Occupational Dose Reduction at Department of Energy Contractor Facilities:

Study of ALARA Programs - Status 1990

B.J. Dionne, C.B. Meinhold, T.A. Khan and J.W. Baum

March 1992

DEPARTMENT OF NUCLEAR ENERGY
BROOKHAVEN NATIONAL LABORATORY, ASSOCIATED UNIVERSITIES, INC.
UPTON, NEW YORK 11973

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FOREWORD

The reduction of radiation exposures to levels that are as low as reasonably achievable (ALARA) is a continuing objective of the Department of Energy (DOE) and its contractors. In an effort to assess the progress and current status of ALARA program implementation within the Department, the Office of Environment, Safety and Health (EH) contracted with the Brookhaven National Laboratory (BNL) in 1988 to survey ALARA programs at selected DOE contractor facilities. During 1989 - 1990, BNL ALARA Center staff made site visits at twelve DOE contractor facilities to assess program implementation and identify whether the ALARA program requirements included in DOE Order 5480.11, "Radiation Protection for Occupational Workers," were being met.

This report describes the results of the BNL survey, and identifies progress that has been achieved since an earlier review of ALARA program implementation was sponsored by DOE Headquarters in 1978. This report also includes information that should prove valuable to the various DOE contractors in implementing their specific facility ALARA programs. Section 3.3.2 of the report, for example, summarizes ALARA equipment or facility design changes that have been utilized by various DOE contractors to successfully reduce dose or contamination levels. The supplemental volume to this report contains examples of generic "good practice" documents typically associated with ALARA program implementation (i.e., an ALARA policy statement, ALARA training lesson plans, ALARA audit checklists). These good-practice ALARA program documents were developed based on the best representative examples from the visited contractor facilities, supplemented as necessary with examples from the commercial nuclear industry; and are provided as an optional resource for incorporation into existing contractor ALARA programs.

Review of DOE exposure trends identifies that ALARA efforts have resulted in significant decreases in the magnitude of collective and individual exposures over the past ten years. Continued emphasis and upgrading of ALARA program implementation is necessary, however, particularly in light of current and future shifts in DOE facility missions and in response to recent recommendations to lower occupational exposure limits. This information on the status of contractor ALARA programs and the good practice examples of ALARA program documents should contribute to information exchange among the contractor facility ALARA program staff and will hopefully stimulate additional cost and dose reductions across the DOE complex.

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ABSTRACT

This report provides the U.S. Department of Energy (DOE) and its contractors with information that will be useful for reducing occupational radiation doses at DOE's nuclear facilities. In 1989 and 1990, health physicists from the Brookhaven National Laboratory's (BNL) ALARA Center visited twelve DOE contractor facilities with annual collective dose equivalents greater than 100 person-rem (100 person-cSv). The health physicists interviewed radiological safety staff, engineers, and training personnel who were responsible for dose control.

The status of ALARA practices at the major contractor facilities was compared with the requirements and recommendation in DOE Order 5480.11 "Radiation Protection for Occupational Workers" and PNL-6577 "Health Physics Manual of Good Practices for Reducing Radiation Exposure to Levels that are as Low as Reasonably Achievable". The information and data collected are described and examples of successful practices are presented. The findings on the status of the DOE Contractor ALARA Programs are summarized and evaluated. In addition, the supplement to this report contains examples of good-practice documents associated with implementing the major elements of a formally documented ALARA program for a major DOE contractor facility.

EXECUTIVE SUMMARY

Introduction

The DOE's Office of Environment, Safety and Health is responsible for developing radiation protection policy and guidance for DOE and contractor nuclear facilities. In December 1988, DOE Order 5480.11 entitled, "Radiation Protection for Occupational Workers" was issued which, in part, strengthened DOE's long-standing policy for taking every reasonable effort to maintain exposures below the limits, and to avoid unnecessary exposures to radiation. In April 1988, DOE contracted with Brookhaven National Laboratory (BNL) to review, evaluate, and summarize ALARA techniques, methods, and practices that reduce occupational dose and the spread of radioactive material within DOE contractor facilities.

This study, by the BNL ALARA Center on ALARA programs at DOE contractor facilities, is a follow-up to one made by Battelle Pacific Northwest Laboratories from 1976 to 1978. This report describes the current status and effectiveness of ALARA programs at DOE contractor facilities.

Method

From May 1988 to January 1990, health physicists from BNL's Department of Nuclear Energy visited twelve contractor facilities to collect information on the implementation and documentation of their ALARA programs. These facilities were selected because they had a total collective exposure of 100 person-rem/yr (100 person cSv/yr) or greater in 1985:

1. Brookhaven National Laboratory - Associated Universities, Inc.
2. Feed Materials Production Center - Westinghouse
3. Hanford Company - Westinghouse
4. EG&G Idaho, Inc.
5. Idaho Chemical Processing Plant - Westinghouse
6. Los Alamos National Laboratory - University of California
7. Mounds Facility - EG&G
8. Oak Ridge National Laboratory and Y-12 Plant - Martin Marietta
9. Pacific Northwest Laboratory - Battelle Memorial Institute
10. Pantex Plant - Mason and Hanger-Silas Company
11. Rocky Flats Plant - EG&G
12. Savannah River Site - Westinghouse

A judgment as to what is a reasonable dose is a fundamental problem in evaluating whether a DOE contractor is maintaining occupational exposures as low as is reasonably achievable. The philosophy of ALARA suggests that there is no a priori dose level below the limits, nor is there a collective dose which is acceptable or unacceptable for all facilities. Therefore, BNL's focus was on the organization and programmatic aspects of a formalized ALARA program, and, to a lesser degree, on the trends in occupational exposures.

The requirements and guidelines for the ALARA program were taken from DOE Order 5480.11 and Battelle report PNL-6577, and were used as the criteria to determine the current status. The health physicists from the BNL ALARA Center visited the facilities, interviewed the contractor's staff, and collected and evaluated the data and information. Examples of successful ALARA techniques and practices are presented in this report. A qualitative and quantitative evaluation was performed which summarizes the data and information which is pertinent to the DOE contractor ALARA programs. In addition, the supplement contains examples of good-practice documents that may be used to implement the major elements of a formally documented ALARA program for a major DOE contractor facility.

Findings

Programs to control exposure at the DOE contractor facilities have been effective in reducing collective and individual exposures. From 1978 to 1988, the DOE collective dose equivalent dropped by approximately 50%, and the average individual dose decreased by 15%. In addition, the recent average annual individual dose for workers has been less than three percent of the occupational dose limit (whole body), i.e., less than 150 mrem/yr (0.15 cSv/yr). The status of the contractors' ALARA programs has evolved significantly since they were last studied during 1976 to 1978. The majority of the ALARA programs reviewed contained the following key elements:

- A policy statement and commitment from management to the ALARA philosophy,
- Documentation which describes implementation of the program and assists in training,
- Designated organizational responsibility and authority for implementing the program,
- A system of in-house audits to evaluate the ALARA program's effectiveness and to ensure that it is improved,
- A structure for setting administrative control levels, reference levels, and goals, measuring the accomplishments of the levels and goals, analyzing dose trends, and judging performance,
- A strategy to ensure that techniques for reducing dose and contamination are considered when developing and reviewing procedures, performing work, research, production, and operation, as well as non-routine operations, and
- A strategy for incorporating ideas for reducing dose and contamination into the initial phases of engineering, design, and construction.

However, there were several areas in which these facilities did not have programs to meet all the requirements of DOE Order 5480.11. Most significant was a lack of formal procedures and capability to perform cost-benefit (i.e., optimization) analysis.

Conclusions and Recommendations

For the most part, the ALARA programs at the visited DOE contractor facilities are in compliance with the ALARA requirements in DOE Order 5480.11 and have been effective in reducing collective and individual exposures over the past 10 years. However, to pursue excellence, increased formalization of the essential program elements is required. The dedicated staffing, formalization, and degree of documentation of the ALARA programs within the nuclear power industry can be used as a model of excellence.

Examples of generic documents associated with implementing the major elements of the ALARA program are provided in this report and in the appendices. These good practice ALARA program documents were developed based on the best representative examples from the visited contractor facilities, supplemented as necessary with examples from the commercial nuclear industry; and are provided as an optional resource for incorporation into existing contractor ALARA programs. Other techniques or practices may be as good or better (the authors would appreciate receiving information on them). The extent of committing resources to implement the various elements of the ALARA program should be commensurate with the magnitude of the radiological hazard. The good-practice documents provided in the supplement can be applied, as appropriate, to the various DOE contractors in the implementation of their facility ALARA programs.

Environment, safety, and health managers and ALARA program coordinators made several suggestions which DOE could implement to further promote ALARA programs at DOE contractor facilities. These are identified in Section 4.3, Conclusions and Recommendations.

The following recommendations are made by the staff at the BNL ALARA Center to enhance ALARA programs at DOE facilities where these improvements are warranted:

- Provide special ALARA training to first-line supervisors to strengthen their awareness and support of the ALARA program, including a better understanding of the biological risk which forms the basis of the ALARA concept.
- Expand the training program for radiation workers to include a module informing them of the DOE and company policy towards ALARA, and to improve their awareness of their responsibilities.
- Provide special ALARA training to design engineers to provide them with the knowledge needed to incorporate into new designs or facility modifications features which will maintain radiation exposures and the spread of radioactive materials as low as reasonably achievable.

- Fill the vacant positions for ALARA program coordinators and radiological engineers with experienced professionals.
- Increase the frequency and scope of internal appraisals of ALARA programs.
- Develop methods for cost-benefit evaluations and other techniques for ALARA decision-making.
- Develop a collecting and recording system to track the collective dose for jobs, construction projects, and experiments which exceed an established reference level, e.g., 1 person-rem, including a standardized method of categorizing similar work.

Increased attention towards dose reduction is warranted in light of the recommendation in the 1991 International Commission on Radiological Protection publication 60 that occupational dose limits be reduced. Persistent and proactive emphasis on reducing individual and collective dose equivalents should reduce the financial and operational impact to DOE associated with the future reductions in occupational dose limits. By approaching occupational dose reduction on a broad front, using a variety of cost-effective approaches, excellence in radiological safety and reduced impact from the potentially impending reduction in occupational dose limits can be achieved.

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1. INTRODUCTION

This study was performed by the Radiological Sciences Division, Department of Nuclear Energy, Brookhaven National Laboratory (BNL) for the U.S. Department of Energy (DOE) Office of Health. The purpose of the project was to review, evaluate, and summarize techniques and practices that reduced occupational doses and the spread of radioactive materials within DOE contractor facilities. This study is a follow-up to a similar one made by Battelle Pacific Northwest Laboratory (PNL) during 1976 to 1978.¹

During May 1988 to January 1990, the ALARA practices at twelve contractor facilities were reviewed by the health physicists from BNL's ALARA Center. Data were collected to evaluate the status of the contractors ALARA programs against the requirements and recommendations in DOE Order 5480.11, "Radiation Protection for Occupational Workers",² and PNL-6577, "Health Physics Manual of Good Practices for Reducing Radiation Exposures to Levels that are As Low As Reasonably Achievable (ALARA)."³ During the visits to the contractors' facilities, various elements of an ALARA program were documented and key staff members interviewed.

This report summarizes the effectiveness of implementation of the ALARA program at DOE contractor facilities. The supplement to this report contains good-practice examples of generic ALARA program documents that may be integrated into existing programs. It is anticipated that highlighting and summarizing these new, successful dose-reduction practices and ALARA documents will encourage their widespread application, facilitate program evolution, reduce duplication of effort, stimulate exchange of information, and result in consistent programs where appropriate.

1.1 Background

Reducing radiation exposure to levels that are "as low as reasonably achievable" has long been the goal of the radiological safety programs at the DOE and its predecessor agencies, the Energy Research and Development Administration and the Atomic Energy Commission (AEC). Because of concerns over possible genetic effects, the AEC stated in its 1960 orders that "...human exposure to ionizing radiation shall be kept as low as practicable."³ However, although the practice of ALARA was recognized during the 1960s and early 1970s, the primary emphasis of radiation protection programs at most AEC facilities was directed towards controlling exposures within the dose limits (see Table 1.1-1).

In the 1970s the emphasis shifted, as a result of evidence of the increased incidence of certain solid tumors in Japanese survivors of the atomic bombs and in British spondylitic patients. In 1972, the United Nations Scientific Committee's report on the Effects of Atomic Radiation (UNSCEAR 72)⁴ and the National Academy of Sciences Advisory

Table 1.1-1. Chronology of Radiation Standards
Occupational External Whole Body Dose Equivalent Limits, 1947-1990.¹

ICRP International Commission on Radiological Protection		NCRP National Council on Radiation Protection & Measurement		FRC (1960 - 1970) Federal Radiation Council EPA (1970 - Present) Environmental Protection Agency		AEC (1946 - 1975) Atomic Energy Commission ERDA (1975 - 1977) Energy Research & Development Administration DOE (1977 - present) Department of Energy		
Year	Criteria	Reference	Criteria	Reference	Criteria	Reference	Criteria	Reference
1947	0.2 R/day 1.0 R/wk		0.1 R/day 0.5 R/wk	NBS Handbook #18			0.1 R/day	NCRP NBS Handbook #18
1949	0.2 R/day 1.0 R/wk		0.3 R/wk	NBS Handbook #42			0.1 R/day	
1950	0.3 R/wk		0.3 R/wk				0.3 R/wk 3.9 R/13 wks	NBS Handbook #42 AEC (DBM)
1951	0.3 R/wk		0.3 R/wk				3.0 R/series 2.0 R/series 3.9 R/13 wks	AEC (LASL/WT 204) AEC (Ranger/ Greenhouse) AEC (DBM)
1952	0.3 R/wk		0.3 R/wk				3.0 R/13 wks	AEC (DBM)
1954	0.3 R/wk		3.0 R/13 wks 0.3 R/wk Max 15 rem/yr	NBS Handbook #59			3.0 R/13 wks 0.3 R/wk Max 15 rem/y	NCRP NBS Handbook #59
1957	0.3 R/wk		5 rem/y Avg 12 rem/y Max	Addendum NBS Handbook #59			3.0 R/13 wks 0.3 R/wk Max 15 rem/y	
1958	0.1 rem/wk 3.0 rem/13 wks 5 (N-18) rem	ICRP Report #1	0.3 rem/wk Max 3 rem/13 wks 12 rem/y Max 5 (N-18) rem	Addendum NBS Handbook #59			0.3 rem/wk 3.0 rem/13 wks 12 rem/y Max 5 (N-18) rem	NCRP NBS Handbook #59
1959	0.1 rem/wk 3.0 rem/13 wks 5 (N-18) rem		0.3 rem/wk Max 3 rem/13 wks 12 rem/y Max 5 (N-18) rem				0.3 rem/wk 3.0 rem/13 wks 12 rem/y Max 5 (N-18) rem	
1960	0.1 rem/wk 3.0 rem/13 wks 5 (N-18) rem		0.3 rem/wk Max 3 rem/13 wks 12 rem/y Max 5 (N-18) rem		3 rem/13 wks 5 rem/y Avg 12 rem/y Max 5 (N-18) rem	FRC Report #1	3 rem/13 wks 5 rem/y Avg 5 (N-18) rem	FRC Report #1
1965	5 rem/y Max ²	ICRP Report #9	0.3 rem/wk Max 3 rem/13 wks 12 rem/y Max 5 (N-18) rem		3 rem/13 wks 5 rem/y Avg 12 rem/y Max 5 (N-18) rem		3 rem/13 wks 5 rem/y Avg 5 (N-18) rem	
1971	5 rem/y Max ²		5 rem/y ³	NCRP Report #39	3 rem/13 wks 5 rem/y Avg 12 rem/y Max 5 (N-18) rem		3 rem/13 wks 5 rem/y Avg 5 (N-18) rem	
1974	5 rem/y Max ²		5 rem/y ³		3 rem/13 wks 5 rem/y Avg 12 rem/y Max 5 (N-18) rem		5 rem/y ³	NCRP #39

Table 1.1-1. Chronology of Radiation Standards
Occupational External Whole Body Dose Equivalent Limits, 1947-1990.¹ (Cont.)

