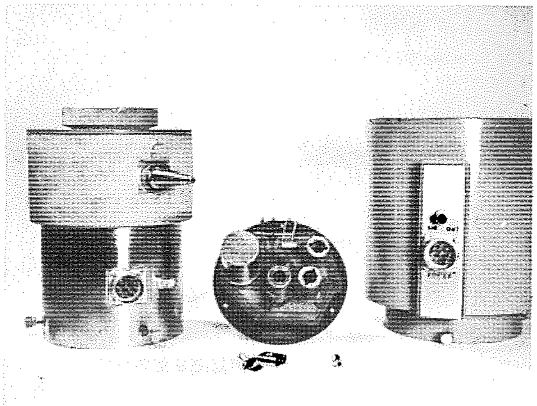


Fig. 70 Pre-amplifier for solid-state detectors.

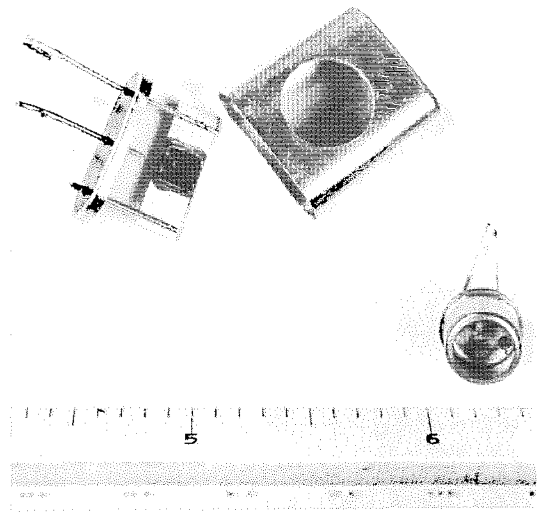


Fig. 71 Solid-state alpha detector.

The maintenance section chief returned from an assignment with the International Atomic Energy Agency to the government of Thailand as an expert on nuclear instrumentation. The development section chief departed to serve in a similar capacity to the government of Turkey. At the request of the International Atomic Energy Agency the maintenance section chief traveled to Vienna in December to act as consultant concerning the tropicalization of nuclear instrumentation and other laboratory equipment being sent into tropical regions of the world.

5. FUTURE PROJECTS

Future projects include the following:

(1) Consideration of movement of the telemetering radio frequency repeater station from the East Butte to a location free from RF interference signals.

(2) Complete calibration and check-out of radiation and weather data telemetering system and the modification of circuits to provide the punched paper tape read-out in a format more compatible with IBM 1620 computer requirements.

(3) Completion and test of the automatic film reading system.

(4) Development and testing of more accurate and refined tools for use in aerial monitoring.

(a) Improved communcations

(b) Improved data transmission and logging

(c) Improved methods for accurate position location.

(5) Design and installation of an audio-amplifier into GM counters for greater ease of monitoring as requested by contractor health physics personnel.

(6) Automation of film badge calibration for the purpose of reduced errors and statistical variation.

(7) Design, fabrication and installation of an improved transistorized pre-amplifier into the existing well-type scintillation counter systems.

(8) Design and fabrication of solid-state switching circuits to couple the outputs of two 400-channel analyzers into one set of data handling and read-out equipment.

(9) Further testing and adaptation of solid-state nuclear radiation detectors for use in the counting room.

XI. ENVIRONMENTAL MONITORING

(Jay S. Silhanek - U. S. Public Health Service*)

1. SCOPE

Due to the interest of the general public in levels of radioactivity in the environment, periodic statements are released to the public indicating the levels of radioactivity in the vicinity of AEC installations. The monitoring program of the Health and Safety Division is designed to detect any increases in environmental radiation due to operations at the NRTS. Air, water and milk samples are collected routinely from fixed stations located beyond the perimeter of the NRTS and analyzed for radioactivity. In addition, strontium-90 is determined in jackrabbit bones, and external radiation levels are determined by a film badge program.

