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Technical Guidelines for Maintaining Occupational Exposures as Low as Practicable

Phase I - Summary of Current Practices

R. L. Gilchrist
J. M. Selby
H. L. Wedlick

August 1978

Prepared for the U.S. Department of Energy
under Contract No. EY-76-C-06-1830

Pacific Northwest Laboratory
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TECHNICAL GUIDELINES FOR MAINTAINING OCCUPATIONAL EXPOSURES AS LOW AS PRACTICABLE

PHASE I - SUMMARY OF CURRENT PRACTICES

R. L. Gilchrist
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Pacific Northwest Laboratory
Richland, Washington 99352

SUMMARY

Reducing radiation exposures to as low as practicable is a principle that was first introduced in 1949.[1] However, the recent controversy over the low-level effects of radiation has led the Department of Energy (DOE) to review its programs. One such review was conducted by the Pacific Northwest Laboratory to survey the implementation of the ALAP principle in the DOE laboratories.

This report contains the results of that survey, performed in 18 major DOE installations. The DOE contractors were asked questions concerning the following eight major areas: management, operational health physics, design, dosimetry, instrumentation, training, risk/cost-benefit, and impact of the ALAP philosophy.

The survey revealed several potential areas of concern, which are described in this report. These areas will be addressed in the forthcoming manual, A Guide to Reducing Radiation Exposures As Low As Practicable (ALAP).

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TECHNICAL GUIDELINES FOR MAINTAINING OCCUPATIONAL EXPOSURES AS LOW AS PRACTICABLE (ALAP)

PHASE I - A SUMMARY OF CURRENT ALAP PRACTICES

INTRODUCTION

The principle that radiation exposures should be maintained as low as practicable (ALAP) was first recommended by the National Committee on Radiation Protection in its 1949 report, Permissible Dose from External Sources of Ionizing Radiation.(1) Similar recommendations by the International Commission on Radiological Protection (ICRP),(2,3,4) the National Academy of Sciences - National Research Council,(5) and the Federal Radiation Council(6) outline the evolution of the ALAP principle.

In determining what radiation levels are as low as practicable, it is important to consider social and economic factors. These considerations are necessary if a balance is to be achieved between permitting the use of radiation in industry and protecting public safety.

A search of the literature reveals that little has been published on what constitutes a good ALAP program or how to establish one. Because of this lack of guidance, various government agencies and several private contractors have developed their own programs. This independent action lends itself to diversification of responsibility, which causes overlapping in regulations among regulatory agencies.

To alleviate the overlapping, the Department of Energy (DOE) asked the Pacific Northwest Laboratory (PNL) to prepare a technical document that will clarify ALAP guidelines. The project, as planned, has three phases: 1) identification and characterization of activities at DOE-owned facilities that result in "reasonably avoidable" radiation exposure, 2) in-depth analysis of data and identification of methods for exposure reduction, and 3) development of minimum criteria for ALAP performance. This report presents the results of the first phase of the project; the second and third phases will be covered in the forthcoming manual, A Guide to Reducing Radiation Exposures As Low As Practicable (ALAP).

For Phase I, a survey of existing ALAP programs was made at the 18 major DOE installations listed in Table 1. These sites were selected because they are representative of the variety and complexity of activities being conducted by DOE contractors. An interviewer visited each site and talked with management and operational staff on topics including: instrumentation, training, and facility layout and design. Facility exposure records and studies relevant to ALAP programs were also reviewed.

The results of each of these interviews were put into report form, edited, and returned to the respective contractors for comment. After the results were thus checked for accuracy and any missing information was added, they were correlated and incorporated into this report.