ICRP International Commission on Radiological Protection		NCRP National Council on Radiation Protection & Measurement		FRC (1960 - 1970) Federal Radiation Council EPA (1970 - Present) Environmental Protection Agency		AEC (1946 - 1975) Atomic Energy Commission ERDA (1975 - 1977) Energy Research & Development Administration DOE (1977 - present) Department of Energy		
Year	Criteria	Reference	Criteria	Reference	Criteria	Reference	Criteria	Reference
1977	5 rem/yr	ICRP 26	5 rem/yr ³		3 rem/13 wks 5 rem/yr Avg 12 rem/yr Max 5 (N-18) rem		5 rem/yr ²	ERDA Append. 0524
1981	5 rem/yr		5 rem/yr ³		3 rem/13 wk 5 rem/yr 12 rem/yr max 5(N-18 rem)		5 rem/yr ²	DOE 5480.1 Ch. XI
1987	5 rem/yr		5 rem/yr Age x 1 rem/yr (guidance only)	NCRP 91	5 rem/yr	EPA Rad. Prot. Guide to Federal Agencies	5 rem/yr ²	
1989	5 rem/yr		5 rem/yr Age x 1 rem/yr (guidance only)		5 rem/yr		5 rem/yr	DOE 5480.11
1990	2 rem/yr Avg. over 5 yr <5 rem in any year	ICRP 60	5 rem/yr Age x 1 rem/yr (guidance only)		5 rem/yr		5 rem/yr	

¹Information derived in part from page 2 of DOE/EV-0045 (Rev. 2-81), "Study of Anticipated Impact on DOE Programs from Proposed Reduction to the External Occupational Radiation Exposure Limit."

²3 rem/13 wks for special cases and if 5(N-18) not exceeded.

³15 rem/yr for special cases.

Committee's report on the Biological Effects of Ionizing Radiation (BEIR I)⁵ were published. From these data and other information, the International Commission on Radiological Protection (ICRP) in Publication 22⁶ (1973) stated, "As any exposure may involve some degree of risk, the Commission recommends that all unnecessary exposures be avoided, and that all justifiable exposures be kept as low as is reasonably achievable, economic, and social considerations being taken into account."

In the mid- to late-1970s, other studies on the effects of radiation were published.^{7,8,9,10,11,12,13,14,15,16} These controversial studies reported an increased incidence in cancer at the Hanford Reservation in Richland, Washington; increased incidence in leukemia among naval shipyard workers in Portsmouth, Maine; and an increased incidence of solid tumors around the Rocky Flats Plant in Colorado.

In 1976, under contract with DOE headquarters, PNL reviewed the operations of DOE's contractors in implementing the ALARA philosophy. First, they identified and characterized the ALARA programs at eighteen DOE facilities, based on surveys in 1977 and 1978. In August 1978, PNL's report, PNL-2663, was published. "Technical Guidelines for Maintaining Occupational Exposures As Low As Practicable - Summary of Current Practices"¹ summarized the findings and identified twelve areas of concern. The second part of the project evaluated data collected from site visits and developed minimum performance criteria for the contractor ALARA programs. This effort resulted in the publication of DOE/EV/1830-T5 in April 1980 entitled, "A Guide to Reducing Radiation Exposure to As Low As Reasonably Achievable (ALARA)."¹⁷

During the period that DOE was evaluating and improving the effectiveness of their ALARA programs, the ICRP suggested that sufficient epidemiological data were available to support a risk-based system of dose limitation. On January 17, 1977, ICRP Publication 26¹⁸ was issued, with basic radiation protection standards that would later result in a major revision of radiation protection regulations and dose limits throughout the world. Based mainly on risk estimates from UNSCEAR 77,¹⁹ the (age-18) $\times$ 5 rem (5 cSv) lifetime limit was dropped and the continuation of the 5 rem/yr (5 cSv/yr) limit was justified, based on the assumption that the resulting average dose would be less than 1 rem/yr (1 cSv/yr), resulting in a lifetime risk of 10^{-4} . This level of risk compared favorably, at that time, with the annual accidental fatality rate for safe industries (DOE had already imposed a 5 rem/yr (5 cSv/yr) annual limit in 1974, based on guidance given in ICRP-9²⁰ and NCRP-39²¹).

Because of the significant changes resulting from ICRP-26,¹⁸ and initial proposals for changes to U.S. Environmental Protection Agency (EPA) federal radiation protection guidance,²² a major revision to the DOE requirements for radiation protection was developed during the 1980s. These requirements, contained in DOE Order 5480.1A, Chapter XI, became effective on August 13, 1981. Strong emphasis was placed on limiting occupational exposures to reasonably achievable levels. During this decade, the DOE

contractor ALARA programs continued to evolve along the guidelines described in DOE/EV/1850-T5, sometimes called the "ALARA Guide."

In 1987, the National Council on Radiological Protection and Measurements (NCRP) revised its limits for exposure to ionizing radiation. These revisions were prompted by evidence on cancer incidence and genetic effects,^{23,24,25} the decrease in risk levels associated with "safe industries", and the inclusion of non-radiation mortality risks into the total occupational risk. The NCRP Report No. 91²⁶ recommended that:

1. The use of (age-18) x 5 rem (5 cSv) be discontinued,
2. Emphasis be placed on the upper boundary of the 5 rem/yr (5 cSv/yr), which should only be approached when the cost of further dose reduction is unreasonable, and
3. Operations be conducted to ensure that the lifetime effective dose equivalent to an individual should not exceed their age x 1 rem (1 cSv).

In the mid-1980s, under an existing contract with PNL, DOE headquarters supported an update to the original "ALARA Guide." DOE requested that this revision reflect advances in technology, changes in national and international guidance, and revisions to federal requirements. In June 1988, PNL-6577, "Health Physics Manual of Good Practices for Reducing Radiation to Levels that are As Low As Reasonably Achievable (ALARA)"³ was published; this document is the current guide for ALARA programs and is endorsed in DOE Order 5480.11.

In 1988, UNSCEAR²⁷ revised their risk estimates based on the updated epidemiological data from Japanese survivors, and on a new dosimetric system for analyzing this data. The previous lifetime risk of mortality due to cancer,^{19,28} on which the recommendations from ICRP-26 were based, was considered low by as much as a factor of four. The BEIR V report,²⁹ released in December 1989, also reviewed the new data on Japanese cancer incidence and dosimetry, and increased their risk estimates by a factor of three to four over the BEIR III³⁰ values.

In April 1988, the DOE expanded the scope of work at the BNL ALARA Center to include monitoring ALARA efforts at DOE contractor facilities. These efforts were in addition to the NRC-funded research on occupational dose reduction at NRC-licensed nuclear power plants.

DOE Order 5480.11, "Radiation Protection for Occupational Workers,"² which became effective on January 1, 1989, superseded DOE Order 5480.1A, Chapter XI. This major revision also incorporated the EPA recommendation entitled, "Radiation Protection Guidance to Federal Agencies for Occupational Exposure,"³¹ which was approved by the President of the United States on January 20, 1987. The revision strengthened DOE's

previous position on ALARA by requiring a documented program for maintaining exposures ALARA. It read as follows:

a. Maintaining Radiation Exposures As Low As Reasonably Achievable (ALARA). It is DOE's policy that exposures to radiation resulting from DOE operations be maintained within limiting values... and as far below all limiting values as reasonably achievable. This policy applies to annual, committed, and cumulative dose equivalents. Plans and programs used to assure that occupational radiation exposures are maintained ALARA shall be documented. The DOE publication PNL-6577, 'Health Physics Manual of Good Practices for Reducing Radiation Exposure to Levels that are As Low As Reasonably Achievable (ALARA),' presents a guide on useful practices for achieving the objective of the ALARA process.

In August 1988, shortly after publication of the revised "ALARA Guide" (June 1988), and shortly before DOE 5480.11 (December 1988) was promulgated, the DOE Office of Safety Policy and Standards finalized the initiation of the project described in this report. The purpose of the project was to review the status of the ALARA practices within the DOE complex with regard to the revised requirements and guidance. Responsibility for this project now lies with the Office of Health.

Section 2 of this report describes the methods used to assess ALARA program implementation at the major contractor facilities. Section 3 describes the findings on the status of implementation of the DOE ALARA programs. Section 4 presents a qualitative and quantitative evaluation of the effectiveness of the DOE contractor ALARA programs. Section 4.3 gives the conclusion of this study and recommendations to further reduce occupational dose at DOE contractor facilities.

2. DESCRIPTION OF METHODS

To assess the status and effectiveness of DOE ALARA programs, twelve contractor facilities were visited from May 1988 to January 1989. Before visiting the DOE facilities, health physicists from BNL reviewed the literature to identify earlier research on DOE ALARA programs.^{1,3,17} After this review, the requirements and recommendations for implementing an ALARA program from DOE Order 5480.11 and PNL-6577 were identified. Next, questions were developed to systematically collect the information needed to evaluate the status of DOE contractors' ALARA and radiological engineering programs. Three surveys were also developed: the first, to identify those ALARA incentives which most effectively motivate managers, the second, to identify those techniques which make workers aware of the need to keep exposures ALARA, and the third, to identify the key elements of an ALARA program. The following four job classifications were targeted for interviews:

1. Environment, Safety and Health Manager (Exhibit A)
2. Facilities Engineering Manager or Radiological Engineer (Exhibit B)
3. Radiation Protection Manager or ALARA Program Coordinator (Exhibit C)
4. Training Supervisor or Radiation Protection Trainer (Exhibit D)

The twelve facilities visited were those which had recorded an annual collective dose equivalent greater than approximately 100 person-rem (100 person-cSv) in 1985.³² The 100 person-rem (100 person-cSv) cutoff was selected to obtain a reasonable number of DOE contractor facilities to visit, and also to encompass the major facilities from the perspective of radiological safety. Each facility, listed below, was visited for two to four days by one or two professionals, who gathered information and held discussions with the health physics, training, and engineering staff responsible for implementing the ALARA and radiological engineering programs.

1. Brookhaven National Laboratory - Associated Universities, Inc.
2. Feed Materials Production Center - Westinghouse
3. Hanford Company - Westinghouse
4. EG&G Idaho, Inc.
5. Idaho Chemical Processing Plant - Westinghouse
6. Los Alamos National Laboratory - University of California
7. Mounds Facility - EG&G
8. Oak Ridge National Laboratory and Y-12 Plant - Martin Marietta
9. Pacific Northwest Laboratory - Battelle Memorial Institute
10. Pantex Plant - Mason and Hanger-Silas Company
11. Rocky Flats Plant - EG&G
12. Savannah River Site - Westinghouse

These facility visits focused on a review of the programmatic aspects of an occupational ALARA program and the implementation of DOE Order 5480.11 ALARA

requirements; time and manpower considerations prevented a detailed analysis of program effectiveness.

After visiting the facilities, the health physicists evaluated the information and drafted a report. Good practice examples of typical ALARA program documentation also were developed by combining documents used by the major DOE contractor facilities and/or from ALARA programs at commercial nuclear power plants. The draft report and good-practice documents were circulated to the DOE contractors that were visited and to the BNL Ad Hoc Dose Reduction Steering Committee for their review and comment.

Several comments were received on the topics of administrative control levels and cost/benefit analysis. A follow-up questionnaire was forwarded to each facility's ALARA program coordinator on April 4, 1991 to collect the needed information to adequately resolve these concerns (see Exhibit F). A summary of the responses has been incorporated into this report. This report describes the status of the major ALARA program elements at the DOE contractor facilities. In addition, a qualitative and quantitative evaluation of the effectiveness of the ALARA programs was performed in an attempt to determine if occupational doses are being maintained as low as reasonably achievable.

3. ALARA PROGRAM FINDINGS

This section provides the findings of the ALARA program from facilities visited during May 1988 to January 1990, organized into the following major categories:

1. Administration and Organization,
2. Dose Control Practices and Databases,
3. Conduct of Operation, Procedures, and Equipment.

A survey was conducted to evaluate the relative priorities of and the extent of use of, the ALARA program elements. These elements are listed in Exhibit E and were derived from the requirements of DOE Order 5480.11², the recommendations of PNL-6577,³ and from a similar study performed at commercial nuclear power plants³³. Twelve environment, safety and health managers and twelve ALARA program coordinators were asked to rate the relative importance of the various program elements, on a scale from one to five (5 = high priority, 4 and 3 = medium priority, and 2 and 1 = low priority). In addition, they were asked if the element was used at their facility. If there was a conflict about the use of an element, the answer was verified by examining the documentation and/or by interviews with the environment, safety and health manager, and/or ALARA program coordinator.

Table 3.1-1 shows the relative priority for the various ALARA program elements and number and percentage of facilities which used the element. A limitation of these results is they indicate the use of the element and not its effectiveness.

3.1 Administration and Organization

The elements that constitute the administration and organization of a formally documented ALARA program were reviewed and their status summarized:

1. Policy and Management Commitment,
2. ALARA Program Manual,
3. Training Programs,
4. Organization, Responsibility, and Authority,
5. ALARA/Radiological Safety Committee, and
6. Audits.

TABLE 3.1-1 ALARA PROGRAM ELEMENTS

ALARA Program Elements ^a	Priority Rating ^b			Facilities that Used Element	Percent Used
	High	Medium	Low		
1. Good Employee ALARA Attitude	19	5	0	7	58
2. ALARA Policy and Management Commitment	18	6	0	11	92
3. ALARA Design Review	14	10	0	10	83
4. ALARA Program Coordinator	14	10	0	9	75
5. Job-Specific Radiological Procedures	13	11	0	10	83
6. Radiological Goals and Tracking System	14	10	0	10	83
7. ALARA Training for Radiation Protection Technician	13	10	1	9	75
8. ALARA Training for Radiation Workers/Researchers	10	13	1	7	58
9. ALARA Job/Experiment Reviews	9	14	1	9	75
10. ALARA Organization and Responsibilities	9	14	1	7	58
11. ALARA Committee	10	12	2	8	67
12. Database System for Collective Doses	9	13	2	12	100
13. ALARA Program Appraisal	7	15	2	8	67
14. ALARA Training for Design Engineers	6	16	2	4	33
15. ALARA Training for General Employees	9	10	5	10	83
16. Annual or Special ALARA Reports	8	11	5	10	83
17. ALARA Training for Administrators	6	17	1	3	25
18. Safety Suggestion Program	6	13	5	12	100
19. Cost/Benefit Methodology	4	14	6	3	25

^aExhibit F contains descriptions of the ALARA program elements.

^bTwelve environmental, safety and health managers and twelve radiation protection managers or ALARA program coordinators rated the priorities.

3.1.1 ALARA Policy Statement and Commitment from Management

Commitment from management at all levels and throughout the organization is an essential characteristic of a successful ALARA program. This key element is stated as a basic recommendation in PNL-6577. The revised "ALARA Guide" states that "...a clear-cut ALARA policy statement shall be formally issued by the facility director."³

ALARA policy statements and commitment from management were rated as a high-priority element by the environment, safety and health managers, and the ALARA program coordinator or radiation protection managers (see Table 3.1-1). ALARA policy

statements were issued by the facility director at eleven of the twelve facilities. A good-practice example document for an ALARA policy statement is shown in Appendix A in the supplement.