The locations of the sampling stations are shown in Figure 72. Whenever possible, different types of samples were collected from the same location. This was done for better correlation of data. Comparisons then can be made

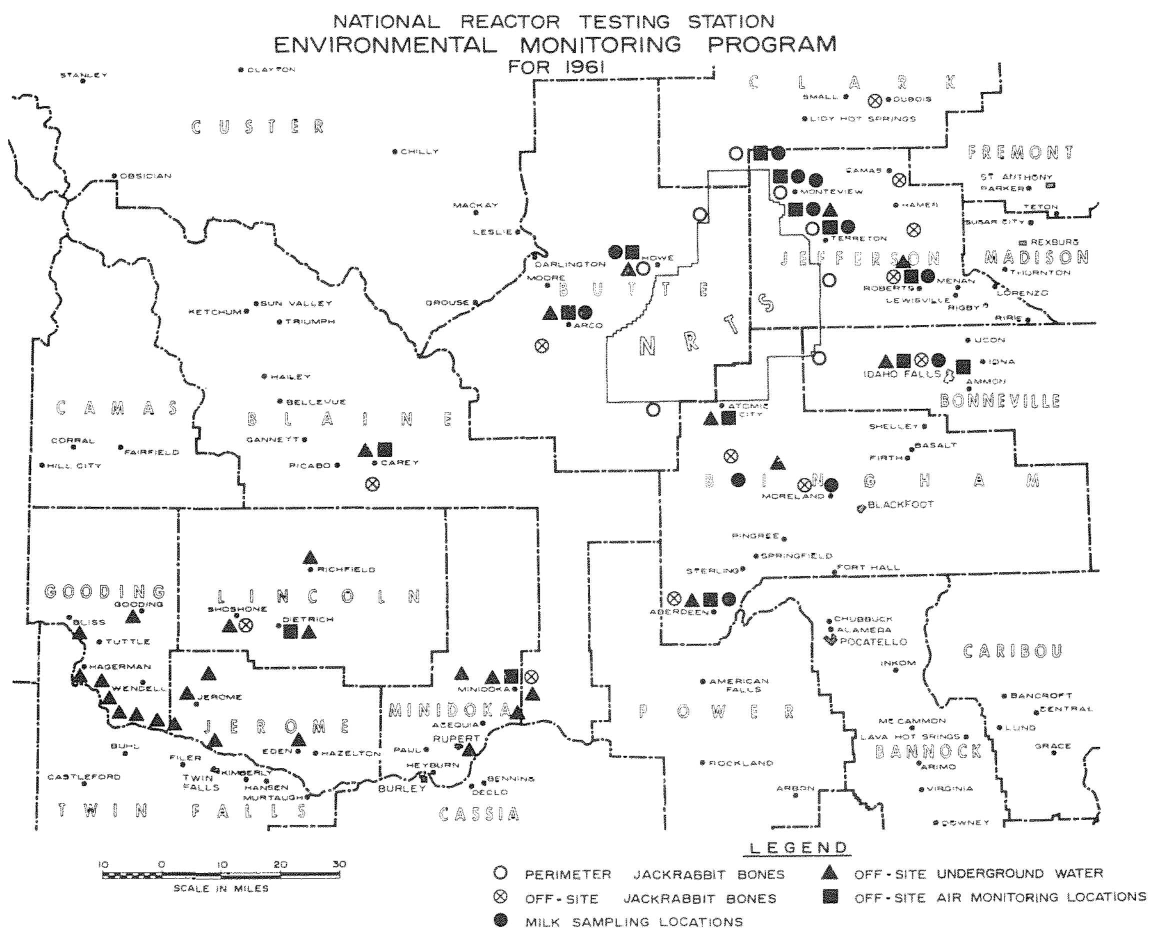


Fig. 72 NRTS environmental monitoring program for 1961.

* Assigned to IDO Health and Safety Division

between different types of sampling methods. Locations for sampling stations are chosen in regard to their wind direction from the site, underground water flow, accessibility, and population density.

A total of 2345 samples were analyzed for radioactivity during the year. The types of samples, number of stations, and approximate frequency of collection is shown in the following data:

Type of Sample	Number of Stations	Approximate Frequency of Collection
Off-site underground water	31	bi-monthly
On-site production well water	22	weekly
Off-site air filters	14	weekly
Perimeter jackrabbit bones	8	quarterly
Off-site jackrabbit bones	12	quarterly
Off-site milk	12	monthly
Area monitoring badges	14	every five weeks

The NRTS is located in a very remote area which, in a large measure, permits controlled releases of radioactivity from the projects with minimum risk to the environs. The AEC is responsible for evaluating environmental activity levels in the vicinity of its installations to assure that the contribution from its operations do not exceed the RCG levels recommended by the Federal Radiation Council. The environmental monitoring program is one of the safeguards employed. Other safeguards are: (a) in-plant controls which include stack monitoring, filtration, absorption and retention tanks; (b) NRTS criteria for the discharge of radioactive materials; and (c) on-site monitoring and sampling during abnormal releases.