TABLE 1. DOE Contractors Visited for this Study

Allied Chemical Corporation	Idaho Falls, ID
Argonne National Laboratory	Argonne, IL
EG&G	Idaho Falls, ID
Pacific Northwest Laboratory	Richland, WA
Brookhaven National Laboratory	Upton, NY
Lawrence Berkely Laboratory	Berkely, CA
Lawrence Livermore Laboratory	Livermore, CA
Los Alamos Scientific Laboratory	Los Alamos, NM
Mound Laboratory	Miamisburg, OH
National Accelerator Laboratory	Batavia, IL
Oak Ridge National Laboratory	Oak Ridge, TN
(1) Y-12	
(2) X-10	
(3) K-25 (ORGDP)	
Pantex Plant	Amarillo, TX
Rocky Flats Plant	Golden, CO
Sandia National Laboratory	Albuquerque, NM
Savannah River Plant	Aiken, SD
Stanford Linear Accelerator Center	Stanford, CA

CONCLUSIONS AND RECOMMENDATIONS

The field studies reported on here revealed several potential problems that merit additional studies. Comments by many contractors, the lack of standard guidelines, and procedural disagreements among contractors suggested the following 12 areas of concern:

- lack of management commitment
- nonuniformity in management approach
- scattered standards and regulations
- deficiency in documentation of procedures
- lack of dosimetry analysis
- deficiency in instrument correction factors
- lack of formal audit programs
- ambiguity in definition of radiation zones
- lack of criteria for training programs
- ineffective data feedback
- nonuniform design criteria
- deficiency in risk/cost-benefit analysis.

All of these areas will be researched and discussed in the forthcoming manual, A Guide to Reducing Radiation Exposures As Low As Practicable (ALAP).

Although ALAP is not a new concept, the current emphasis is to actively involve all professions in an active role. For example, without the support of management, ALAP will not receive sufficient priority and proper funding. However, without the cooperation of the workers, it will be impossible to reduce radiation exposures to ALAP. Therefore, the first step in establishing a good ALAP program should be to emphasize the team concept, with management and the health physics staff jointly directing the program. This concept, as well as the general philosophy of ALAP, will be elaborated on in the forthcoming manual.

In discussing reducing radiation exposures by implementing an ALAP program, it must be recognized that no two programs will be exactly alike. Therefore, it is necessary to talk in generalities that would apply to all facilities.

SURVEY FINDINGS

1.0 MANAGEMENT

1.1 Commitment and Planning

A good ALAP program should be based on a firm commitment by upper-level management. This commitment, if exemplified by written statements and supported by a planning program with lower management, would encourage active participation by radiation workers, and thereby achieve ALAP.

Although 13 facilities reported that they have management commitment to a general safety program, only eight contractors have a formal statement on reducing radiation exposure to ALAP. The fact that these eight statements range from a two-page document to a multi-page document supports the finding that there is no uniform management approach to planning for reducing exposures to ALAP.

The responsibility for achieving a good ALAP program is normally placed on lower management or the operational health physics staff. However, in one of the five facilities with a formal ALAP statement, upper management works closely with the operational group to plan a method for reducing exposures to ALAP. Another method, which was initiated by one of the five contractors, is to raise the ALAP priority and require upper management to make an informal in-plant investigation and to report their findings to the executive safety council.

1.2 ALAP Objectives

Objectives, clearly defined by management, can give the workers a better understanding of what the ALAP program is striving to achieve. These objectives can be in the form of an overall program direction, a specified reduction in overall exposures, or a specified reduction in individual exposures.

Only four of the contractors reported having a management ALAP objective of overall exposure reduction, and only two of the four specified a desired percent reduction over the previous year's exposures.

1.3 Administrative Manuals

A problem shared by all the contractors is decentralized documentation of ALAP procedures. Some facilities have as many as 20 manuals, each containing a portion of the overall ALAP program. This material needs to be consolidated so it will be easier to define management responsibility and to determine what other information is needed (see section 2.3, Procedure Manuals).

1.4 Health Physics Mode of Communication

All of the health physics personnel contacted said that they have good rapport with upper management and that their safety managers report high enough in the chain of command to fulfill their responsibilities without conflict. At six facilities, the managers of health physics departments report directly to the plant manager or assistant plant manager. At the remaining facilities, the health physics section is at the third to fifth level in the organizational structure.

1.5 Review and Audit Program

An effective internal management review program assures managers that their objectives for ALAP are being met and makes them aware of any need for changes. This direct interaction also emphasizes to the workers that ALAP programs are important. Three contractors reported that they have a management audit to ensure active participation in ALAP.