All twelve environment, safety and health managers, or their equivalents, stated that their upper management demonstrated their commitment to ALARA verbally and by their actions. However, the majority of the managers, and several ALARA program coordinators or radiation protection managers, believed that an improvement in attitude toward ALARA and support by first-line supervisors was needed. The environment, safety and health managers and ALARA program coordinators or radiation protection managers rated good attitudes toward ALARA by employees as the highest priority of ALARA program elements (see Table 3.1-1). However, only 58% of the individuals surveyed felt that workers at their facility had good attitudes.

A survey was conducted to evaluate what motivates line managers to support occupational dose reduction and what reminds a worker to practice ALARA. The incentives for managers and techniques for stimulating worker awareness were derived from a similar study performed at nuclear power plants for the Nuclear Regulatory Commission by the BNL ALARA Center.³³ Forty-eight individuals, twelve each of environment, health and safety managers, engineering managers, ALARA program coordinators or radiation protection managers, and training supervisors were asked to rate, on a scale from one to five, the priority of various incentives for managers and various techniques for stimulating worker awareness. In addition, these individuals were asked to state if the incentive or technique was used at their facility.

Table 3.1-2 shows the priority of the incentives which motivates management to practice ALARA, and the number and percentage of respondents who felt that the incentive was used at their facility.

The two highest rated and most utilized management incentives are:

1. Improved personnel relations due to management's concern for health and safety, and,
2. Concern for fellow workers.

The highest-rated management incentives, related to employee performance are:

1. Beneficial performance review for good dose reduction, and,
2. Directive from the plant's director for line management to promote ALARA at the staff level.

TABLE 3.1-2 ALARA INCENTIVES FOR LINE MANAGEMENT

Manager ALARA Incentives ^a	Priority Rating ^b			Number Indicating Incentive Used	Percent Used
	High	Medium	Low		
1. Improved Personnel Relations Due to Management's Concern for Health and Safety	25	22	1	39	81
2. Concern for Fellow Workers	25	21	2	40	83
3. Beneficial Performance Review for Good Dose Reduction	22	24	2	27	56
4. Director Level Directive for Line Management to Promote ALARA at Staff Level	25	17	6	30	62
5. Good Public Relations for Favorable Press Release	21	24	3	30	62
6. Establish National Reputation as a Low-Dose Facility	22	20	6	27	56
7. Allow Increased Usage of Experienced Workers	18	24	6	32	66
8. Avoid Technical Safety Appraisal Findings for Failing to Follow ALARA Requirements in DOE Order 5480.11	18	22	8	33	68
9. Avoid Probable Causation Liability Suits	18	20	10	31	64
10. Avoid Adverse Job Security for Poor ALARA Performance	12	22	14	11	23
11. Obtain Monetary Savings from Production and Labor Savings	12	20	16	22	46

^aForty-eight DOE contractor personnel rated the priority of each incentive and indicated if the ALARA incentive was used at their facility.

^bTwelve people from each group were surveyed: environmental, safety and health managers; radiological engineers, radiation protection managers or ALARA program coordinators; and training supervisors.

Other highly rated incentives, reflecting a manager's concern to be perceived positively by the public, are:

1. Establish good public relations from press releases that are favorable, and,
2. Establish a national reputation as a low-dose facility.

Table 3.1-3 shows the priority of the techniques to make workers more aware of ALARA, and the number and percentage of respondents who said that the techniques were used at their facility.

TABLE 3.1-3 TECHNIQUES FOR WORKER ALARA AWARENESS

ALARA Awareness Techniques ^a	Priority Rating ^b			Number Indicating Technique Used	Percent Used
	High	Medium	Low		
1. Worker/Researcher Involvement in ALARA Job Reviews	26	22	0	37	77
2. Periodic Verbal Reminders from Line Management	25	20	3	38	80
3. Publicize Workers Dose and Facility Total Dose vs. Goals	19	26	3	29	60
4. Publicizing Implementation of Employee's Suggestions	13	33	2	15	31
5. Visible ALARA Program Coordinator	20	21	7	25	52
6. Suggestion Program	15	27	6	36	75
7. Publicize Receipt of ALARA Suggestion Awards	9	35	4	13	27
8. Visible ALARA Office	14	24	10	19	40
9. ALARA Posters in the Facility	8	30	10	15	31
10. ALARA T-Shirts, Hats, and Pens	0	27	21	2	4

^aForty-eight DOE contractor personnel rated the priority of each technique and indicated if the technique was used at their facility.

^bTwelve people from each group were surveyed: environmental, safety and health managers; radiological engineers; radiation protection managers or ALARA program coordinators; and training supervisors.

The two most popular techniques to remind workers to reduce their dose, are the following:

1. Workers' or researchers' involvement in ALARA reviews of the job or experiment, and,
2. Verbal reminders to workers from line management.

Good attitudes towards dose reduction can be developed by training workers and managers about the risk from radiation exposure and the reason behind the ALARA philosophy, teaching them specific techniques for their job or craft which reduce dose and the spread of radioactive contamination, and impressing upon them the benefits of and consequences for failing to practice it. Rewards issued by the facilities for workers promoting ALARA practices included the following:

1. Day off with pay,
2. Savings bond,
3. Front-row parking space,
4. Picture in facility newsletter,
5. Prizes for winning ALARA slogan or logo contests, and

6. Dinner for two at a local restaurant.

Reported negative consequences for workers failing to practice ALARA included:

1. Potential for increased radiological risk,
2. Impact on worker's performance review,
3. Potential to exceed administrative dose control guide or DOE occupational dose limit,
4. Potential for increasing exposure to fellow workers,
5. Potential to contaminate fellow workers,
6. Potential to contaminate facility, and
7. Negative findings on technical safety appraisals or "Tiger Team" audits.

"ALARA Awareness Campaigns" also were successfully used at contractor facilities to develop an improved attitude in workers. These campaigns involve ALARA logo contests, poster contests, slogan contests, presentations at monthly safety meetings, ALARA hot lines, and publicity campaigns in the company newsletter.

3.1.2 ALARA Program Manual and/or Procedures

DOE 5480.11 requires documenting of "...plans and programs used to assure that radiation exposures are maintained ALARA."² An ALARA program manual or a series of approved ALARA program procedures provides a formal, written description of how the program is implemented. At a minimum, the manual must describe the implementation of the required program elements in DOE 5480.11, e.g., ALARA training, radiological design criteria, and internal audits of an ALARA program, and also should include the relevant guidance from PNL-6577. The depth and complexity of the program should be proportional to the relative radiation and contamination levels, and the degree of radiological hazard involved in carrying out the facility's mission.

The ALARA program manual is typically approved by the facility's director. The use of ALARA program manuals or procedures was not included as a specific program element in the survey; however, it is expected that this element would have been rated as a high priority based on observed frequency of use. ALARA program manuals were available at eight of the twelve facilities (the other four facilities had ALARA procedures); a review of these documents shows that the majority identified and described the implementation of the following key program elements:

1. Responsibilities/authorities,
2. Goals,
3. ALARA training,
4. ALARA job/experiment reviews, and
5. ALARA design reviews.

In addition to these key elements, an ALARA program manual at a nuclear facility should reflect the relative priority and degree of implementation of the program elements shown in Table 3.1-1. It can be anticipated that those elements rated as a high priority by the survey's respondents will be fundamental to most or all DOE ALARA programs (see Exhibit F for a description of each element):

1. Good employee ALARA attitude,
2. ALARA policy and management commitment,
3. ALARA design reviews,
4. ALARA program coordinator,
5. Job-specific radiological procedures,
6. Goals and tracking system,
7. ALARA training for radiation protection technicians.

Appendix B shows a good-practice example of an ALARA program manual, which incorporates DOE Order requirements and these highly rated elements.

3.1.3 ALARA Training Programs

All individuals who may enter a radiologically controlled area, and line managers who supervise in radiological areas, must be instructed on the health risks associated with radiation and on basic principles for radiation protection. DOE 5480.11 requires that radiation workers and radiation protection technicians receive initial training, and retraining at least every two years. In addition, all employees are required to receive training in radiation safety within one month of their initial assignment.² PNL-6577 also recommends that specific ALARA training be given to managers and supervisors, as well as to planners, schedulers, and design engineers.³

The following types of ALARA training programs were rated and used at the contractor facilities:

<u>Training Type</u>	<u>Priority</u>	<u>Percent Used</u>
1. General Employee	Low	83
2. Radiation Worker/Researcher	High	58
3. Radiation Protection Technician	High	75
4. Engineer and Planner	Medium	33
5. Manager and Supervisor	Low	25

During the visits to contractor facilities, lesson plans were collected on the various types of ALARA training programs. Most facilities have ALARA training for general employees, radiation workers, and radiation protection technicians, consisting predominantly of introducing the ALARA concept, and discussing time, distance,

shielding, and protective practices for controlling contamination. Good practices for lesson plans for these types of training are shown in Appendix C; these lesson plans conform to the guidance contained in ORAU 88/H-99, "Guide to Good Practice in Radiation Protection Training."³⁴

Only two examples of lesson plans for Engineer ALARA Training, and one example of Administrator Training were obtained. A good practice for a lesson plan for Manager and Supervisor ALARA Training is also included in Appendix C.

Those training supervisors responsible for radiation safety training were interviewed to determine the status and needs in the ALARA training area. The percentages of training supervisors who indicated that they would like to receive training material for the various types of training were as follows:

<u>Types of Training</u>	<u>Percent Needed</u>
1. General Employee	55
2. Radiation Worker/Researcher	73
3. Radiation Protection Technician	82
4. Engineer	91

Ninety-one percent of the training supervisors chose video tapes as the preferred training media for these ALARA training programs; 45% chose slides/tapes, and 54% wanted lesson plans with student manuals.

Job-specific training for high-dose jobs was performed at several of the facilities. Some facilities had specialized training. Examples of mock-ups and video tapes that were used for high-dose job training included the following:

1. Mock-up of reactor vessel,
2. Mock-up of coolant tube nozzle trench,
3. Mock-up of "band-aid" for calcine cyclone separator,
4. Mock-up of automatic welding machines for piping,
5. Mock-up for testing reactor cooling tubes,
6. Mock-up for repairing remote manipulators,
7. Video tape of pump repair in tank farm,
8. Video tape of dry fuel storage, and,
9. Video tape of weapon assembly.

When asked, "What suggestions do you have for improving ALARA training at DOE?", the training supervisors responded as follows:

1. Remind workers about ALARA from time to time.

2. Stimulate more communication between facility training personnel throughout the DOE complex.
3. Develop examples of lesson plans, video tape programs, slide/tape programs, student manuals, and examinations for ALARA training.
4. Continue the Training Resource and Data Exchange (TRADE) program.
5. Improve the job-specific training for radiation workers that includes ALARA.
6. Improve the training facilities that include mock-ups and craft-type equipment.
7. Develop a database of the various types of ALARA training programs that are used within and outside DOE.
8. Develop an ALARA training program specific for design engineers.
9. Provide training to promote and develop ALARA attitudes.
10. Establish the lines of communication within the organization for effectively implementing the ALARA program.
11. Establish ALARA performance criteria for each group of personnel; develop a method to measure performance, and distribute the performance data to all personnel.

3.1.4 ALARA Organization and Responsibilities

The application of the ALARA principle by workers requires the support, cooperation, and coordination of numerous functional groups, including operations, maintenance, production, research, engineering, planning/scheduling, training, and radiation protection. A well-defined ALARA organization, together with detailed ALARA responsibilities, will assure the coordination among all these groups. Therefore, the responsibilities of the various personnel involved in the ALARA program, especially line management, must be clearly defined and documented.

PNL-6577 recommends establishing specific and formal assignments of ALARA responsibility. In addition, it suggests that management designate an individual to coordinate the program with the independence, authority, and major responsibility to make it effective.³

ALARA organization and responsibilities were rated as a medium priority and were formally documented at seven of the twelve facilities visited; a good-practice example is shown in Appendix D.

At each of the contractor facilities, the environment, safety and health manager, the radiological engineer, and the ALARA program coordinator or the radiation protection manager were all questioned on their ALARA responsibilities. In general, they were ware of their role in implementing the ALARA program.

Nine of the twelve facilities had assigned an individual to coordinate the ALARA program (three were acting in a temporary capacity). However, six of the twelve facilities were seeking an individual to assist in, or act as, the ALARA program coordinator. Lack of the timely assignment of a permanent, full-time professional was considered by several Environment, Safety and Health managers to be an impediment in implementing an effective program.

Half of the facilities had no radiological engineer in the engineering department or they did not have an engineer with a health physics background to review designs for radiological safety. Several facilities employed individuals with electrical, mechanical, or chemical backgrounds for radiological reviews and safety evaluations. All twelve contractor facilities send design packages, involving radioactive systems to their Environment, Safety and Health Department for a safety review.

A common concern at the facilities was the inability to attract technically qualified professionals to fill these vacancies. Another frequently voiced concern was that the responsibility of first-line managers and supervisors for reducing employees' doses and the spread of radioactive materials was sometimes compromised to meet production or research needs.

3.1.5 ALARA/Radiological Safety Committee

As suggested in PNL-6577, the ALARA/Radiological Safety Committee is an independent oversight group which is appointed by, and reports to, the facility director or president on matters pertaining to the ALARA program. The relevant technical disciplines should be represented and chosen from departments involved in radiological activities. The chairperson should be the head of the contractor facility or an individual appointed by, and reporting directly to, the facility director. PNL-6577 provides a basic recommendation that the committee keep accurate records of its deliberations and document any significant actions.³

The ALARA/Radiological Safety Committee was rated as a medium priority and was used at eight of the twelve facilities. Most of the committees were involved in developing collective dose goals.

Nine facilities provided copies of their ALARA/Safety Committee's charters (one committee had not convened a meeting in two years). The charters had the following common areas of responsibility:

1. Review the status of occupational and off-site dose trends, ALARA goals, and the effectiveness of the ALARA/Radiological Safety program,
2. Review radiological incidents, accidents, problems, audits, and evaluations, and recommend corrective actions,
3. Evaluate ALARA/radiological safety suggestions and track the status of approved suggestions, and,
4. Review selected construction projects, jobs, experiments, and new production processes that are radiologically intensive, and review their associated procedures to ensure that reasonable steps are incorporated to reduce dose and the spread of radioactive material.

A good practice example for an ALARA/Radiological Safety Committee charter is shown in Appendix E.

3.1.6 ALARA Audits

Management is responsible for reviewing, auditing, and evaluating the effectiveness of their ALARA program. These audits must be conducted by a technically qualified individual or may be assigned to the ALARA Committee. DOE 5480.11, which became effective January 1, 1989, requires that contractors conduct internal audits of the ALARA program as often as necessary, but no less frequently than every three years;² these audits must follow the guidelines in DOE 5482.1B.³⁵ PNL-6577 recommends that a quality assurance audit be conducted on the ALARA program at least annually.³

Appraisal of the ALARA program was rated as a medium priority, and only three of the twelve facilities performed appraisals. Concerns were expressed about the lack of qualified independent auditors.