2. OFF-SITE UNDERGROUND WATER

Although liquid wastes are monitored at the NRTS before release to the soil or the underground water table, for monitoring purposes off-site samples are taken from locations around the NRTS. As can be seen from the map in Figure 72, most of the samples are taken from an area southwest of the site. This is believed to be the prevalent direction of flow of the underground water. Samples are taken in other directions around the site as a control, as well as to check the possibility of contamination from variations in the regional pattern.

During 1961, 177 samples were collected on a bi-monthly basis from 31 sampling stations. Of the 177 samples analyzed, 160 were less than the detection limit of 4×10^{-9} microcuries per milliliter for alpha activity and the remainder less than 7×10^{-9} $\mu c/ml$. All 177 samples were less than the detection limit of 2×10^{-7} $\mu c/ml$ for beta activity. These indicated results are well below the RCG levels of 10×10^{-9} $\mu c/ml$, alpha, and 30×10^{-7} $\mu c/ml$, beta. All of the 88 off-site water samples monitored for tritium (H-3) were below the detection limit.

Type of Sample	Number of Samples	Maximum Activity of Single Sample ($\mu c/ml$)	Average Activity Per Sample ($\mu c/ml$)
Off-site Underground water	177	$\alpha\ 6.6 \times 10^{-9}$	$\alpha < 4 \times 10^{-9}$
		$\beta\ 2.2 \times 10^{-7}$	$\beta < 2 \times 10^{-7}$
	88	H-3 6×10^{-6}	H-3 $< 6 \times 10^{-6}$

3. ON-SITE PRODUCTION WELL WATER

On-site samples were taken from production wells near the plant sites in order to monitor potable water for personnel consumption and to define possible sources of contamination if it occurred. A separate research study of test wells around two plants indicated the presence of tritium contamination; therefore, analyses for tritium were started in the third quarter of 1961 for on-site and off-site samples.

Specific isotopic analysis would be made on any water sample showing significant alpha or beta activity. Isotopic analysis was not required on any of the water samples collected during 1961.

For the entire year, 789 samples were analyzed from 22 sampling stations on a weekly basis. Only a few samples were above the detection limits.

The tritium analyses indicated low-level contamination which was well below the suggested RCG limits of $30{,}000 \times 10^{-6}\ \mu c/ml$. The tritium detection limit for the method of analysis used is now $4 \times 10^{-6}\ \mu c/ml$.

Type of Sample	Number of Samples	Maximum Activity of Single Sample ($\mu c/ml$)	Average Activity Per Sample ($\mu c/ml$)
On-site production well water	789	$\alpha\ 11 \times 10^{-9}$	$\alpha < 3.5 \times 10^{-9}$
		$\beta\ 4.3 \times 10^{-7}$	$\beta < 2 \times 10^{-7}$
	273	H-3 62×10^{-6}	H-3 $< 5 \times 10^{-6}$

4. OFF-SITE AIR FILTERS

Off-site air samples are collected by passing air through a carbon impregnated MSA-BM 2133 pre-filter followed by an activated carbon cartridge connected to a low-volume vacuum pump. The filter is counted for gross beta activity and the cartridge for gamma activity to indicate the presence of gaseous radioiodine. In addition, a network of high-volume air samples can be activated manually to monitor air activity levels in cases of planned or accidental releases of radioactivity.

An air sampling station was set up in Idaho Falls as a control location to determine the amount of fallout from atmospheric nuclear tests in that area. The radioactive content of the air did increase shortly after the Russian tests began. A graph of the data from this station is shown in Figure 73.

During the year, 653 air samples were collected from 14 permanent stations and analyzed for radioactivity. Although no appreciable increase was noted in the first three quarters, an increase was observed in the fourth quarter of the year due to fallout from the atmospheric tests. All results indicating air concentrations of radioactive materials were still well below the RCG limits of 100 x $10^{-12}\mu c/cc$ (or $100 \mu\mu c/m^3$).

