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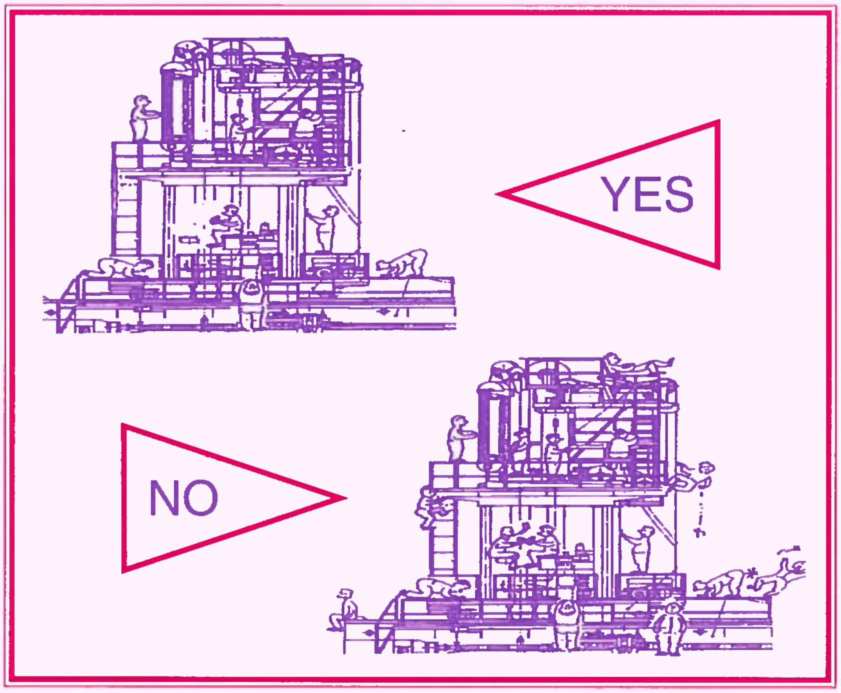
Work Management in the Nuclear Power Industry



NUCLEAR ENERGY AGENCY

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Work Management in the Nuclear Power Industry

A Manual prepared for the NEA Committee on Radiation Protection and Public Health by the ISOE Expert Group on the Impact of Work Management on Occupational Exposure

NUCLEAR ENERGY AGENCY
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Pursuant to Article 1 of the Convention signed in Paris on 14th December 1960, and which came into force on 30th September 1961, the Organisation for Economic Co-operation and Development (OECD) shall promote policies designed:

- to achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;
- to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development; and
- to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

The original Member countries of the OECD are Austria, Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The following countries became Members subsequently through accession at the dates indicated hereafter: Japan (28th April 1964), Finland (28th January 1969), Australia (7th June 1971), New Zealand (29th May 1973), Mexico (18th May 1994), the Czech Republic (21st December 1995), Hungary (7th May 1996), Poland (22nd November 1996) and the Republic of Korea (12th December 1996). The Commission of the European Communities takes part in the work of the OECD (Article 13 of the OECD Convention).

NUCLEAR ENERGY AGENCY

The OECD Nuclear Energy Agency (NEA) was established on 1st February 1958 under the name of the OEEC European Nuclear Energy Agency. It received its present designation on 20th April 1972, when Japan became its first non-European full Member. NEA membership today consists of all European Member countries of OECD as well as Australia, Canada, Japan, Republic of Korea, Mexico and the United States. The Commission of the European Communities takes part in the work of the Agency.

The primary objective of NEA is to promote co-operation among the governments of its participating countries in furthering the development of nuclear power as a safe, environmentally acceptable and economic energy source.

This is achieved by:

- *encouraging harmonization of national regulatory policies and practices, with particular reference to the safety of nuclear installations, protection of man against ionising radiation and preservation of the environment, radioactive waste management, and nuclear third party liability and insurance;*
- *assessing the contribution of nuclear power to the overall energy supply by keeping under review the technical and economic aspects of nuclear power growth and forecasting demand and supply for the different phases of the nuclear fuel cycle;*
- *developing exchanges of scientific and technical information particularly through participation in common services;*
- *setting up international research and development programmes and joint undertakings.*

In these and related tasks, NEA works in close collaboration with the International Atomic Energy Agency in Vienna, with which it has concluded a Co-operation Agreement, as well as with other international organisations in the nuclear field.