1.6 Safety Committees

Since radiation protection is closely related to general safety (e.g., industrial hygiene), a large number of facilities assign all safety-related matters to one committee. All of the contractors reported some form of safety program, with management-level accident review committees to investigate special problems or occurrences and to determine their causes. Five contractors reported having special committees to review all work involving radioactive material.

Most facilities have lower-level committees staffed by operational personnel to review the safety of current projects and to watch over daily operations. These committees usually report directly to the general safety committee.

2.0 OPERATIONAL AND ADMINISTRATIVE HEALTH PHYSICS

2.1 Radiation Exposure Planning

Thoroughly understanding each job, before beginning it, enables the health physics staff to plan methods for reducing personnel exposure. This planning can range from simple calculations to complex time and motion studies.

All of the contractors contacted reported that they have guidelines for reviewing and planning jobs to be performed in potentially hazardous areas. These safety guidelines are covered in operational, building, or safe-work procedures, as well as in radiation work permits and in job safety analysis documents.

Prejob planning is used primarily by the operational staff for coordinating personnel and material. Although radiation exposure planning is normally the responsibility of these operational supervisors, they do consult with the radiation safety staff when they anticipate that exposures will exceed specified levels. These levels vary among contractors; however, most of them consult the radiation safety staff when:

- the exposure rate is above a specified level, e.g., 100 mR/hr,
- exposures are expected to be greater than 50 mR/shift or 300 mR/week,
- contamination levels are expected to be higher than normal, or
- the jobs or operations are new.

2.2 Collection and Documentation of Exposure Data

Radiation exposure data is collected by the use of film or more commonly, thermoluminescent dosimeters (TLDs). These dosimeters are normally placed in a security badge holder and worn by all personnel who could receive an exposure. Although most contractors allow personnel to take their badges home, four require that all dosimeters be kept at a central badge station on plant.

Dosimeters are collected monthly, quarterly, or yearly, depending on the worker classification, which is based on exposure criteria (see section 4.1). The dosimeter results are reviewed by the health physics staff at each site and passed on to the line managers. Seven contractors reported using a computer to list and store the exposure information, which is then sent to the field health physicists.

Daily and weekly field records are maintained on pocket dosimeters (gamma pencils), used to supplement the standard dosimeter. Fourteen contractors reported using pocket dosimeters to monitor personnel working in high radiation areas. The pocket dosimeter records are normally discarded after the film or TLD results are received.

2.3 Procedure Manuals

Nine contractors reported an extensive manual system, with three broad catagories of manuals written or reviewed by the health and/or safety section.

1. The laboratory safety manual, which is normally written by the radiation safety staff, summarizes current governing work with radioactive materials and radiation devices. Most of the contractors distribute the manual to first-line supervisors; however, one contractor distributes it to all radiation workers.

2. The building manual, area safety manual, specific project safety manual, protocol, or safety analysis report deals with the safety operations of a specific facility or large project. Most contractors reported that the radiation safety staff formally reviews this manual, which is normally written by operations management and deals primarily with work procedures. Procedural manuals written by the operations staff are not normally reviewed for safety, except on request.

3. Radiation work permits and safety work permits are written for a specific job or operation and normally require review by the safety staff. In some instances, the permit is developed during the planning stages of a job. In most instances, it is a trigger mechanism to make sure all jobs are reviewed for safety.

These documents are generally reviewed and/or revised annually. Dissemination of the proper manual to the appropriate personnel is normally the responsibility of line management.

One contractor requires each building or facility to have an extensive building manual, which is similiar to a brief safety analysis report. It covers all work normally done in the facility; any work not covered by the manual must be approved by the safety department. These building manuals are reviewed during the annual safety audit.

2.4 Supervision of Radiation Areas

Most facilities have high-security areas and badge checks are required to ensure that only authorized personnel enter radiation areas. In a few instances, the security badge is coded with other information related to entry control, radiation-worker status, training, etc., to allow quick identification of authorized personnel.

The management of operations is normally responsible for identifying, barricading, and posting radiation areas, with the advice of the health physics staff. All locations with above-background dose rates and/or potential radioactive contamination are posted as radiation zones.