Type of Samples	Number of Samples	Maximum Activity of Single Sample	Average Activity Per Sample
Off-site air filters	653	β 66 $\mu\mu c/m^3$	β 7.1 $\mu\mu c/m^3$

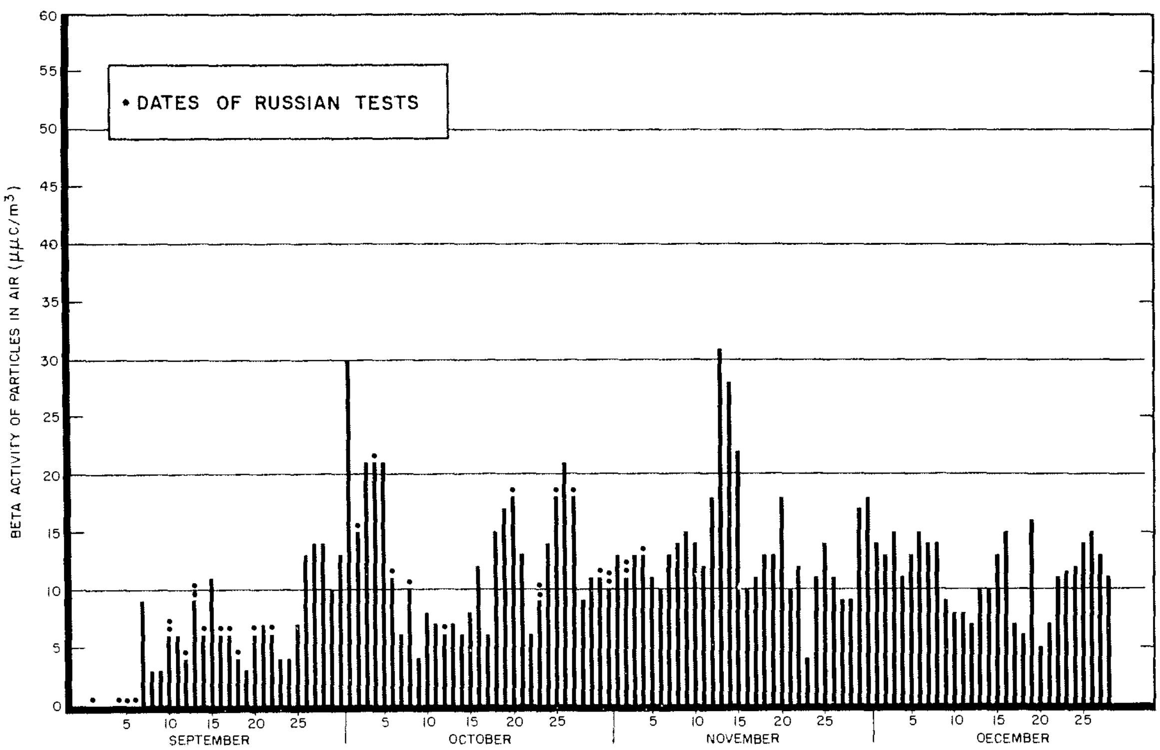


Fig. 73 High-volume air sampling data for Idaho Falls, Idaho, September-December, 1961.

5. JACKRABBIT BONES

The analysis of strontium-90 in the bones of jackrabbits, both on-site and off-site, is used as another guide in monitoring radioactivity in the area. There is no RPG value provided for this biological system since it is very difficult to correlate data for the jackrabbit and the human. The jackrabbit, however, is a good biological indicator of environmental strontium-90 contamination in this arid section of the country and can be used as a guide for general levels of environmental contamination and for other types of sampling programs.

The strontium-90 values for 1961 indicated no significant contamination of the NRTS environs from site operations.

Type of Sample	Number of Samples	Maximum Activity of Single Sample	Average Activity Per Sample
Perimeter jack-rabbit bones	45	37 $\mu\mu c$ of Sr-90/g calcium	11 $\mu\mu c$ of Sr-90/g calcium
Off-site jack-rabbit bones	85	25 $\mu\mu c$ of Sr-90/g calcium	10 $\mu\mu c$ of Sr-90/g calcium

6. OFF-SITE MILK

During 1961 the RCG value for iodine-131 in milk was lowered from 20×10^{-7} $\mu c/ml$ to 1×10^{-7} $\mu c/ml$. This necessitated lowering the analytical detection limit from 2×10^{-7} $\mu c/ml$ to 0.5×10^{-7} $\mu c/ml$. The iodine-131 in milk increased considerably due to fallout from the atmospheric tests, and then decreased gradually from a high in September to less than the detection limit in December.