FOREWORD

Occupational exposures at nuclear power plants worldwide have been steadily decreasing over the past decade. Regulatory pressures, particularly after the issuance of ICRP 60 in 1990, technological advances, improved plant designs, and improved water chemistry and plant operational procedures, as well as other factors, have contributed to this trend. However, as the world's nuclear power plants age, the task of maintaining low occupational exposures has become increasingly difficult. In addition, economic pressures have led plant operation managers to streamline refuelling and maintenance operations as much as possible, thus adding scheduling and budgetary pressure to the task of reducing operational exposures.

In response to these pressures, radiation protection personnel have found that by properly planning, preparing, implementing, and reviewing jobs, occupational exposures can be kept as low as reasonably achievable (ALARA). This concept has been broadly termed Work Management. If properly applied, work management can lead to the reduction of the number of workers needed to perform a job, the number of person-hours spent in the radiologically controlled zone, and thus the overall cost of doing work, as well as to a reduction of occupational exposures in an ALARA fashion.

To further study the process of the application of work management techniques in the nuclear power industry, the NEA, in February, 1992, sponsored a Workshop entitled, Work Management to Reduce Occupational Doses. During this workshop, radiation protection personnel from around the world presented numerous case studies showing how the application of work management had saved them time, dose, and money. It was widely felt that work management practices were slowly diffusing throughout the nuclear power industry, however, in conclusion, it was felt that further work should be performed in the area of quantifying the effects of work management practices. One of the Workshop recommendations was "To continue along the same lines, it was considered of great interest to try to develop some guidance on the quantification of ALARA measures. If one is able to present quantitative evidence, in the form of gain in time, money, and dose, for example, by introducing dose reduction measures, it would be much easier to make the case for such measures and get them accepted. It was therefore recommended that the NEA set up an ad hoc group to study the question of quantification of work management actions."

Based on this recommendation, in 1993 the ISOE Steering Group, with the consent of the NEA Committee on Radiation Protection and Public Health (CRPPH), formed an Expert Group on the Impact of Work Management on Occupational Exposure, and charged this group to produce a study on the quantification of the impact of key work management factors on worker doses and operational costs. To this end, this report attempts to provide a comprehensive review of work management practices, and to provide for each of several broad areas of work management, application techniques for the quantification of impacts.

Quantification techniques are illustrated with actual case studies.

The work of preparing this report and compiling the illustrative case studies was performed by the Expert Group on the Impact of Work Management on Occupational Exposure, which was chaired by Dr. David W. Miller (United States). The members of the Expert Group were:

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All illustrations in this report were kindly drawn by Mr. Björn Wahlström.

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EXECUTIVE SUMMARY

Introduction

As we near the beginning of the 21st century, the industrialised world continues to change. More and more, in all facets of modern industry, economic pressures have made productivity and cost competitiveness essential concepts to the very survival of companies. In response to these pressures, many companies have adopted a very global approach to their work, stressing the importance of approaching jobs from the multi-disciplinary team perspective, and of following jobs completely through the stages of conception, design, planning, preparation, implementation, and follow-up. By focusing such attention on jobs, their successful completion – on schedule, within budget, with a sufficient level of quality, with minimum cost, and with a maximum chance of fulfilling the originally desired goal - can be assured. This multi-disciplinary, start-to-finish approach to jobs can be broadly termed ***Work Management.***

The nuclear power industry is experiencing the same economic pressures as most other modern industries, and is working to increase revenues and to reduce costs, all while maintaining a sufficient margin of safety for the public, and while reducing the risks to which its workers are exposed. In the case of the nuclear power industry, increasing revenues means maximising the operation time (or minimising the outage time) of nuclear reactors. Reducing costs means lowering expenditures for maintenance during normal operation and during refuelling outages. While these two goals may at first seem to be in conflict with the goals of maintaining a sufficient margin of public safety and reducing risks to nuclear workers, thirty years of nuclear power plant operation have demonstrated that the application of the above mentioned Work Management principles in the nuclear power industry can simultaneously fulfil all these goals.

To further study the process of the application of work management techniques in the nuclear power industry, the NEA, in February, 1992, sponsored a Workshop titled, "Work Management to Reduce Occupational Doses". During this workshop, radiation protection personnel from around the world presented numerous case studies showing how the application of work management had saved them time, dose, and money. It was widely felt that work management practices were slowly diffusing throughout the nuclear power industry, however, in conclusion, it was felt that further work should be performed in the area of quantifying the effects of work management practices. The Workshop's recommendation, as published in the NEA Workshop Proceedings document, is as follows:

> *To continue along the same lines, it was considered of great interest to try to develop some guidance on the quantification of ALARA measures. If one is able to present quantitative evidence, in the form of gain in time, money, and dose, for example, by introducing dose reduction measures, it would be much easier to make the case for such measures and get them accepted. It was therefore recommended that the NEA set up an ad-hoc group to study the question of quantification of "work management" actions.*

Based on this recommendation, in 1993 the NEA formed an Expert Group on the Impact of Work Management on Occupational Exposure, and charged this group to produce a study on *"the quantification of the impact of key work management factors on worker doses and operational costs"*. To this end, this "Handbook of Good Practices" has been prepared, and attempts to provide a comprehensive review of work management practices, and to provide for each of several broad areas of work management, application techniques for the quantification of impacts. Quantification techniques are illustrated with actual case studies.