Posting of radiological conditions varies among contractors and is primarily dependent upon the type of work being done; however, little information was available on this topic. Because the radiological conditions generally change quite frequently, radiation work permits for most areas are updated periodically, based on routine measurements.

2.5 Contamination Control

Contamination control techniques vary considerably among the contractors. After primary control by containment in hoods, glove boxes, and hot cells, the most common contamination control techniques are administrative control of entry to and exit from radiation areas, and surveys to determine the status of contamination control.

Most facilities with potential contamination from transuranics have extensive air sampling programs and routine surveillance programs. Improvements in the air sampling and detection instruments over the past several years have helped improve contamination control. Most contractors now allow the operational staff to make their own contamination survey at their work locations; others still require a health physics technician to monitor the radiation zones, and the staff and objects that leave them. One contractor has the readout and alarm of the air monitoring system routed to a central monitoring station as well as to the work location.

Allowable levels of smearable contamination vary, depending upon the operation. A few contractors allow normal work in areas where smearable contamination exceeds 1000 dis/min; however, when there are levels above 2000 dis/min, protective measures are required. Some contractors have color coded three types of work areas: uncontrolled (clean, no contamination allowed), controlled (contamination potential), and contaminated areas. This system facilitates traffic control and proper use of protective clothing and equipment.

2.6 Waste Management

Little information was available on the impact of waste management on ALAP. One contractor requires that waste for shipment be prepared inside the glove box or hot cell to minimize handling and the associated exposure of personnel. Most of the installations transfer the waste to an outside contractor for ultimate disposal.

2.7 Audit Program

In addition to periodic appraisals and audits by the local Department of Energy (DOE) office, most of the contractors' health and safety departments perform their own internal audit of operational facilities.

An individual or team from the safety staff generally audits each facility annually; facilities with a high potential for hazards or rapidly changing operations are audited more frequently. Most audits are formally conducted to check for compliance on specific items, in cooperation with the responsible facility or operational manager. Instances of noncompliance and/or recommendations are followed up with a second visit within a specified time period.

Audits or appraisals of the safety department are sometimes performed. A team, which sometimes includes outside experts, is formed to review specific functions and operations within the safety department.

3.0 DESIGN AND ENGINEERING

3.1 Health Physics Participation

Fourteen contractors reported on the manner in which the health physics staff participates in the design and engineering of new facilities and the modification of existing facilities. This participation ranges from involvement during the conceptual phase of design projects (implemented by six contractors), to review and approval of completed designs. One contractor stipulates that when a new facility, the modification of existing facilities, process aids, or equipment costs over $2000, the health and safety department must review and approve all work. To ensure a final review of all approved work, several contractors require that the manager of the health physics section sign formal authorization papers.

3.2 Documentation of Procedures or Criteria

For the majority of the contractors, information on the subject of documentation was not obtained. Of the four on which information was available, three contractors reported following the criteria in DOE Manual Chapter 6301. The fourth contractor reported using two manuals, one containing design criteria, and the other explaining the responsibilities and authority of personnel, and how facility planning and engineering tasks should interface.

3.3 Radiation Design Criteria

Approximately one half of the contractors have formal design criteria. (The remaining contractors did not respond.) The major effort of most contractors is to limit routine occupational exposures to less than 1 mR/hr; however, one contractor does not specify an hourly limit, but uses a design criterion of 1 rem/yr instead.

One contractor that handles explosives has designed its facilities so that a serious accident, such as an explosion, would result in the facility collapsing down upon itself. All contamination from such an accident should thus be contained. Overburdens on the order of 15 ft of gravel/sand are the typical methods of achieving this effect.

4.0 DOSIMETRY

4.1 External Dosimetry

The external dosimeter currently used by most contractors is the thermoluminescent dosimeter (TLD). Three facilities did not report the type of dosimeter in use, and six use a combination of beta-gamma film and Nuclear Track (NTA) film. In addition, finger-ring dosimeters and self-reading pencil dosimeters are issued by most contractors as necessary. Pocket dosimeters are also used as a secondary check on exposure for personnel working in areas that may have high dose rates. These dosimeters have an audible warning for use around potential high-rate-of-change areas.