The 117 samples processed from 12 sampling stations in 1961 disclosed that the average level of radioactivity approached the RCG value of 10^{-7} $\mu c/ml$.

Type of Sample	Number of Samples	Maximum Activity of Single Sample	Average Activity Per Sample
Off-site milk	117	Iodine-131 11×10^{-7} $\mu c/ml$	Iodine-131 $<1 \times 10^{-7}$ $\mu c/ml$

7. AREA MONITORING BADGES

Film badge stations are located around the perimeter of the NRTS site at the same locations as the air sampling equipment. Data were obtained from 118 samples in 14 different locations. For the first two quarters, badges were changed on a monthly basis, while for the last two quarters changes were made on a six-week schedule.

The sensitivity of this method of radiation detection is 10 mrem for beta or gamma radiation. The data indicate the maximum level per badge and the total activity for that station for the sampling interval. The only indication of levels above background was in the first quarter of the year. This probably was caused by low-level radiation following the SL-1 accident.

The total exposure for the year is well below the suggested guide value of 500 mrem/yr γ, 3000 mrem/yr β, and reflects the general background from natural radiation at this general elevation.

Type of Sample	Number of Stations	Number of Samples	Maximum Per Year	Total for Year
Area monitoring badges	14	118	γ 40 mrem	γ<130 mrem
			β 10 mrem	β<100 mrem

XII. APPENDIX
HEALTH PHYSICS APPRAISAL CHECKLIST

A. Description of Facility and Associated Health Physics Hazards

1. Description of facilities

2. Nature of work involved

3. Special HP facilities, offices, labs

4. History or prognosis of unusual HP problems of direct, contemporary nature

5. Plans for new facilities and projects which will have an impact on HP operations

6. Total number of people involved in facility

B. General Operating Philosophies

C. General Health Physics Program Data

1. Organization

   a. General structure

   b. HP relation to top management

   c. HP authorities, lines of authority, division of responsibility, work stoppage authority, delegation of responsibility

   d. HP influence in nuclear safety or safeguard committees

   e. Numbers of professional HP's and technicians and general background philosophies; turnover rate

2. Management support

   a. Interest and participation of management in HP problems

   b. Degree of review of HP policies and standards by management

   c. Management's general attitude toward HP

   d. Degree to which management enhances HP issuances, standards, etc

3. Training and orientation

   a. Material covered and people involved in orientation

   b. Frequency of reorientations

   c. Records of orientation lectures: test given, if any

d. Specialized HP training: who, material, duration, quizzes, etc

e. Procedures for determining effectiveness of training

4. Costs

a. Cost of overall HP activities, in dollars

b. Percent of total operating costs devoted to HP

c. Breakdown of regular time vs overtime paid

D. Routine Operational Health Physics Data

1. Time distribution of personnel

a. Shift structure

b. Percent of technicians' time used for:

(1) Routine surveys

(2) Job monitoring

(3) Research

c. Percent of supervisors' time used for:

(1) Daily routine work

(2) Management meetings

(3) Research

2. Internal inspections and evaluations

a. Effectiveness of corrective action based on internal inspections

b. Who makes inspections

c. Records

3. Policies, standards, written instructions

a. Pertaining to:

(1) Organization and administration (including specific duties)

(2) Radiation and contamination control

(3) Exposure control

(a) Administrative control limits

(b) Authorization for exceeding limits

(c) Action taken following exposures reported in excess of limits

(4) Waste control

(5) Record keeping

b. Distribution

c. Frequency of evaluation and updating

4. Personnel monitoring

a. General badging and recording methods

(1) Special pulls

(2) Visitors and experiments

(3) "Notification of exposure" policy

(4) Recording system; recipients of information for administrative control

b. Review of records

(1) Frequency and discussion of "high" exposures

c. Supervisor's use of film badge data

d. Dosimeter use

(1) General methods of use

(2) Types

(3) Records

e. Urinalysis procedures

(1) Who and when

(2) Handling of reported data

f. Whole-body counting

(1) Who and when

(2) Handling of reported data

5. Protective clothing and equipment

a. Respiratory apparatus

(1) Rules governing use

(2) Filter types

(3) Contained air

(4) Plant air

(5) Availability (placement)