ALARA program implementation has routinely been included as an assessment area during the former EH Technical Safety Appraisals (TSAs) and the current EH Tiger Team assessments. A review of TSA and Tiger Team findings and concerns specific to the ALARA area was conducted using the EH Safety Performance Measurement System (SPMS) Computer Assisted Tracing System (CATS) subdirectory. The following lists the TSA findings reported and the number of facilities which received this type of finding:

TSA ALARA Findings/Concerns (September 1986 to March 1990)

- Formal documentation of the program - 5
- Internal audit of the ALARA program - 5
- Radiological goals - 5
- Dose/dose rate and air sample database - 4

- ALARA Committee - 3
- ALARA responsibilities - 3
- ALARA policy - 2
- ALARA staffing - 2
- ALARA training - 1
- ALARA annual reports - 1

Tiger Team Assessment (August 1989 to July 1990)

As for Tiger Team assessment findings, fifty-three percent of the first 16 facilities assessed demonstrated that a formally structured, auditable program was not in place with established milestones to ensure that exposures are maintained as low as reasonable (ALARA). The titles and the number of the supporting concerns were as follows:³⁶

- A formal, documented As Low As Reasonably Achievable Program had not been implemented as required by DOE 5480.11 - 4
- The ALARA program does not ensure that collective exposures are kept as low as reasonably achievable, as required by DOE 5480.11 - 1
- External radiation exposure control is not adequate to minimize exposures or to quickly recognize that higher than normal exposure is being received by personnel - 1
- The ALARA principles were not incorporated during the handling and processing of radioactive samples - 1
- Inadequate precautions are taken to avoid exposures to uranium decay products when cleaning out large UF₆ cylinders in preparation for periodic hydrostatic tests - 1
- The existing Radiation Work Permit form lacks information required to ensure work "as low as reasonably achievable" - 1
- ALARA programs for the prime contractors do not have established goals and milestones as required by DOE 5480.11 - 2
- Management has not assured the performance of job As Low as Reasonably Achievable reviews will result in the work being performed ALARA as required by DOE 5480.11 - 1
- Management has not established radiological action levels that require escalation of the As Low as Reasonably Achievable review process to higher management - 1

DOE 5480.11 and PNL-6577 were reviewed to identify the requirements for ALARA and radiological engineering programs; these requirements were compiled into an audit checklist. Appendix F shows a good-practice example document for an audit checklist for an ALARA program, and Appendix G shows a good practice for an audit checklist for radiological engineering. These checklists can be used to determine compliance with the applicable requirements, but do not evaluate the effectiveness of the program nor performance in achieving ALARA goals.

An internal appraisal should also be performed periodically to review the performance in achieving ALARA goals, and to evaluate the effectiveness and degree of implementation of the ALARA and radiological engineering program. To appraise the performance in achieving goals, information is needed on the status of the quantitative and qualitative ALARA goals, such as those described in sections 3.2.3 and 3.2.4. To appraise the effectiveness and the degree of implementation of the program, each of the applicable ALARA program elements listed in Table 3.1-1 should be reviewed. An appraisal of the effectiveness of the ALARA and radiological engineering programs in reducing occupational doses to levels that are reasonably achievable is subjective and requires professional judgment, and would involve:

- A review of representative jobs, experiments, or production to determine if all reasonable dose-reduction techniques were incorporated and, if not, whether there is sound justification for their omission.
- A review of representative modifications and new facilities which are completed, as well as modifications and new facilities which are being designed, to determine if reasonable radiological design features were incorporated and, if not, whether there is sound justification for their omission.

A personal-computer-based system to perform radiation safety and ALARA program appraisals was developed by DOE's Field Office, Savannah River, under contract with NUS Corporation. This system provides audit and appraisal checklists, as well as audit and appraisal reports. The large database contains criteria on ALARA compiled from DOE Orders, mandatory standards, other standards and guidelines, and good-practice documents. This system has the potential to provide consistency, as well as to efficiently streamline the time-consuming process of documenting audits and appraisals,³⁷ but, as with many customized software packages, it may require modifications to meet the user's needs.

3.2 Dose Control Practices and Databases

The elements that constitute the quantitative aspects of a formally documented ALARA program were reviewed and the status summarized:

1. Cost/benefit methodology,
2. Administrative radiological control levels,
3. Quantitative ALARA goals,
4. Qualitative ALARA goals, and,
5. Dose control data, databases, and ALARA reports.

3.2.1 Cost/Benefit Methodology

The policy of DOE is to operate its facilities and conduct its research to maintain radiation exposures as far below the prescribed limits as is reasonably achievable. Optimization is the process of making something, such as a design, system, or operational practice as perfect, functional, or effective as possible. ICRP-55³⁸ states that "...optimization provides a basic framework of thinking wherein it is proper to carry out some kind of balancing of the resources put into production, and the level of protection obtained against a background of other factors and constraints, so as to obtain the best that can be achieved in the circumstances." ALARA is synonymously defined in DOE 5480.11 as "An approach to radiation protection to control or manage exposures (both individual and collective to the work force and general public) as low as social, technical, economic, practical, and public policy considerations permit. As used in this Order, ALARA is not a dose limit but a process, which has the objective of dose levels as far below applicable limits of the Order as reasonably achievable."²

To determine if alternatives will reduce dose and the spread of radioactive contamination to as low as is reasonably achievable, a quantitative method or decision-making technique should be employed. DOE 5480.11² requires that design objectives use the optimization principles, such as those discussed in ICRP-37³⁹ when justifying changes in facility design to control occupational exposures. ICRP-55³⁸ also provides relevant guidance on optimization and the decision-making process. DOE 5400.5 requires that "...contractors develop a program to implement the ALARA process for all activities that cause dose to the general public."⁴⁰ Furthermore, DOE 5400.5 states that "... Factors to be considered, at the minimum, shall include:

1. The maximum dose to the public,
2. The collective dose to the population,
3. Alternative methods of processing, treating, controlling, and operating radioactive effluent systems,
4. The dose associated with each alternative,
5. The cost for each technological alternative,
6. Examination of the changes in costs associated with the various alternatives, and,
7. Examination of the changes in societal impact associated with the various alternatives."⁴⁰

In addition, PNL-6577 states that the following minimum steps are needed for cost-benefit analysis to optimize dose reduction:

- "1. Identify all possible options...
2. For each option, determine both the individual and collective dose equivalents that will result...
3. For each viable option, identify all associated costs and determine the net cost for each option by summing the identified costs...
4. Determine the cost equivalent of the doses resulting from each option...
5. Sum the costs identified in Steps (3) and (4) to determine the total net cost for each option...
6. The option with the lowest total net cost is the optimal option...
7. A sensitivity analysis should be performed to determine how the solution depends on the assumptions that are required to perform the optimization analysis..."³

Cost/benefit methodology was rated by the twenty-four contractors as the element with the lowest priority; only three facilities had performed and documented a cost/benefit analysis. Most decisions to incorporate items to reduce dose and the spread of radioactive material relied upon "good engineering judgment" rather than on formally documented analysis. Eight of the twelve facilities had not established a value for the cost of a person-rem (person-cSv). The four facilities that had a value used those values for radiation detriment boundaries recommended in DOE/EV/1830-T5, i.e., <\$2,000 per person-rem (person-cSv) is acceptable; \$2,000 to \$60,000 per person-rem (person-cSv) is questionable; and >\$60,000 per person-rem (person-cSv) requires management's approval.¹⁷ These values can be compared to the range of results obtained during the PNL study from 1976 to 1979, which cited \$1,000 to \$10,000 as the value of the person-rem (person-cSv) used.

The following reasons for not performing cost benefit analysis were given in response to the follow-up questionnaire (Exhibit E):

- It is a subjective process, which often involves estimates or projections of savings and costs. Their reliability is questionable and their outcome can be manipulated.
- There are difficulties in quantifying the cost or weighing the various socio-political factors.
- It can be a complicated and difficult process, which requires a knowledge of engineering economics and, on occasion, sensitivity analysis.
- Management is not familiar with the methodology of converting dose savings to cost savings and, therefore, is not willing to endorse or promote a methodology.
- There is a lack of guidance on performing cost/benefit analysis and on selecting an appropriate monetary value for the radiation detriment, i.e., dollar per person-rem.

- There are no clear requirements nor criteria for when a cost/benefit should be performed.
- It can be costly and time-consuming to formally document a cost/benefit analysis.
- There are a lack of radiological projects or modifications which are significant enough to warrant a formal cost/benefit analysis.

These barriers must be overcome for this key element of an ALARA program to be more widely used.

Lastly, when all environment, safety and health managers were asked: "What documentation would you use to show that your program is ALARA?," they unanimously responded "collective-dose trends." However, many cautioned that changes in operations, production, and research must be factored in, together with changes in the radiological conditions and intensity of these activities, when using such trends to evaluate the success of an ALARA program. ALARA may be said to be achieved when, under constant radiological and operating conditions, dose trends exponentially approach some optimum value. Other documentation which could demonstrate that a contractor's efforts are maintaining exposure and the spread of radioactive materials to levels that are ALARA are as follows:

1. Trends of the average annual individual effective dose equivalent.
2. Trends of the percentage of the facility's area which is contaminated.
3. Trends of the number of confirmed internal uptakes.
4. Trends of the number of incidents of external contamination of personnel.

Again, caution must be exercised in reviewing these trends to account for those factors which are not related to ALARA performance, e.g., facility shutdown.

3.2.2 Administrative Radiological Control Levels

DOE's policy is to implement radiation protection standards that are consistent with the Presidentially approved radiation protection guidance to Federal Agencies for occupational exposure promulgated by the EPA. The most recent guidance, issued on January 27, 1987, states that "Radiation exposure control measures should be designed, selected, utilized, and maintained to ensure that anticipated and actual doses meet the objectives of this guidance. Establishment of administrative control levels below the limiting values for control may be useful to determine the need to take such actions as recording, investigation, and intervention. Since such administrative control and reference levels will often involve ALARA considerations, they may be developed for specific categories of workers or work situations."³¹

PNL-6577 recommends that "...administrative dose control guides should be established to provide a level of control below the prescribed dose limits... and to alert personnel where additional exposure controls should be exercised."³

3.2.2.1 Administrative Control Levels. Radiological control levels are numerical guides established by management below the DOE occupational radiological limits; when these levels are approached, they require escalating degrees of review, intervention, and approval prior to exceeding them. The two types of radiological control levels that were reviewed are dose control guides and intake control guides.

In April 1991, additional information was collected from the DOE contractors via a follow-up questionnaire (see Exhibit E). Eleven of the facilities who responded had established dose control guides; ten contractors had annual control guides that ranged from 1.0 to 3.0 rem/yr (cSv/yr); four had quarterly guides that ranged from 0.5 to 1.8 rem/qtr (cSv/qtr); and four had other types of dose control guides such as 0.6 rem/mo (cSv/mo), 0.15 rem/wk (cSv/wk), and 0.75 rem/wk (cSv/wk). The one exception had an exposure investigation level at which an investigation would be made to determine the cause for an individual's exposure exceeding 50 mrem/d (0.05 cSv/d), or 300 mrem/wk (0.3 cSv/wk). Some facilities have been steadily reducing their dose control guides so as to apply downward pressure to reduce occupational risks from radiation. One facility has proactively reduced its dose control guide to 1000 mrem/yr (1 cSv/yr) in response to the upward trend in the estimates of radiological risks as reported by UNSCEAR^{4,19,27,28} and BEIR.^{5,29,30}

Only three of the facilities responding to the questionnaire had established intake control guides, namely, 0.1 rem (cSv) first year annual effective dose equivalent (AEDE); 1% effective dose equivalent; or 10 mrem AEDE, and one-half the annual limit of intake (ALI). The low number of facilities that have established intake control guides is believed to be due to the fact that most facilities do not allow planned intakes of radioactive material.

Control guides for individuals have been selected based on the accuracy and timeliness of dosimetry results, the potential for unplanned exposures, the historical levels of occupational doses, the training and experience level of the workforce, as well as the rigor of the radiation protection program in relation to costs and practicality of additional dose-reduction efforts. On occasion, control guides are being developed for specific categories of workers and are selected at an exposure or intake level that will prove challenging for that work group. Authorization to exceed the various tiered control guides is based on legitimate need, such as: (1) unique ability or experience of the individual to perform a task with comparably low dose, and (2) other comparably qualified workers with lower exposures are not readily available. Typically, department/division managers approve individuals exceeding the first tier of the control guides, with approval levels ranging from immediate supervisor to the head of the DOE

field organization. Usually, instances in which workers have inadvertently exceeded the control guides are investigated and documented by radiological safety personnel.⁴¹

3.2.2.2 Reference or Investigation Levels. Reference or investigation levels are radiological levels established by management which are used to initiate a course of action such as recording, investigation, or intervention when the value of a parameter has been or is projected to be exceeded. The three types of investigation levels that were reviewed were exposure investigation level, intake investigation level, and personnel contamination investigation level. What follows is a summary of the responses from the follow-up questionnaire.

Exposure investigation levels were used at ten of the twelve facilities that responded. Typical investigation levels included 0.05 rem/d (cSv/d), 0.3 rem/wk (cSv/wk), 0.2 rem/mo (cSv/mo), 0.5 rem/qtr (cSv/qtr), and 1.5 rem/yr (cSv/yr). These levels, if exceeded, would require that the cause for exceeding this level be investigated and documented.

Intake investigation levels were used at all but one of the facilities that responded. The one exception was in the process of negotiating an investigation level. The type and magnitude of this investigation level were dependent on the levels and frequency of past intakes. Typical investigation levels included any positive WBC, urinalysis or fecal sample results, and 10 mrem (10^{-3} cSv) AEDE. These levels, if exceeded, would require that the internal dose be evaluated and recorded. Usually the cause of the intake would be investigated, corrective action(s) taken if necessary, and the results of the investigation documented.

Personnel contamination investigation levels were used at all but one of the facilities that responded. The one exception was again in the process of negotiating an investigation level. Typically, investigation levels included any detectable radioactive material or the removable and fixed contamination levels found in the DOE Order 5480.11, Attachment 2, Surface Radioactivity Guides. These levels, if exceeded, would require that the personnel contamination be documented, investigated and corrective action(s) taken.

3.2.3 Quantitative ALARA Goals

A quantitative goal is a measurable endpoint towards which efforts are directed, such as a percentage reduction in collective dose. The Presidentially approved guidance to federal agencies for occupational exposure also referred to establishing dose goals. Federal agencies were "...encouraged to establish measures by which management can assess the effectiveness of ALARA efforts, including where appropriate, local goals for limiting individual and collective occupational doses."³¹

Management establishes goals to direct their employees in areas where improvement in performance is desired; to achieve this, there must be a change in performance.

Therefore, if a goal can be achieved without a change or improvement in performance, then it is not a goal; it is a repeat of past performance. PNL-6577 recommends that goals be measurable and realistic, yet challenging, and also states that "Upper management support for setting ALARA goals and working toward meeting the goal is also required."³ In addition, PNL-6577 recommends that "...procedures... include a system for assuring that trend analysis and dose tracking are performed..."³ so that status of achieving the goals can be reviewed.

A review of the relevant procedures regarding facility ALARA goals showed that the six discrete steps are common for establishing these goals:

1. Upper management decides which areas need improvement.
2. The existing condition(s), root cause(s), and corrective actions are evaluated by line management.
3. Line management determines the degree of improvement needed and proposes the goal.
4. The goal is presented by line management to upper management or their designee for approval.
5. The responsible supervisor or department head develops and implements a detailed action plan.
6. The performance in achieving the goal is periodically reviewed by line management and action plans are modified, if necessary.