A wide variation in dosimeter exchange periods for radiation workers indicates a need for standardization based on exposure levels and the type of dosimeter being used. Currently, one contractor exchanges all personnel dosimeters every 2 weeks, while another two exchange them on a quarterly basis. All three contractors use the same exposure criteria and the same type of dosimeter. Preliminary studies indicate that the recorded exposures may vary with the frequency of exchange due to a bias in dosimeter analysis, thereby introducing ineffective data feedback.

Nonradiation workers are normally assigned an accident dosimeter in case they inadvertently receive an unusual dose. This type of dosimeter is exchanged and analyzed annually except when an accident occurs.

4.2 Internal Dosimetry

Of the 10 contractors that reported on their internal dosimetry program, nine perform routine bioassays, but all 10 have a program to handle emergencies (accidental exposures). Only five contractors reported that they have facilities for whole-body counting. Two other contractors, which do not have whole-body-counting facilities, require daily nose wipes for staff leaving primary radiation control zones to detect potential internal deposition.

In an effort to prevent internal deposition, several contractors have established a face-mask fitting program. Any employee not properly fitted is not allowed to enter a control zone where masks are required.

4.3 Records and Analysis

To ensure compliance with the Code of Federal Regulations, provide exposure data for trend analyses, and provide personnel with an exposure history, formal dose records are maintained by all 12 of the contractors who responded on this topic.

Six contractors have dosimeter readouts and bioassays analyzed by computer systems. Currently, these readouts provide only individual record sheets and do not summarize or evaluate data by group, craft group, or facility.

Three of the 12 contractors that responded rely on outside companies to evaluate their dosimeters and supply them with written reports of the results. The dosimetry group within each company tabulates and summarizes the data each year in an annual report.

4.4 Quality Assurance

To maintain impartiality in recording exposure levels and provide a good quality assurance program, two contractors send their dosimeters and bioassay samples to an outside contractor for independent analysis. To ensure accurate analysis, spiked samples and dosimeters exposed to known levels of radiation are included. Through this process, these two contractors have determined that the outside contractors do have acceptable quality control programs. Contractors with their own dosimetry facilities have similar quality assurance programs.

5.0 INSTRUMENTATION AND ANALYSIS

5.1 Air Monitoring

Eleven of the contractors reported on their air sampling (monitoring) programs. In most cases, stack monitoring is handled by the health physics section. Several contractors have procedures for routine checks of stack and room air monitors. Programs for monitoring of room air include the use of alpha air monitors, tritium monitors, and particulate samplers.

5.2 Portable Monitoring Instruments

Information on the utilization of portable monitoring instruments was obtained from 15 contractors. Some contractors develop and build their own instruments, while others purchase commercially available models. In most instances, the portable instruments are calibrated and controlled by the health physics or safety groups, although they are often purchased by specific operating groups. Some contractors that have previously developed their own instruments are currently phasing them out in favor of commercially available instruments because of the variety now available. In most cases, instrument selection is based on review of commercial specifications; however, some contractors develop and use their own technical specifications.

Several types of instruments are routinely used by many of the contractors interviewed. The Geiger-Muller (GM) type of instrument is commonly used to survey for contaminated items. Exposure rates may be determined by Cutie Pies, Junos, or similar instruments employing the ionization chamber principle. The portable alpha monitor (PAM), which uses a scintillation detector, is one of the most common instruments used for alpha survey work.

One novel approach to reduction of personnel exposure is the use of dosimeters that continuously telemeter the individuals' exposures to a monitoring station, thus reducing the exposures received by the health physics monitoring staff. Up to six workers may be monitored at one time with this system.

Calibration procedures and frequencies vary considerably among the contractors interviewed for this study. Calibration procedures for dose rate and survey instruments range from source checking at one point on one scale to calibrating two points on each scale. Dose rate instruments are calibrated every 2 weeks by one contractor and every 3 months (6 months for low-range instruments) by another contractor. Some survey instruments are calibrated monthly, and some are calibrated only after failure. Other types of monitors and fixed instruments may be calibrated as often as every 2 months, or as infrequently as annually.