(6) Responsibility for testing and cleaning

(a) Testing methods

(b) Cleaning methods

b. Anti-C clothing

(1) Amounts and types

(2) Issue and collection methods

(3) Rules governing use

(4) Reimbursement policy

(5) Reimbursement and personnel decontamination history

c. Any others, such as special air cleaning equipment, dry boxes, interlocks, etc

d. Remote handling equipment used at instigation of HP

6. Routine surveys

a. Direct radiation

(1) Administrative levels

(2) Equipment used

(3) Responsibility

(4) Frequency and length of time involved

(a) Routine surveys

b. Contamination

(1) Administrative levels

(2) Frequency, time and areas involved in routine surveys

(3) Systems used

(4) Responsibility

7. Instrumentation

a. Portable

(1) Number of each type on hand

(2) Availability (placement)

(3) Dependability checks

(4) Calibration methods and frequency

(5) Mortality

(6) Maintenance

b. In-line

(1) Constant in-plant air monitors

(a) Number, type, placement

(b) Alarm levels

(c) Calibration methods, and frequency

(d) Dependability (history)

(e) Maintenance

(2) Air and liquid effluent monitors

(a) Types and placement

(b) Alarm levels

(c) Calibration methods and frequency

(d) Dependability (history)

(e) Maintenance

(3) Moveable monitoring

(a) Number, types, placement

(b) Alarm points

(c) Calibration

(d) Dependability (history)

(e) Maintenance

(4) Remote area

(a) Description of system(s)

(b) Alarm points

(c) Calibration

(d) Dependability (history)

(e) Maintenance

(5) Fixed personnel

(a) Number, types, location

(b) Alarm points

(c) Calibration

(d) Dependability (history)

(e) Maintenance

(6) Counting and analytical

(a) Number, type, and placement

(b) Calibration methods and frequency

(c) Dependability (history)

(d) Maintenance

8. Access and traffic control

a. General limits on radiation and contamination access

b. Description of signs, barriers, tapes, etc

c. Interlocks and key-access areas

9. Decontamination

a. Facilities

b. Methods

10. Waste disposal

a. Gaseous

(1) Points of release

(2) Principal isotopes

(3) Calculations and sampling data

(4) Normal release rate

(5) Effluent alert data

(6) History of releases

b. Liquids

(1) Points of release

(2) Principal isotopes

(3) Calculations and sampling data

(4) Normal release rate

(5) Control of effluent release

(6) Limits of release

(7) History of releases

c. Solid

(1) Principal material

(2) Method of disposal

(3) Calculations

(4) Limits of release

d. Preparation of waste reports

e. Combustion and incineration facilities

11. Transportation

a. Radiation limits

(1) Off-site

(2) On-site

b. Contamination limits

(1) Off-site

(2) On-site

c. HP responsibility for shipments

d. Labeling requirements

e. History of accidents

f. History of compliance with rules

12. Ventilation

a. General description of built-in air control, including pressure areas and filters

b. Special ventilation methods

c. Hoods, etc

13. Emergency procedures

a. General plan

b. Evacuation alarms

(1) Authority to initiate

(2) Audibility (placement)

c. Frequency of drills

d. Information to personnel

e. Reentry kits and procedures

14. Written procedures

a. Scope

b. Distribution

c. Authority (to write; and enforce)

d. Availability

15. Records and reports

a. Types, completeness and distribution of records for:

(1) Personnel exposures

(2) Overexposures and incident investigations

(3) Handling of visitor exposures and follow-up

(4) Air sample records

(5) Contamination survey records

(6) Water sample records

(7) Area survey records

(8) Records of incoming and outgoing shipments of radioactive materials

(9) Records of waste disposal - shipments, discharges, incinerations

(10) Bio-assay records

(11) Internal inspection reports

b. Reports

(1) Annual exposure reports (internal and external)

(2) Special reports - accidents, exposures in excess of limits

(3) Shipments

(4) Radioactive waste

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