ALARA goals and tracking systems were rated as a high priority and were used at ten of the twelve facilities. The most common quantitative goals are included in the following:

1. Facility collective dose (see Appendix H, Figures 1, 2 and 3),
2. Department collective dose (see Appendix H, Figure 4),
3. Average committed effective dose equivalent by job classification (see Appendix H, Figure 5),
4. Number of individuals above dose control guides (see Appendix H, Figure 5),
5. Maximum individual dose (see Appendix H, Figure 6),
6. Number of individuals with intakes of radioactive material (see Appendix H, Figure 7),
7. Number of individuals with external contamination (see Appendix H, Figure 8),
8. Number of area contamination incidents, i.e., spills (see Appendix H, Figure 9), and,
9. Number of radiological occurrence reports (see Appendix H, Figure 10).

Appendix H gives examples of dose control data for the DOE complex, showing how some of these goals are tracked. Dose control data and databases are described in Section 3.2.5.

3.2.4 Qualitative ALARA Goals

The requirements and guidelines for quantitative ALARA goals also apply to qualitative goals. Unlike quantitative goals, qualitative goals are not based on specific percentages, an amount reduction, or a specific value of the associated goal. Instead qualitative goals are tied to program improvement or upgrades which may require more subjective evaluation of success.

A selected sample of various types of qualitative goals or ALARA action items from the facilities are listed below.

1. Issue an approved 5-year plan on the facility's initiatives for dose-reduction.
2. Develop a verbal and written system to alert departmental supervisors of individuals approaching their dose control guide and their pro-rated individual exposure goal.
3. Review those operating procedures involving work in radiological control areas, and incorporate reasonable exposure and contamination controls and radiological hold points.
4. Produce an annual ALARA report, summarizing and documenting ALARA goals, dose-reduction initiatives, significant radiological problems, and the corrective measures taken.
5. Develop a computerized tracking system, with adequate storage for the dosimetry and associated demographic information. Data output reports should be developed that will track administrative radiological control levels and goals. These reports should be disseminated to line management so that adverse radiological trends can be readily identified and corrected.
6. Develop a system by which materials for employee training and retraining incorporate lessons learned from the corrective actions listed in the radiological occurrence reports and other ALARA records.
7. Implement an employee "ALARA" awareness campaign to increase workers' consciousness about reducing their dose and the spread of radioactive materials.
8. Design, fabricate, and install permanent shielding around the hydrofluorinators and selected equipment.

9. Move all non-operations personnel from the process areas into non-controlled areas.
10. Develop a methodology for cost/benefit analysis and use it at the operational and engineering levels.
11. Develop a priority system for reviewing, evaluating, implementing, and following up all ALARA improvements.
12. Develop a training program for planners, schedulers, and design engineers to provide them with the knowledge needed to incorporate the principles of dose and radioactive material reduction into design and construction.

3.2.5 Dose Control Data, Databases and ALARA Reports

Traditionally, dose control data consisted of hand- or computer-generated listings of individual exposures by department. In addition, summary reports of radiation exposures were produced periodically, as required by DOE Order 5484.1.⁴² However, with the recent widespread use of personal computers and database management software, more sophisticated and detailed types of radiological data records are being developed (see Appendix H).

The collective dose database system was rated as a medium priority and was used at all twelve contractor facilities. Currently, routine reports to line management, job supervisors, and the radiation protection staff permit a detailed evaluation of the efficacy of the ALARA program. With the aid of mainframe, mini- and personal computers, dose control databases provide data in the current reporting period, and also can track the status of the various administrative control levels, reference levels, and ALARA goals e.g., individual annual dose vs. dose control guide and department's individual goals; individual internal burden vs. intake control guide; department collective dose vs. department ALARA goal; job dose estimate vs. actual job dose; and facility collective dose vs. facility ALARA goal. However, an important element which requires further development is the use of a database for job-specific collective dose tracking. Only two facilities could track job doses automatically. A collecting and recording system to track doses for jobs, construction projects and experiments, which exceed an established reference level, (e.g., 1 person-rem) should be developed, where appropriate.

Probably the most universal and best developed elements of the ALARA programs at the DOE contractor facilities were the dose and goals tracking systems. As stated previously, all contractor facilities had administrative control levels or reference levels approved by management. Most had ALARA goals and a system for periodically tracking, reviewing, and adjusting the goals.

As discussed, periodic ALARA reports provide a means to document the accomplishments and recommended improvements in an ALARA program. Such reports give line management the necessary information to assess the status of and effectiveness of ALARA efforts. A review of DOE contractor ALARA reports identified the most common topics in these reports as the following:

1. Historical trends of facility collective exposure,
2. ALARA goals and associated annual performance,
3. Specific actions taken to reduce dose and radioactive contamination and, where possible, associated dose saved, dose-reduction factors obtained, and decontamination factors achieved,
4. A list of high-dose jobs or experiments along with collective dose estimates and actual collective doses,
5. Incident statistics of area and personnel contamination for the year, and
6. Recommended list of systems, elements, work areas, jobs, production activities, operations, and experiments which require a review for ways to reduce dose and the spread of radioactive material.

Annual and special ALARA reports were rated as a low priority, yet they were produced at all but one of the facilities.

3.3 Conduct of Operations, Procedures, and Equipment

The elements that constitute the operational elements of a formally documented ALARA program were reviewed and the status summarized:

1. ALARA procedures for work and workers, and
2. ALARA tools and equipment.

3.3.1 ALARA Procedures for Work and Workers

The PNL ALARA Guide states that "...applying ALARA principles to field work performance is the ultimate purpose of the ALARA program and effort. The operational application of ALARA design, engineering, planning, and administration results in maintaining radiation exposure to workers as low as reasonably achievable. The operational application of ALARA requires the cooperation and coordination of numerous groups, including radiation protection, operations, maintenance, planning and scheduling, training, engineering, and administration."³ In more practical terms, conducting operations for ALARA requires communication and documentation to use knowledge gained from experience to avoid repeating mistakes and to optimize job performance so that exposures are achieved that are as low as reasonably achievable. The following practices or procedures have been developed to control workers' exposures and to document radiological problems and associated corrective actions:

1. Radiation work permits,
2. Radiation occurrence reports,
3. ALARA job/experiment reviews,
4. ALARA/radiological safety suggestions, and
5. Job-specific radiological procedures.

3.3.1.1 Radiation Work Permits (RWPs). RWPs represent one of the primary administrative control methods by which radiological work can be planned and workers' radiological safety can be controlled. RWPs are formal, documented mechanisms for radiation protection personnel to communicate radiological conditions and controls to the workers. PNL-6577 describes how the radiation work permit is issued, used, and terminated.³

RWPs were used at all but one of the facilities visited; that one facility considered it more appropriate to use specific radiological control steps in the various production and assembly procedures. In addition, they did not use an RWP because the production line work was repetitive. Of eight RWP forms reviewed, the majority contained job description, job location, RWP number, protective equipment requirements, and the signature of the radiation protection manager and/or job supervisor. The majority of the facilities require an RWP for any work in a controlled area. Some facilities have the ALARA job/experiment review process (see Section 3.3.1.3) integrated into the RWP process. A noteworthy survey of RWPs from 33 nuclear power plants performed in February 1984⁴³ tallied the common characteristics of RWP forms used at NRC-licensed nuclear power plants. The elements common to most were the following:

1. Job description,
2. Estimated person-hours and person-rem (person-cSv),
3. Job start/finish dates,
4. Results of radiological survey in the work location,
5. Protective requirements,
6. Special instructions, e.g., ALARA controls, and
7. Review and approval signatures

Appendix I shows a good-practice document for an RWP form.

3.3.1.2 Radiological Occurrence Reports. Radiation safety performance should be regularly monitored by identifying and evaluating problems and trends. DOE Order 5484.1, Chapter I, describes the investigation, notification, and reporting requirements for various significant hazardous incidents, including radiological incidents which are typically handled using the facility's "Incident Investigation Report" or "Unusual Occurrence Report." On May 30, 1990, a new DOE Order 5300.3A entitled "Occurrence Reporting and Processing of Operations Information," was issued. This order describes the requirements for reporting and processing of occurrences to provide for appropriate corrective actions. These occurrences are now formally reported using the Occurrence

Reporting and Processing System (ORPS). All facilities reviewed as part of this survey had a formal mechanism to comply with the requirements of 5484.1 and 5000.3A (since its issuance).

Facilities also should internally document and track those radiological problems that are significant but do not meet the severity thresholds of 5484.1. A formal internal reporting mechanism, frequently called a Radiological Occurrence Report (ROR), may be used to document the identification, tracking, and closure of such concerns. Only three of the twelve facilities had such a formal mechanism in place to document and trend less significant radiological problems.

Appendix J gives a good-practice example of an ROR form. The classification and coding of radiological occurrences, shown on the reverse side of Appendix J, lends itself to computer tracking and trending. Root causes also can be trended. Later, these can be reviewed to see if changes are needed in equipment, procedures, personnel, or training to prevent recurrence.

3.3.1.3 ALARA Job/Experiment Reviews. A systematic pre- and post-job review should be conducted on radiologically significant jobs and experiments to ensure that techniques for reducing dose and the spread of radioactive materials are incorporated into the job performance and that improvement and lessons learned are formally documented for use in future work. PNL-6577 provides a basic recommendation "...that adequate planning and preparation be performed before work is initiated in a radiation area, so that workers' doses are maintained ALARA."³ The three phases of a formally documented ALARA job/experiment review are as follows:

1. Pre-job planning and estimates of dose,
2. Implementing ALARA controls and tracking job collective dose during work performance, and
3. Post-job review.

Pre-job planning consists of estimating the dose for the job or experiment, planning the ALARA controls to reduce dose and the spread of radioactive materials, and documenting these controls. Implementation involves briefing the workers or experimenters on the ALARA controls that are required during the job or experiment, ensuring their implementation, and tracking the actual dose against the estimated dose. The post-job or experiment review compares the actual person-hours and person-rem (person-cSv) to the estimates, evaluates the effectiveness of the ALARA controls, and documents the lessons learned, along with recommendations to reduce dose and the spread of radioactive material during future jobs or experiments.

The ALARA job/experiment review was rated as a medium priority and was used at nine of the twelve contractor facilities. Eight of the facilities had, on occasion, tracked actual exposures for specific high-dose jobs. Most used manual methods to determine

the total dose; as described in Section 3.2.5, only two facilities had a computerized method of tracking actual job doses. Copies of the facility procedure for pre-job planning and post-job reviews were obtained from four of the facilities.

Job dose control guides are numerical criteria established by management which, when estimated or projected to be exceeded, require an ALARA review before performing the job. Four of the twelve facilities established radiological control levels above which an ALARA job/experiment review would be performed. The following list gives examples of the various levels:

1. An estimated dose for job/experiment >0.5 rem (>0.5 cSv),
2. An area dose rate $>5,000$ mrem/hr (>5 cSv/hr),
3. Surface contamination levels $>20,000$ dpm/100 cm² beta-gamma or >250 dpm/100 cm² alpha,
4. Airborne concentration $>$ Derived Air Concentration,
5. Breaching a radioactive system, and
6. Individual weekly dose >300 mrem (>0.3 cSv).

3.3.1.4 ALARA/Radiological Safety Suggestions. A formal program to submit, document, evaluate, and implement employees' suggestions to reduce radiation exposure and the spread of radioactive contamination is typically incorporated into the facility's safety suggestion program. Safety suggestion programs are not required by DOE 5480.11 nor are they recommended by PNL-6577. Even though this element was rated low priority, all surveyed facilities featured a safety suggestion program.

The effectiveness of the various suggestion programs varied but, in general, were more effective if they were highly publicized and if they gave a reward for suggestions that were used. The types of rewards included the following:

1. An article about winners in the facility's newsletter,
2. A company jacket,
3. A gift certificate for a dinner for two,
4. A check for a certain percentage of the cost-savings realized by implementing the suggestion,
5. A gold pen,
6. A sunscreen for car windshield,
7. A letter for the employee's file for suggestions with significant savings,
8. A U.S. Government savings bond,
9. A wall plaque, and,
10. Coupons for purchasing prizes from a gift catalog.

Safety suggestion forms were obtained at eleven facilities. A good-practice procedure and suggestion form for an ALARA/radiological safety suggestion program is shown in Appendix L.

An innovative practice, recently started at one facility, was a "SURETY program," in which an employee calls the SURE hotline and reports a safety suggestion. By advertising this new program via the facility newsletter and via a video tape, shown in the facility's cafeteria, the number of suggestions dramatically increased.

3.3.1.5 Job-Specific Radiological Procedures. The need for comprehensive and detailed procedures for work in radiological areas is dictated by the task's complexity, degree of difficulty, frequency, and its relevance to safety. Procedures which involve high collective doses or require work in highly contaminated areas should incorporate steps and radiological hold points to reduce dose and the spread of radioactive materials. PNL-6577 provides a basic recommendation that "...a systematic review and feedback of information about the procedure, based on use, should be established."³ Since the ALARA program coordinator or radiological engineer records lessons learned and future improvements, these individuals should be involved in reviewing procedures.

Job-specific radiological procedures were rated as a high priority and used at ten of the twelve facilities. All twelve facilities review and modify procedures for those operation and maintenance activities, where they can reasonably expect to reduce dose and the spread of radioactive materials. Examples of some activities that incorporate such steps into their procedures are as follows:

1. Electro-decontamination of metallic surfaces,
2. Removal of model A manipulator thru-tube from north cell station for repair,
3. Decontamination of remote manipulator before repair,
4. Waste management at a TRU waste storage facility,
5. Robotic waste removal at a chemical processing facility,
6. Radiation protection requirements for safely handling devices that produce ionizing radiation, and
7. Radiation protection requirements for safely operating unenclosed and portable industrial devices that produce x-rays and gamma rays.

The diagrams shown in Figures 3.3-1 and 3.3-2 depict the general techniques for reducing exposure time and controlling the radioactive source. These diagrams and the ALARA controls checklist (Appendix K) may be useful in selecting radiological controls and radiological hold points to be incorporated into an ALARA procedure for a specific job, operation, or experiment. The DOE Office of Environment, Safety and Health has also funded the development of good-practice manuals for several types of nuclear facilities. To date, health physics manuals have been published for accelerators,⁴⁴ uranium facilities,⁴⁵ and plutonium facilities.⁴⁶ These manuals describe the various elements in an acceptable radiation protection program that relate to dose reduction, including radiological design considerations, exposure control, contamination control, and ALARA.

3.3.2 ALARA Tools and Equipment

Contractor should maintain adequate tools and equipment to protect workers against radiation and contamination. ALARA supplies routinely stocked and used at the DOE contractor facilities included lead blankets, lead bricks, lead-impregnated gloves, lead aprons, concrete shield blocks, sheets of Plexiglas, catch containments, glove bags and boxes, tents, portable ventilation blowers, wet-vacs, and vacuum cleaners.

The twelve ALARA program coordinators and radiological engineers or their equivalents were asked: "What special equipment or design changes have been made or used for dose/contamination control which you consider to be cost-effective and has proven to be successful?" The following responses were identified:

1. Remote tooling for beryllium reflector change-out,
2. A mobile shield for "hot" chemistry samples,
3. Kelly steam cleaning systems for decontaminating hot cells,
4. Remote audiovisual monitoring of workers repacking waste drums,
5. Heavy rubber mats for shielding fixed beta contamination on floors,
6. Eight-inch aluminum kick plate around the work area to prevent spread of contamination,
7. Tritium effluent treatment facility,
8. Waterbed mattresses to shield neutron and gamma rays emanating from a pit containing neutron sources,
9. Freon decontamination system,
10. Robots to retrieve radioactive devices from the storage vaults,
11. Electrochemical decontamination of aluminum or stainless steel glove boxes,
12. Advanced radioactive waste compacting facility,
13. New handling equipment configuration for overpacking of thorium materials,
14. Thick Plexiglas containers for ^{32}P waste and "temporary" storage,
15. Mandatory cooldown and decay periods before entry into reactor and accelerator cells, and
16. Radiation-hardened materials and electronics for greater reliability and less maintenance.