The basic premise behind reducing exposures to ALAP is that the individual exposure level is a known value. A common error in using portable monitoring instruments, however, is to assume that meter readings correspond to exposures received. In an effort to alleviate this problem, one contractor is currently involved in a study to determine the proper correction factors to be applied to various geometric configurations and nonuniform beams. This contractor's goal is to develop computer programs that use source dimension, receptor dimensions, and the distance between the source and receptor to compute a table of correction factors.

5.3 Solid-State Detectors and Gas-Flow Counters

Two contractors provided information on the use of solid-state detectors and/or gas-flow counters in their facilities. One uses a special monitoring instrument with a tissue-equivalent proportional chamber, which offers a time-keeping as well as a dose-rate function. The other contractor has a solid-state, air-sample counter that allows the simultaneous counting and analysis of alpha and beta radiations.

6.0 TRAINING

The contractors' reports show a great variation in the types and frequencies of programs used to train staff in radiation safety. The consensus of the contractors is that this variation is brought about by a lack of standardized training criteria. Strong emphasis is placed on on-the-job training, and health physics technicians are more likely than other personnel to receive a formal training program, which is usually administered by the safety group. Most training, however, is performed as a part-time function by a junior-level staff member; only a few contractors have a full-time training staff.

6.1 New Employees

Initial training and orientation in radiological safety are provided by:

- video tapes or recorded lectures
- on-the-job training from the individual's manager, with or without a formal guide, outline, or check list
- informal communication between the new staff member and the building's radiation safety personnel.

In some plants, all workers receive an orientation with an emphasis on radiological safety and emergency procedures. At other locations, only radiation workers receive an orientation.

Documentation of attendance at orientation sessions ranges from none to the inclusion of attendance records in dosimeter or personnel files and the distribution of computerized printouts to all supervisors.

6.2 Radiation Workers

Radiation workers whose job classifications and duties are listed in various regulations (e.g., nuclear material handlers, reactor operators, machine operators, etc.) are likely to receive formal training and retraining, with documentation of attendance.

Other personnel (lab technicians, senior scientists, etc.) receive training according to requirements outlined in the contractors' manuals. Usually, training an individual is the responsibility of the administrative manager. The bulk of radiation safety training and retraining is therefore conducted on the job and at safety meetings.

Some contractors have regularly scheduled classes in radiation safety. The classes are offered during work hours and may be attended by interested personnel. Many organizations depend on classes offered at local colleges or sponsored by the local chapter of the Health Physics Society for offsite, after-hours education and training. At one facility, yearly retraining of radiation workers is required. This retraining is documented formally and sponsored by the radiation safety department. At most contractor sites, retraining occurs at safety meetings.

The radiation safety training program is usually funded through the safety organization, with the training staff managed by the head of the safety department. (In one organization, training is administered by a central training group that is responsible for job-related or skills training.) In most instances the costs of training are not easily identifiable, particularly the costs of preparation and teaching; however, training is usually considered part of the normal function of the safety staff and is not itemized separately.

Some contractors give training low priority and make little effort to fund it. This stance is not consistent with the philosophy that communication and training are a necessary part of ALAP.

6.3 Radiation Monitors (Health Physics Technicians)

Reports from the contractors indicate a shortage of qualified health physics technicians and a lack of standardized training programs and recognized definitions or job descriptions for this group. The National Registry of Radiation Protection Technologists may meet the training and definition needs for senior technicians, but a standard descirption of the junior technician level and minimum training requirements is needed.

Contractors use the following mechanisms to assure adequate training and qualification of their health physics technicians:

- Hire qualified technicians (e.g., Navy-trained engineering lab technicians from the nuclear branch of the service, or graduates of one of the few schools offering related associate degree programs).
- Offer onsite, a 40-50-hr classroom session for trainees. Such classes are offered by those contractors that have formal training programs, usually in conjuction with on-the-job training. One contractor requires 1 year of experience and training before the technicains are allowed to work unsupervised.
- Establish formal grading and qualification levels for health physics technicians, with several years or more required to move from trainee status to the senior technician level. Persons with previous experience or a few years of college may enter at an advanced level. One contractor has a formal training and certification program to allow technicians to advance. Formal classroom training, on-the-job training with a rigorous check list, and written and oral examinations are part of the program. Senior-level technicians are required to be recertified every 2 years.

Many contractors depend solely upon on-the-job training for their technicians, and also hire only experienced professional personnel. New personnel are assigned to work with experienced senior technicians, and informal classroom lectures are given as needed.

Some contractors have co-op programs with local schools and colleges, or an agreement is reached to apply some work experience and training toward partial credit leading to an associate degree.

Health physics technicians at some contractor sites are concerned with industrial safety, as well as radiological safety. (Training of the technician in the industrial safety field was not reviewed for this report.) The duties of the technicians depend upon the responsibilities and administrative functions of the safety department.

6.4 Professional Staff (Management and Health Physics)

The professional health physics staff normally attends off-site training classes as necessary. None of the contractors reported having a formal training program for the safety professionals.

Two contractors offer formal classes for middle-management personnel, to review and update operational management responsibilities in safety. These programs appear to be structured toward the ALAP philosophy and result in a high level of safety awareness. Table 2 summarizes the findings on these topics.

6.5 Registration and Certification

Most contractors urge their staffs to obtain registration and/or certification within their safety disciplines. Most contractors also provide tuition reimbursement for outside classes but do not provide funds for examination fees. Some organizations require certification by the American Board of Health Physics for senior-level positions. In no instance was it reported that registration or certification is recognized by salary compensation; however, such qualifications do play a strong part in promotions and merit increases.

7.0 RISK/COST-BENEFIT

Risk, in terms of radiation, can be defined as the probability of intentional or unintentional exposure to an individual or group that has a harmful consequence. Throughout the nuclear industry, the careful weighing of expected benefit versus the risk of radiation exposure has always been recognized and accepted; however, little effort

TABLE 2. Formal Programs for Radiation Safety Training

	Number of Contractors Replying		
	Yes	No	Not Specified
New Employees			
Orientation	9		9
Documentation	3	1	14
On-Job-Training	6		12
Radiation Workers			
Formal Training	9	1	8
On-Job-Training	8		10
Retraining	1		17
Health Physics Technicians			
Formal Training	11	1	6
On-Job-Training	7		11
Retraining	7		11
Professional Staff (Management and Health Physics)			
Management Formal Training	2	1	15

has been made to identify a cost associated with risk-benefit.

The difficulty of addressing the problem of risk/cost-benefit proceeds from the unequal assumption of risks, benefits and costs by various members of industry. If these imbalances are to be ameliorated, some method of equating the various unrelated factors must be developed. The different kinds of risks must be treated differently and should only be equated through the use of weighting factors. This process of comparison requires an analytical approach as opposed to the subjective method that is currently the most commonly used.

On the subject of risk/cost-benefit analysis, the U.S. Environmental Protection Agency has said:

> "Perhaps the most important problems are those for which there are no data--the effect of today's radiation ten generations hence, the probability of a nuclear meltdown, the future buildup of nuclear wastes--but, at best, only guesses which may be off by several orders of magnitude. Here, benefit-cost analysis cannot be done in terms of dollars or other common units but, with a different focus, it can identify issues which must be recognized if rational decisions are to be made. The questions of who pays (rural people, future generations) versus who benefits (city people, present generation); of maximum and minimum possible harm from a given course of action; of alternative course of action, can be spelled out."(7)

The weight of risk or benefit versus cost has been investigated by six DOE contractors in an effort to determine a dollar value per man-rem. The results range from $1,000 to $10,000 but most contractors agree that these numbers are not currently being used because of lack of information on how to effectively use risk/cost-benefit analysis. This lack of understanding is clearly demonstrated by the remaining contractors: nine have not performed a risk/cost-benefit analysis and four feel that the usefulness of such information is limited.

Since risk/cost-benefit analyses are relatively new, there is little documentation of methods, procedures, and results. The area of risk/cost-benefit is clearly one that needs a great deal of work.

8.0 IMPACT OF ALAP PHILOSOPHY

The general consensus of the 12 contractors responding to this topic is that the ALAP philosophy, being simply good health physics practice, has been in use as long as their facilities; therefore, it has made no significant impact on their programs. The recent emphasis on ALAP, however, has led two of the 12 to begin an internal investigation of their programs.

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