Numerous reports were obtained which document innovative techniques for reducing dose and contamination. Exhibit G shows some examples of these reports. In addition, the DOE Office of Health is funding the periodic publication of a series of BNL reports entitled "ALARA Engineering at Department of Energy Facilities: Bibliography of Selected Readings in Radiation Protection and ALARA"⁴⁷. This series contains abstracts selected from the proceedings of technical meetings, journals, research reports, and searches of the DOE Energy Database. The abstracts relate to operational health physics and other subjects which have a bearing on dose reduction. The types of nuclear facilities covered include radioactive waste, uranium enrichment, fuel fabrication, unirradiated fissile material storage, irradiated fissile material storage, reprocessing, decommissioning, recovery, hot laboratories, tritium production, reactors (research and production), and accelerators.

EXPOSURE TIME REDUCTION

Figure 3.3-1. Diagram of Radiological Protection Considerations to Reduce Radiation Exposure Time.

Figure 3.3-2. Diagram of Radiological Protection Considerations to Control Radioactive Sources.

4. ALARA PROGRAMS: QUALITATIVE AND QUANTITATIVE RESULTS

The concept of ALARA embraces both the qualitative and quantitative aspects of radiation control and dose limitation. Qualitative aspects of the DOE ALARA programs include the administration and organization of the program, together with the conduct of operations, procedures, and equipment. The quantitative aspects of ALARA decision-making and dose control include cost-benefit analysis, establishing administrative control and reference levels, developing ALARA goals, and reviewing data and documentation on dose control.

To evaluate the effectiveness of the DOE contractor's actions in maintaining radiation doses and the spread of radioactive materials as low as reasonably achievable, DOE standards and guidelines will be applied for evaluating the qualitative aspects. An analysis of the quantitative results of the DOE contractor facilities ALARA programs is complex and requires detailed information on the scope of work and ALARA controls that were implemented. As this evaluation is beyond the scope of the effort we will simply present the past trends in occupational doses.

4.1 Qualitative Results

The qualitative evaluation of the effectiveness of the contractors' ALARA programs will be based on: 1) the required program elements in DOE 5480.11, 2) the basic recommendations contained in PNL-6577, and 3) the program elements which the environment, safety and health managers and radiation protection managers/ALARA program coordinators considered high priorities.

Table 4.1-1 summarizes the results of the survey of ALARA program elements described in Section 3. Table 4.1-1 shows the relative priority for the various ALARA program elements and percentage of facilities which used the elements. A limitation of these results is that although an element may be used, it may not be used effectively.

4.1.1 Requirements of DOE Order 5480.11

These ALARA program elements are required by DOE 5480.11; the percent of their use at the facilities follows:

<u>ALARA Program Element</u>	<u>Percent Used</u>
1. ALARA Program Manual or Procedures	100
2. ALARA Design Reviews	83
3. Cost/Benefit Methodology	25
4. General Employee ALARA Training	83
5. Radiation Worker/Researcher ALARA Training	58
6. Radiation Protection Technician ALARA Training	75
7. ALARA Program Appraisal	67

TABLE 4.1-1 ALARA PROGRAM ELEMENTS

ALARA Program Elements ^a	Rated Priority ^b	Percent Used
1. Good Employee ALARA Attitude	High	58
2. ALARA Policy and Management Commitment	High	92
3. ALARA Design Review	High	83
4. ALARA Program Coordinator	High	75
5. Job-Specific Radiological Procedures	High	83
6. Radiological Goals and Tracking System	High	83
7. ALARA Training for Radiation Protection Technician	High	75
8. ALARA Training for Radiation Workers/Researchers	Medium	58
9. ALARA Job/Experiment Reviews	Medium	75
10. ALARA Organization and Responsibilities	Medium	58
11. ALARA Committee	Medium	67
12. Database System for Collective Dose	Medium	100
13. ALARA Program Appraisal	Medium	67
14. ALARA Training for Design Engineers	Medium	33
15. ALARA Training for General Employees	Medium	83
16. Annual or Special ALARA Reports	Medium	83
17. ALARA Training for Administrators	Medium	25
18. Safety Suggestion Program	Medium	100
19. Cost/Benefit Methodology	Medium	25

^aExhibit F describes the ALARA program elements.

^bTwelve environmental, safety and health managers and twelve radiation protection managers or ALARA program coordinators rated the priorities.

Because all facilities are not implementing these requirements, further attention is warranted to improve overall program compliance with and awareness of the DOE Order 5480.11 requirements.

4.1.2 Basic Recommendations of PNL-6577, "ALARA Guide"

PNL-6577, the revised "ALARA Guide," recommends that these basic ALARA program elements shall or must be performed; the percent of their use is as follows:

<u>ALARA Program Element</u>	<u>Percent Used</u>
1. ALARA Policy and Management Commitment	92
2. Job-Specific ALARA Procedures	83
3. ALARA Job/Experiment Reviews	75
4. ALARA Organization and Responsibilities	58
5. ALARA Committee	67

Because some facilities are not implementing these basic recommendations, additional attention is warranted to evaluate if the alternatives are justified.

4.1.3 High Priority Program Elements

The following ALARA program elements were rated as a high priority by the contractors surveyed although not specifically required by DOE 5480.11 or PNL-6577:

<u>ALARA Program Element</u>	<u>Percent Used</u>
1. Good Employee ALARA Attitude	58
2. ALARA Program Coordinator	75
3. Goals and Tracking System	83

In summary, except for cost-benefit methodology (Section 3.2.1), the majority of the participating facilities are using the required and essential elements of a formally documented ALARA program. However, additional attention is needed to ensure unilateral and full implementation of all the ALARA requirements at the contractor facilities.

4.2 Quantitative Results

The annual occupational dose data at DOE Contractor facilities were analyzed to evaluate the impact of efforts by DOE contractors to reduce dose. This analysis examined the trends from 1974 to 1988 in annual collective dose and average individual dose.

Another important consideration in the evaluation of ALARA efforts is how the dose distribution for occupational exposures has changed. Therefore, an analysis of the number and percentage of individuals with annual exposures > 1.0, 2.0, and 3.0 rem (> 1.0, 2.0, and 3.0 cSv) from 1974 to 1988 was evaluated. The change in the percentage of contractors with measurable exposures vs. dose equivalent range from 1974 to 1988 was also evaluated.

The collective and average individual doses were derived from the DOE annual reports on "Radiation Exposures for DOE and DOE Contractor Employees." These doses are for DOE and DOE contractor personnel only, and exclude exposures for visitors. The average individual doses are calculated using the number of individuals with measurable exposures. In 1987, DOE started reporting actual exposure data in the annual report, rather than the midpoint summing method used earlier to calculate collective exposure, i.e., collective doses calculated by multiplying the midpoints of the dose equivalent ranges by the number of individuals in those ranges. The use of actual versus calculated collective exposure resulted in a significant decrease (approximately 15-25%) in the values for 1987 and the 1988 total collective dose. To provide consistency in trend evaluation, the 1987 and 1988 total collective dose data given in this report were calculated by the pre-1987 midpoint summing method and will differ from values reported in the DOE annual reports.

This dose data do not reflect any contributions from internal dose nor, for the case of accelerators, whole-body doses associated with protons and elementary particles. However, in both situations, the contribution of these exposures to the totals and averages of the annual effective dose equivalents is expected to be insignificant.

4.2.1 Annual Collective and Average Individual Dose Trends

Figure 4.2-1 shows the collective radiation dose trend for DOE/DOE Contractor employees at all DOE nuclear facilities. There is a dramatic drop in exposures during 1975 to 1980, followed by a modest increase from 1981 to 1985, and a strong decrease over the final three years, ending in 1988. During the period 1978 to 1988, collective dose equivalents have dropped by approximately 50%, due, in part, to continued emphasis and strengthening of ALARA practices. Several additional factors, including a reduction in operation and production levels and a revision to dose reporting methodology, also significantly contributed to the dose reductions in 1987 to 1988.

In Figure 4.2-1, the average individual dose trend for DOE/DOE contractor employees with measurable exposure also shows a dramatic drop in exposures during 1975 to 1980. However, during 1980 to 1985, there was a slight increase in the average individual dose. In 1988, the average individual dose fell to its lowest level on record. In 1988, the average individual dose equivalent for employees with measurable exposure decreased from its 1978 value by 15%, and slid from its 1987 level by about 30%. The average individual dose of 150 mrem/yr (.15 cSv/yr) for 1988, and those values reported over the past decade have consistently been maintained far below the DOE limit (less than 5% of 5,000 mrem/yr [5 cSv/yr]). Again, caution must be exercised in interpreting these trends, because they do not factor in changes in operations, production, and research, together with any changes in radiological conditions at the facilities.

To determine the impact of efforts by contractors in reducing doses at the various types of facilities, the collective and average individual dose at the facilities in the nuclear

weapons complex (Figure 4.2.-2) and the nuclear energy/research complex (Figure 4.2-3) were reviewed. The types of facilities which experienced the greatest percentage reduction in collective dose from 1978 to 1988 were: Uranium enrichment, 91%; Reactors, 68%; Fuel Processing, 65%; Accelerators, 61%; and General Research, 66%.

In general, collective and average individual doses have decreased at DOE facilities. The noteworthy exception is the increase in collective doses in the category called "other facilities" (miscellaneous).

4.2.2 Trends in Dose Distribution

An observable effect of the DOE contractors' efforts to reduce dose is a general decline in the number and percentage of individuals receiving dose in the higher dose ranges.

Table 4.2-1 shows the distributions of radiation dose from 1974 to 1988. These data show that the percentage of individuals in the dose ranges has been relatively constant from 1978 to 1987. In 1988, the percentage of individuals with measurable exposure to 1 rem (1 cSv) increased to 98.34% from 95.43% from the previous year. Also significant was the fact that no employee received a dose greater than 3 rem (3 cSv), and the percentage of individuals with measurable exposure to between 2 and 3 rem (2 and 3 cSv) dropped from 0.82% in 1987 to 0.10% in 1988.

Figure 4.2-4 shows the number of employees who received annual dose equivalents greater than 1 rem (1 cSv), 2 rem (2 cSv), and 3 rem (3 cSv), and the percentage of employees with measurable exposures greater than these annual doses. These results further support the finding from 1978 to 1987 that the number and percentage of individuals in various dose ranges were relatively constant. About 1,500 employees or about 4% received greater than 1 rem (1 cSv); about 400 employees or 1% received greater than 2 rem (2 cSv); and about 50 employees or 0.1% received greater than 3 rem (3 cSv).

The number of individuals with annual dose equivalents greater than 1 rem (1 cSv) decreased by 66% between 1987 and 1988, and those receiving greater than 2 rem (2 cSv) decreased by 90%. In addition, as noted, no employees received a dose greater than 3 rem (3 cSv) in 1988. The individuals who received greater than 5 rem (5 cSv) after 1974 were primarily due to situations in which individuals inadvertently exceeded the occupational dose limit.

Figure 4.2-1

Annual Collective and Average Individual Dose
(Number of Employees with Measurable Doses)
at DOE Contractor Nuclear Facilities

Figure 4.2-2

Annual Collective and Average Individual Dose
(Number of Employees with Measurable Doses)
at DOE Nuclear Weapons Facilities

Uranium Enrichment Facilities

Fuel Fabrication Facilities

Reactor Facilities

Figure 4.2-2 (continued)

Annual Collective and Average Individual Dose
(Number of Employees with Measurable Doses)
at DOE Nuclear Weapons Facilities

Fuel Processing Facilities

Weapons Testing and Fabrication Facilities

Figure 4.2-3

Collective and Average Individual Dose
(Number of Employees with Measurable Doses)
at DOE Nuclear Energy and Research Facilities

Accelerator Facilities

General Research Facilities
(Fusion Research was included in this category prior to 1987)

Other Facilities*
(Construction, Irradiation Facilities, ...)

*Maintenance & Support and Waste Handling were included in this category prior to 1987. Consequently, data points for 1987 and 1988 have been intentionally omitted.

Figure 4.2-4
 Number and Percentage
 of
 DOE/DOE Contractors (excluding visitors)
 with
 Annual Exposures Greater than 1.0, 2.0, and 3.0 Rem

TABLE 4.2-1 PERCENTAGE OF DOE/DOE CONTRACTORS WITH MEASURABLE EXPOSURES (EXCLUDING VISITORS) VS. DOSE EQUIVALENT RANGE (Rem)*

Year	Number of Workers with Measurable Exposures	Percent Meas.-1.0	Percent 1.0-2.0	Percent 2.0-3.0	Percent 3.0-4.0	Percent 4.0-5.0	Percent >5.0	Number of Individuals >5 Rem
1974	35,048	92.73	4.76	1.96	0.43	0.11	0.01	4
1975	45,115	93.40	4.09	1.67	0.52	0.32	<0.01	1
1976	50,117	95.55	3.35	0.95	0.14	0.01	<0.01	1
1977	52,203	95.68	3.03	1.04	0.20	0.05	<0.01	5
1978	57,122	96.80	2.32	0.77	0.09	0.02	<0.01	0
1979	54,983	96.82	2.34	0.76	0.06	0.02	<0.01	3
1980	40,411	96.25	2.75	0.96	0.04	0.00	0.00	0
1981	37,825	96.66	2.56	0.69	0.08	0.01	0.00	0
1982	36,356	93.13	2.78	0.86	0.15	0.08	0.00	0
1983	38,412	95.72	3.30	0.77	0.13	0.08	0.00	0
1984	44,276	96.43	2.77	0.71	0.07	0.02	0.00	0
1985	39,876	95.53	3.43	0.89	0.13	0.02	<0.01	1
1986	39,456	95.73	3.29	0.88	0.09	<0.01	<0.01	2
1987	34,516	95.43	3.65	0.82	0.10	0.00	0.00	0
1988	31,796	98.34	1.56	0.10	0.00	0.00	0.00	0

*Data extracted from U.S. Department of Energy report DOE/EH-0171P, Twenty-first Annual Report, Radiation Exposures for DOE and DOE Contractor Employee - 1988, December 1990.

4.3 Conclusions and Recommendations

The ALARA programs at DOE contractor facilities are, for the most part, in compliance with the ALARA requirements in DOE 5480.11. Additional effort should be expended to correct those exceptions noted in Sections 3.1.1, 3.1.3, 3.1.6, and 3.2.1. DOE and contractor line management should enforce these ALARA requirements and basic recommendations to ensure full compliance. To pursue excellence in the DOE ALARA programs, dedicated staff, improved documentation, and formalization is required. The quality of other programs in the commercial nuclear power industry can be used as a model of excellence.

The essential elements of an ALARA program recommended in PNL-6577 and those rated in the survey as high priority elements were used at most of the facilities. Internal audits of contractor ALARA programs should focus on full implementation of these essential elements. In addition, the effectiveness of implementation also should be evaluated and, if required, recommendations should be made.

With further development, the ALARA programs at DOE contractor facilities could form the basis for a model program. The implementation of the DOE contractor ALARA program has evolved significantly since they were studied during 1976 to 1978:

- 62% of the facilities visited in 1978 had ALARA policy statements vs. 92% in 1988-1990;
- ALARA goals had 30% utilization in 1978 vs. 83% in 1988-1990;
- 23% of the facilities had conducted audits in ALARA vs. 67% in 1988-1990; and
- the dollar value for collective dose has increased from 1,000 to 10,000 \$/person-rem (\$/person-cSv) in 1978 to 2,000 to 60,000 \$/person-rem (\$/person-cSv) in 1988-1990.

Although a decreasing trend in collective and average individual doses was experienced recently (1978 to 1989), continued vigilance and increased emphasis will be required to maintain this trend in light of environmental restoration and facility modernization/reconfiguration. Those facility types with an increasing trend in collective and/or average individual dose, shown in Figures 4.2-2 and 4.2-3, warrant additional attention.

As part of this review, participating environment, safety and health managers and ALARA program coordinators identified the following recommendations in response to the question "What would you like to see DOE do to promote ALARA?":

1. DOE should establish consistent performance indicators to measure the effectiveness of the contractors' ALARA programs.
2. DOE should evaluate the importance that contractor management places on ALARA during technical safety appraisals and "Tiger Team" inspections.
3. DOE-sponsored workshops for contractor radiation protection managers, ALARA program coordinators, and radiological engineers should be held periodically to exchange information and develop programs.
4. DOE should provide a coordinated and consistent interpretation of the ALARA requirements.
5. Senior management in the DOE should continue to emphasize their commitment to reducing dose and the spread of radioactive materials.
6. A portion of the award fees for DOE contractors should be dedicated to achieving the annual ALARA goals.
7. DOE should strongly encourage contractors to strengthen the process of design review, including the mechanisms to incorporate techniques to reduce dose and the spread of radioactive materials.

8. DOE should provide guidance on the number of ALARA staff needed to implement the ALARA program, e.g., 1 professional/100 person-rem (100 person-cSv).
9. DOE should provide guidance for determining the appropriate value for radiation detriment, i.e. dollar per person-rem.

The strengths and areas for improvement in the ALARA program that were observed during the visits to the DOE contractor facilities are summarized as follows:

Strengths

1. Broad and effective support and commitment from upper management was reported (see Section 3.1.1).
2. A computer-based system to perform radiation protection appraisals (including ALARA appraisal) for personnel, developed by the DOE Field Office, Savannah River Operations Office, provides consistent and streamlined appraisals (see Section 3.1.6).
3. A proactive administrative dose control level of 1,000 mrem/yr (1 cSv/yr) was established at the Pantex Plant (see Section 3.2.2).
4. The most universal and best developed ALARA program element was the implementing and reporting of ALARA goals (see Section 3.2.5).
5. An award fee at some DOE contractor facilities, partly based on the achievement of collective dose goals, has tied ALARA performance to financial incentives.

Items for Improvement

1. Provide special ALARA training to first-line supervisors to strengthen their awareness and support of the ALARA program, including a better understanding of the biological risk which forms the basis of the ALARA concept. (see Section 3.1.1, Section 3.1.3 and Section 3.1.4).
2. Expand the training program for radiation workers to include a module informing them of the DOE and company policy towards ALARA, and to improve their awareness of their responsibilities (see Section 3.1.1 and Section 3.1.3).
3. Provide special ALARA training to design engineers to provide them with the knowledge needed to incorporate into new designs or facilities modifications features which will maintain radiation exposures and the spread of radioactive materials as low as reasonably achievable (see Section 3.1.3).

4. Fill the vacant positions for ALARA program coordinators and radiological engineers with experienced professionals (see Section 3.1.4).
5. Increase the frequency and scope of internal appraisals of ALARA programs (see Section 3.1.6).
6. Develop methods for cost-benefit evaluations and other techniques for ALARA decision-making (see Section 3.2.1).
7. Develop a collecting and recording system to track the collective dose for jobs, construction projects, and experiments, which exceed an established reference level, e.g., 1 person-rem, including a standardized method of categorizing similar work (see Section 3.2.5).

Occupational radiation exposures throughout the DOE complex are relatively low in terms of collective and average individual exposures; therefore, additional reductions in doses will prove to be challenging. The DOE contractor facilities are faced with a greater variety of radiological work environments than those typically found in other nuclear industries. The DOE is involved in various low- to moderate-exposure operations that range from basic research to plutonium production. As a result, dose reduction within DOE must be attacked on numerous fronts. Therefore, success can best be assured if the ALARA philosophy is understood and embraced throughout the entire organization and ingrained in the way business is done.

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EXHIBIT A

Facility _____

BNL-ALARA Project

Questions for the
Environment, Health & Safety Manager
or Equivalent

1. Discuss and review policies related to ALARA.
Is there a written policy?
Are administrative dose limits used?
If so, what are they?
2. Discuss ALARA design review procedures.
Who does them?
When?
Any ALARA input?
Sign-offs?
3. Is there an ALARA task force or committee?
ALARA Committee charter?
4. Management commitment adequate?
Support demonstrated?
5. Does the facility use a suggestion system?
Any ALARA suggestions?
Special emphasis on ALARA?
Awards?
Feedback on implementation?
6. What ALARA training is given to new employees?
Health Physics technicians?
Engineers?
Researchers?
Laborers?
7. What cost-benefit studies have been done?
Methods?
What \$/rem value is used?
Who performs?
8. Do you use ALARA dose goals?
If so, how are they established?
How are they measured, evaluated, and trended?
9. Is there a special ALARA coordinator, or is this function fully integrated into the Health Physics staff functions?

Facility _____

10. Do you use RWPs?
Who approves them and does ALARA Coordinator review?
When are they required?
Is there an RWP procedure?
11. Do you have sufficient resources and qualified personnel to support the ALARA program?
How many?
Are the ALARA responsibilities and organization defined?
Is the reporting level high enough to ensure senior management attention?
12. If required to show that your program is ALARA (optimized, as contrasted to very high or low doses), what documentation would support you?
13. Any suggestions on how ALARA can be assured at your facilities?
At other DOE and contractor facilities in general?
14. What would you like to see DOE do to promote ALARA?
What do you think of DOE Order 5480.11 paragraph 9.a on "Maintaining Radiation Exposure as Low as Reasonably Achievable"?

Facility _____

15. For each of the ALARA Incentive items, rate each for relative importance on a scale from 1-5 (5 being most important). Indicate whether you utilize this item in your ALARA program (yes) or not (no).

ALARA INCENTIVE ITEMS	RATING (1-5)	UTILIZED	
		Yes	No
I. WORKER INCENTIVES (AWARENESS)			
A. Suggestion Program	_____	_____	_____
B. Worker/Researcher Involvement in ALARA Job Reviews	_____	_____	_____
C. Visible ALARA Office	_____	_____	_____
D. Visible ALARA Coordinator	_____	_____	_____
E. Publicize Workers Dose and Facility Total Dose vs. Goals	_____	_____	_____
F. Publicizing ALARA Suggestion Implementation	_____	_____	_____
G. Publicize Receipt of ALARA Suggestion Award	_____	_____	_____
H. ALARA T-Shirts, Hats, and Pens	_____	_____	_____
I. ALARA Posters in the Facility	_____	_____	_____
J. Periodic Verbal Reminders from Line Management	_____	_____	_____
K. Other (specify)	_____	_____	_____
II. MANAGEMENT INCENTIVES			
A. Avoid Safety Evaluation Findings for Failing to Follow ALARA Requirements in DOE Order 5480.11	_____	_____	_____
B. Monetary Savings from Critical Path and Labor Savings	_____	_____	_____
C. Improved Personnel Relations Due to Management Concern for Health and Safety	_____	_____	_____
D. Decreased Usage of Contractors	_____	_____	_____
E. Increased Usage of Experienced Workers	_____	_____	_____
F. Good Public Relations from Favorable Press Releases	_____	_____	_____
G. National Reputation as a Low-Dose Facility	_____	_____	_____
H. Adverse Job Security for Poor ALARA Performance	_____	_____	_____
I. Avoid Probable Causation Liability Suits	_____	_____	_____
J. Concern for Fellow Workers	_____	_____	_____
K. Beneficial Performance Review for Good Dose Reduction	_____	_____	_____
L. Director Level Directive for Line Management to Promote ALARA at Staff Level	_____	_____	_____
M. Other (specify)	_____	_____	_____

Facility _____

16. For each of the ALARA Program Key Component items, rate each for relative importance on a scale from 1-5 (5 being most important). Indicate whether you utilize this item in your ALARA program (yes) or not (no).

ALARA PROGRAM KEY COMPONENTS	RATING (1-5)	UTILIZED	
		Yes	No
I. ALARA PROGRAM			
A. ALARA Coordinator	_____	_____	_____
B. ALARA Organization and Responsibilities	_____	_____	_____
C. ALARA Committee	_____	_____	_____
D. ALARA Policy and Management Commitment	_____	_____	_____
E. Administrator ALARA Training	_____	_____	_____
F. Engineer ALARA Training	_____	_____	_____
G. H.P. Technician ALARA Training	_____	_____	_____
H. Worker/Researcher Job-Specific ALARA Training	_____	_____	_____
I. General Employee ALARA Training	_____	_____	_____
J. Collective Dose Data Base System	_____	_____	_____
K. Goals and Tracking System	_____	_____	_____
L. ALARA Job Reviews	_____	_____	_____
M. ALARA Design Reviews	_____	_____	_____
N. ALARA Suggestion Program	_____	_____	_____
O. Job-Specific Radiological Procedures	_____	_____	_____
P. ALARA Program Appraisal	_____	_____	_____
Q. Annual or Special ALARA Reports	_____	_____	_____
R. Cost/Benefit Methodology	_____	_____	_____
S. Good Employee ALARA Attitude	_____	_____	_____
T. Other (specify)	_____	_____	_____
U. Other (specify)	_____	_____	_____

Person Interviewed: _____
 Start Time: _____
 Finish Time: _____
 Date: _____

Attachments: ALARA Policy
 ALARA Design Review Procedure
 ALARA Committee Charter
 Copies of ALARA Suggestion
 Cost/Benefit Studies
 RWP Procedure
 ALARA Responsibilities
 ALARA Organization Diagram

EXHIBIT B

Facility _____

BNL-ALARA Project

Questions for the
Plant/Facilities Engineering Manager
or Safety Coordinator/Representative from Engineering
or Equivalent

1. What are your responsibilities for ALARA?
Engineer's responsibilities?
2. How is ALARA integrated into a design?
By Engineering?
By Health Physics?
When?
3. Does an engineer do a cost/benefit calculation on estimated dose saving?
Or is this left to Health Physics to cost justify?
How soon does it get integrated into the process?
What \$/rem value is used?
4. What ALARA or radiological engineering expertise exist in the
engineering staff, e.g. Nuclear Engineers, Health Physicists?
5. What special equipment or design changes have been made or used for
dose/contamination control which you considered to be cost effective and
have proven to be highly successful?
Anything new which may be of interest to others?
Remote tooling?
Remote surveillance?
Robotics?
Special shielding?
Any references, pictures, drawings, or descriptions?
6. What procedures assure that ALARA has been included in design?
Backfits?
Maintenance?
Inspections?
Operations?
7. Any suggestions on how ALARA can be assured at your facility?
At other DOE and contractor facilities in general?

Facility _____

8. For each of the ALARA Incentive items, rate each for relative importance on a scale from 1-5 (5 being most important). Indicate whether you utilize this item in your ALARA program (yes) or not (no).

ALARA INCENTIVE ITEMS	RATING (1-5)	UTILIZED	
		Yes	No
I. WORKER INCENTIVES (AWARENESS)			
A. Suggestion Program	_____	_____	_____
B. Worker/Researcher Involvement in ALARA Job Reviews	_____	_____	_____
C. Visible ALARA Office	_____	_____	_____
D. Visible ALARA Coordinator	_____	_____	_____
E. Publicize Workers Dose and Facility Total Dose vs. Goals	_____	_____	_____
F. Publicizing ALARA Suggestion Implementation	_____	_____	_____
G. Publicize Receipt of ALARA Suggestion Awards	_____	_____	_____
H. ALARA T-Shirts, Hats, and Pens	_____	_____	_____
I. ALARA Posters in the Facility	_____	_____	_____
J. Periodic Verbal Reminders from Line Management	_____	_____	_____
K. Other (specify)	_____	_____	_____
II. MANAGEMENT INCENTIVES			
A. Avoid Safety Evaluation Findings for Failing to Follow ALARA Requirements in DOE Order 5480.11	_____	_____	_____
B. Monetary Savings from Critical Path and Labor Savings	_____	_____	_____
C. Improved Personnel Relations Due to Management Concern for Health and Safety	_____	_____	_____
D. Decreased Usage of Contractors	_____	_____	_____
E. Increased Usage of Experienced Workers	_____	_____	_____
F. Good Public Relations from Favorable Press Releases	_____	_____	_____
G. National Reputation as a Low-Dose Facility	_____	_____	_____
H. Adverse Job Security for Poor ALARA Performance	_____	_____	_____
I. Avoid Probable Causation Liability Suits	_____	_____	_____
J. Concern for Fellow Workers	_____	_____	_____
K. Beneficial Performance Review for Good Dose Reduction	_____	_____	_____
L. Director Level Directive for Line Management to Promote ALARA at Staff Level	_____	_____	_____
M. Other (specify)	_____	_____	_____

Person Interviewed: _____
 Start Time: _____
 Finish Time: _____
 Date: _____

Attachments: Cost/Benefit Calculations
 Information on Equipment or Design Changes Effective
 in Dose and Contamination Reduction
 ALARA Design Review Procedure

EXHIBIT C

Facility _____

BNL-ALARA Project

Questions for the
Radiation Protection or Health Physics Manager
or ALARA Coordinator or Equivalent

1. What is your responsibility for ALARA?
Is there a written ALARA policy?
Do you participate in policy formulation?
2. Have you published any ALARA reports that summarize dose reduction efforts and collective dose savings/expenditures?
3. What ALARA training is given to new employees?
Health Physics technicians?
Engineers?
Researchers?
Radiation Workers?
By whom?
How often?
Any training on mock-ups?
4. Have you identified high-dose jobs or experiments for special attention?
Any dose tracking?
What procedures are used to insure high-dose jobs or experiments are ALARA?
e.g., pre-job planning, post-job reviews, and safety evaluations?
5. What is the H.P./ALARA role in design reviews?
Sign off?
6. What cost/benefit studies have been done?
By which group?
Using what methods?
\$/rem values, etc.?
Are examples available?
References?
7. What would you like to see DOE do to promote ALARA?
What do you think of DOE Order 5480.11 paragraph 9.a on "Maintaining Radiation Exposure as Low as Reasonably Achievable"?
8. Are you using any special, new, or unique dose/contamination controls, equipment, or techniques which you consider to be cost effective and proven to be highly successful?
Any references, pictures, or descriptions?

Facility _____

9. What is the minimum detectable dose on your personnel badges?
Is it recorded as zero?
Added as the minimum?
Monthly?
Weekly?
10. What has been the collective effective dose equivalent for your facility over the past 5 years?
11. Has anyone done an overall ALARA study for the facility?
i.e., prioritize dose reduction opportunities?
12. Do you use dose goals?
How are they measured, evaluated, and trended?
Are they effective?
Misused?
Needed?
13. How often are ALARA appraisals done?
By which group?
Have formal review criteria?
Costs to perform?
14. Do you have any written ALARA procedures/instructions?
Copies?
15. Any suggestions as to how ALARA can be assured at your facility?
At other DOE and contractor facilities in general?

Facility _____

16. For each of the ALARA Incentive items, rate each for relative importance on a scale from 1-5 (5 being most important). Indicate whether you utilize this item in your ALARA program (yes) or not (no).

ALARA INCENTIVE ITEMS	RATING (1-5)	UTILIZED	
		Yes	No
I. WORKER INCENTIVES (AWARENESS)			
A. Suggestion Program	_____	_____	_____
B. Worker/Researcher Involvement in ALARA Job Reviews	_____	_____	_____
C. Visible ALARA Office	_____	_____	_____
D. Visible ALARA Coordinator	_____	_____	_____
E. Publicize Workers Dose and Facility Total Dose vs. Goals	_____	_____	_____
F. Publicizing ALARA Suggestion Implementation	_____	_____	_____
G. Publicize Receipt of ALARA Suggestion Award	_____	_____	_____
H. ALARA T-Shirts, Hats, and Pens	_____	_____	_____
I. ALARA Posters in the Facility	_____	_____	_____
J. Periodic Verbal Reminders from Line Management	_____	_____	_____
K. Other (specify)	_____	_____	_____
II. MANAGEMENT INCENTIVES			
A. Avoid Safety Evaluation Findings for Failing to Follow ALARA Requirements in DOE Order 5480.11	_____	_____	_____
B. Monetary Savings from Critical Path and Labor Savings	_____	_____	_____
C. Improved Personnel Relations Due to Management Concern for Health and Safety	_____	_____	_____
D. Decreased Usage of Contractors	_____	_____	_____
E. Increased Usage of Experienced Workers	_____	_____	_____
F. Good Public Relations for Favorable Press Releases	_____	_____	_____
G. National Reputation as a Low-Dose Facility	_____	_____	_____
H. Adverse Job Security for Poor ALARA Performance	_____	_____	_____
I. Avoid Probable Causation Liability Suits	_____	_____	_____
J. Concern for Fellow Workers	_____	_____	_____
K. Beneficial Performance Review for Good Dose Reduction	_____	_____	_____
L. Director Level Directive for Line Management to Promote ALARA at Staff Level	_____	_____	_____
M. Other (specify)	_____	_____	_____

Facility _____

17. For each of the ALARA Program Key Component items, rate each for relative importance on a scale from 1-5 (5 being most important). Indicate whether you utilize this item in your ALARA program (yes) or not (no).

ALARA PROGRAM KEY COMPONENTS	RATING (1-5)	UTILIZED	
		Yes	No
I. ALARA PROGRAM			
A. ALARA Coordinator	_____	_____	_____
B. ALARA Organization and Responsibilities	_____	_____	_____
C. ALARA Committee	_____	_____	_____
D. ALARA Policy and Management Commitment	_____	_____	_____
E. Administrator ALARA Training	_____	_____	_____
F. Engineer ALARA Training	_____	_____	_____
G. H.P. Technician ALARA Training	_____	_____	_____
H. Worker/Researcher Job-Specific ALARA Training	_____	_____	_____
I. General Employee ALARA Training	_____	_____	_____
J. Collective Dose Data Base System	_____	_____	_____
K. Goals and Tracking System	_____	_____	_____
L. ALARA Job Reviews	_____	_____	_____
M. ALARA Design Reviews	_____	_____	_____
N. ALARA Suggestion Program	_____	_____	_____
O. Job-Specific Radiological Procedures	_____	_____	_____
P. ALARA Program Appraisals	_____	_____	_____
Q. Annual or Special ALARA Reports	_____	_____	_____
R. Cost/Benefit Methodology	_____	_____	_____
S. Good Employee ALARA Attitude	_____	_____	_____
T. Other (specify)	_____	_____	_____
U. Other (specify)	_____	_____	_____

Person Interviewed: _____
 Start Time: _____
 Finish Time: _____
 Date: _____

Attachments: ALARA Policy
 RWP Procedure
 ALARA Job Review Procedure
 ALARA Procedure and Instructions
 ALARA Reports
 ALARA Appraisal Reports
 Cost/Benefit Calculations
 Information on Equipment or Design Changes
 Effective in Dose and Contamination Reduction
 ALARA Study for Facility

EXHIBIT D

Facility _____

BNL-ALARA Project

Questions for the
Training Supervisor or Equivalent

1. Which training modules include instruction on ALARA?
New employee?
Health Physics technician?
Engineers?
Researchers?
Radiation Workers?
Are examples of ALARA training materials available?
2. If DOE or the BNL ALARA Center were to develop materials for "ALARA Training," which type of training programs would you like to receive (General Employee, Radiation Worker, Health Physics Technician, Engineer, Researcher)?
Video tapes?
Manuals?
Slides?
Cost-benefit methods?
3. Are you involved in job-specific training for high-dose jobs?
Does your lab make job-specific video tapes for use in training?
Any mock-ups?
4. What suggestions do you have for improving ALARA training at DOE facilities?
5. Are there other training groups who are involved with Radiation Protection or ALARA training?

Facility _____

6. For each of the ALARA Incentive items, rate each for relative importance on a scale from 1-5 (5 being most important). Indicate whether you utilize this item in your ALARA program (yes) or not (no).

ALARA INCENTIVE ITEMS	RATING (1-5)	UTILIZED	
		Yes	No
I. WORKER INCENTIVES (AWARENESS)			
A. Suggestion Program	_____	_____	_____
B. Worker/Researcher Involvement in ALARA Job Reviews	_____	_____	_____
C. Visible ALARA Office	_____	_____	_____
D. Visible ALARA Coordinator	_____	_____	_____
E. Publicize Workers Dose and Facility Total Dose vs. Goals	_____	_____	_____
F. Publicizing ALARA Suggestion Implementation	_____	_____	_____
G. Publicize Receipt of ALARA Suggestion Awards	_____	_____	_____
H. ALARA T-Shirts, Hats, and Pens	_____	_____	_____
I. ALARA Posters in the Facility	_____	_____	_____
J. Periodic Verbal Reminders from Line Management	_____	_____	_____
K. Other (specify)	_____	_____	_____
II. MANAGEMENT INCENTIVES			
A. Avoid Safety Evaluation Findings for Failing to Follow ALARA Requirements in DOE Order 5480.11	_____	_____	_____
B. Monetary Savings from Critical Path and Labor Savings	_____	_____	_____
C. Improved Personnel Relations Due to Management Concern for Health and Safety	_____	_____	_____
D. Decreased Usage of Contractors	_____	_____	_____
E. Increased Usage of Experienced Workers	_____	_____	_____
F. Good Public Relations for Favorable Press Release	_____	_____	_____
G. National Reputation as a Low-Dose Facility	_____	_____	_____
H. Adverse Job Security for Good ALARA Performance	_____	_____	_____
I. Avoid Probable Causation Liability Suits	_____	_____	_____
J. Concern for Fellow Workers	_____	_____	_____
K. Beneficial Performance Review for Good Dose Reduction	_____	_____	_____
L. Director Level Directive for Line Management to Promote ALARA at Staff Level	_____	_____	_____
M. Other (specify)	_____	_____	_____

Person Interviewed: _____
 Start Time: _____
 Finish Time: _____
 Date: _____

Attachments: ALARA Training Materials

EXHIBIT E

FOLLOW-UP QUESTIONNAIRE
TO THE BNL ALARA CENTER
STUDY OF ALARA PROGRAMS

ADMINISTRATIVE CONTROLS

1. What are the dose control guides established by management, below the DOE occupational dose limits, that require approval prior to exceeding them?

_____ Annual _____ Quarterly _____ Other
2. Who approves individuals exceeding these dose control guides? (Please attach section(s) of policy or procedure describing this.)

3. Does your facility have an exposure "reference level," other than those in 1 above, at which an investigation would be performed to determine the cause for an individual exceeding this exposure reference level? What are your exposure reference levels?

☐ Yes ☐ No

_____ Daily _____ Monthly
_____ Weekly _____ Other
4. Does your facility have an intake control guide established at some percentage below the occupational dose limit, e.g., ALI or DAC·hr that requires approval prior to exceeding? (Please attach section(s) of policy or procedure describing this.)

☐ Yes ☐ No

_____ Daily _____ Monthly
_____ Weekly _____ Other
5. What are the intake investigation/reference levels which, when exceeded, require a documented investigation to be performed to determine the cause for an individual's intake?

6. What are the levels at which personnel external contaminations are documented and investigated?

_____ Skin _____ Clothing

EXHIBIT E (Cont.)

OPTIMIZATION

1. What are the problems or barriers which prevent you and facility engineers from performing cost/benefit analyses?

Signature

Date

Facility Name

Exhibit F

Description of ALARA Program Elements

1. Good Employee ALARA Attitude: An ethic or philosophy in which an employee has a strong desire to reduce exposure and the spread of radioactive contamination.
2. ALARA Policy Statement: A written statement signed by upper management, which documents management's commitment to the ALARA philosophy.
3. ALARA Design Review: A systematic review of the design and construction to ensure that ALARA considerations are evaluated, incorporated if reasonable, and documented for radiologically significant modifications to existing and new nuclear facilities.
4. ALARA Program Coordinator: An individual who is responsible for coordinating activities to reduce occupational doses and the spread of radioactive materials to levels that are as low as reasonably achievable.
5. Job/Experiment Specific Procedures: Written instructions that describe the techniques for radiation protection and dose reduction to be incorporated into a job or an experiment.
6. Radiological Goal: An administratively derived objective which focuses efforts to improve radiological performance.
7. ALARA Training for Radiation Protection Technicians: A portion of the radiation protection technician's formal training should include information pertinent to reducing dose and the spread of radioactive material. This training should include:
 - DOE Orders and guides,
 - ALARA concepts,
 - ALARA program elements,
 - ALARA responsibilities and incentives,
 - ALARA job review process and job coverage, and
 - Dose-reduction techniques and job/craft-specific instructions to reduce dose.
8. ALARA Training for Radiation Workers/Researchers. A specialized formal training program which may be included as a segment in facility operation, maintenance, or other production-type training programs. This training should include:

- ALARA concept,
 - ALARA program review,
 - ALARA responsibility and incentives, and
 - Job/craft-specific instructions to reduce dose and the spread of radioactive material.
9. ALARA Job/Experiment Reviews. A systematic pre- and post-job review of high-dose activities to ensure that ALARA controls are planned, evaluated, implemented where reasonable, and documented.
 10. ALARA Organization and Responsibilities: A document that clearly defines the organization and responsibilities of line management and workers involved in implementing the ALARA program.
 11. ALARA Committee: A multi-disciplined forum that reviews and advises management on the implementation of the facility's ALARA program.
 12. Data Base System for Collective Dose: A system to store radiological data and rapidly produce ALARA data summaries. Examples of ALARA goals to be tracked are: stations annual collective dose, department annual or quarterly collective dose, outage collective dose, and job dose totals. Examples of other ALARA data summaries are: workgroup internal and external dose; job, system, component, and area dose totals; shielding dose-reduction factors; decontamination factors; and personnel and area external contamination incidents.
 13. ALARA Program Appraisal: An internal review and evaluation of the ALARA program, designed to ensure that the program effectively complies with federal and management requirements, as well as good practices.
 14. ALARA Training for Engineers: A formal training program for engineers in the application of appropriate engineering and design methods to maintain radiation exposures and the spread of radioactive material in a new design or modification of a facility as low as reasonably achievable. This training should include:
 - DOE Orders and guides,
 - ALARA concept and incentives,
 - Overview of ALARA program,
 - ALARA design considerations,
 - ALARA design review,
 - ALARA job review and dose-reduction techniques, and
 - Cost-effectiveness evaluations.

15. ALARA Training for General Employees. A segment in the initial employee training would discuss the meaning of ALARA, the company policy regarding ALARA, and the employee's responsibility for ALARA and why the employee should not enter rooms/areas bearing the radiation symbol.
16. Annual or Special ALARA Reports: An annual or special report that documents the accomplishments and recommended improvements in the ALARA program.
17. ALARA Training for Administrators: A formal training program for administrators and line managers that will inform them of the need for ALARA and their responsibilities to implement the program. This training should include:
 - DOE Orders and guides,
 - ALARA concept,
 - Overview of the ALARA program,
 - Responsibilities for ALARA, and
 - Evaluating performance.
18. Safety Suggestion: A formal program to submit, document, evaluate, and implement employees' suggestions to improve radiological safety.
19. Cost/Benefit Methodology: A documented methodology which describes how the factors affecting a protection decision, i.e., social, technical, economic, practical, and public policy are transformed into a monetary system to compare costs and benefits.

Exhibit G

DOE Contractor Reports on Innovative Techniques for Reducing Dose and Contamination

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2. Coulson, L.V., Elwyn, A.J., and Freeman, W.S., "Accelerator Health Physics at DOE Laboratories: A Characterization," Report FN-510, Fermi National Accelerator Laboratory, Batavia, IL, April 1989.
3. Ostenak, C.A. et al., "Task Force Recommendations for TA-55 Vault Improvements," Los Alamos National Laboratory, Los Alamos, NM, August 1, 1985.
4. Stanley, H.C., Unruh, W.P., Sprouse, L.L., Kuckertz, T.H., Baird, W., McAtee, J.L. and Treadway, W.A., "Semi-Automated Monitoring of Glovebox Work Stations for Radiation Hazards," Report LA-UR-88-1300, Los Alamos National Laboratory, Los Alamos, NM, November 1988.
5. Anderson, J.M. and Wallace, W.K., "Mound's Plutonium (Alpha) Area Certification Program," EG&G Mounds, Miamisburgh, OH, November 17, 1980.
6. Childs, E.L. and Winkel, J.R., "Electrodecontamination of Glove-Box Materials," Nuclear Technology, 63: 271-85, November 1983.
7. Long, J.L., Humiston, T.J., and Murray, A.M., "Preliminary Molten Salt Extraction Experiments with Dicesium Hexachloroplutonate (CS_2PuCl_6)," Report RFP-4203, Rockwell International, Rocky Flats Plant, Golden, CO, January 30, 1989.
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9. Katayama, Y.B. and Holton, L.K., Jr., "324 and 325 Building Hot Cell Cleanout Program, Decontamination of C-Cell," Report PNL-6976, Pacific Northwest Laboratory, Richland, Washington, October 1989.
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11. Gravley, K.D. and Webber, G.L., "HS&E Design Criteria for Plutonium Recovery Facilities," Rockwell International, Rocky Flats Plant, Golden, CO, February 1989.
12. Heine, W.F. and Speer, D.R., "Decontamination and Decommissioning of a Fuel Reprocessing Pilot Plant," Proceedings of the Institution of Mechanical Engineers International Conference - Decommissioning of Major Radioactive Facilities, pp. 139-44, 1988.
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14. Metcalf, J.H., "Simple Method for Isolating a Source of Tritiated Water Vapor," Report SAND88-2816C, Sandia National Laboratory, Mercury, NV, 1988.
15. Mihalovich, G.S. and Heisler, S.W., Jr., "Demonstration of New Handling Equipment Configurations for the Overpacking of Thorium Materials," Report FMPC-2141, Westinghouse Materials Company of Ohio, Cincinnati, OH, 1988.
16. Rankin, W.N., Fogle, R.F., and Looper, M.G., "Robotic Decontamination at the Savannah River Plant," Report DP-MS-88-107, E. I. du Pont de Nemours and Company, Savannah River Laboratory, Aiken, SC, 1988.
17. Heckerdorn, F.M. and Fogle, R.F., "Lead Removal from Radioactive Vessels Using a Mobile Robot," Report DP-MS-88-95, E.I. du Pont de Nemours and Co., Savannah River Laboratory, Aiken, SC, 1988.
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END

**DATE
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6/17/92