The objective of the Handbook of Good Practices, is to focus on the application of Work Management principles to the reduction of occupational exposure, which is only one part of one of the goals of Work Management mentioned previously. However, because the reduction of dose is often accomplished by the reduction of the number of workers in the radiologically controlled zone, by the reduction of the time spent by workers in that zone, and by the reduction of the amount of rework (due to faulty design, planning, preparation, implementation, or follow-up) the goals of reducing costs, as well as classical safety risks, and the goal of minimising the time required for an outage, can often also be simultaneously fulfilled.

This Executive Summary is intended to be a brief review of the principles included in the Handbook of Good Practices. The specific case studies illustrating these principles are include only in the body of the Handbook.

Regulatory Issues

This chapter briefly discusses international radiological standards and the means by which they are implemented in regulations in various countries. Although not having such direct influence on the application of Work Management as plant policy, regulatory policy indirectly effects the way that Work Management is applied. Based broadly on the application of the ALARA principle, regulatory policy attempts to assure that both the public and the worker are protected from the hazards of radiation exposure.

Recent trends in regulation have been more towards "performance standard" type rules as opposed to more prescriptive type rules. For example, a performance standard type rule would require that secondary side water contamination concentration remain below a certain limit or constraint, while a prescriptive rule would require systematic steam generator tube inspection during every refuelling outage. The former type or regulation fulfils the regulatory authority's obligation to protect workers and the public while leaving the operator free to optimise work to obtain the best results from his/her standpoint. This is an example of regulatory application of Work Management.

For the purposes of exploring the application of Work Management principles, it is useful to consider regulations in three categories: 1. those issued to respond to nuclear safety concerns, 2. those issued to respond to radiation exposure concerns, and 3. those which are historical in nature. The first category includes regulations to protect the public from radiation hazards, such as would occur after an accident. As an example, such regulations might be concerned with the frequency of system or component inspection and maintenance. A performance based regulation, in this case, would allow maintenance based on component history and status, necessitating monitoring, but not necessarily systematic actions each outage.

The second category includes regulations to protect the public and the worker from the harmful effects of radiation, but address dose limits, constraints, and operational restrictions directly. Dose limits are an example of performance based regulations. New concepts from ICRP Publication 60, such as dose constraints and dose operational restrictions, also follow this performance based approach, allowing the operator of the radiation source (electric utility, accelerator, fixed source, etc.) a fair amount of flexibility in terms of how to meet regulatory limits, constraints, or operational restrictions.

Finally, historical regulations are those which have been in application for some time, and which may no longer be valid or be in line with current philosophy. Here again, the performance based approach to regulations would allow the questioning of such regulations, and their eventual improvement or elimination to better reflect current circumstances. Such a questioning approach by the operators of radiation sources should be welcomed by regulatory authorities.

Work Management Policy

As with the implementation of any initiative, success depends upon motivation and support originating at the highest levels of the organisation. Work Management is no exception to this rule, and requires that plant management be willing to support, in policy and budget, the idea that multi-disciplinary teams will be required to plan, schedule, implement, and follow-up jobs. A type of "customer / client" relationship, in other words a service oriented relationship, should be fostered between these teams and the plant.

Management commitment to any project is always demonstrated by management presence. Management policy should thus encourage managers to make frequent visits to the work site(s), and to have first-hand knowledge of project status and problems. Plant tours should be conducted with a specific purpose or area of concentration (e.g., housekeeping, cleanliness, worker procedural compliance, tool staging adequacy, support group timeliness, specific repair task progress, etc.). This can be facilitated by the appropriate delegation of authority, which will free manager's time to accomplish thorough plant observation tours.

In addition, management policy can require that work be performed within specified limits (dose, man-hours, time, etc.). This can be implemented via contractual requirements for contractors, and by management's willingness to fund, in terms of money and personnel, the projects necessary to meet the assigned goals. The communication of these goals, and of management's commitment to them, to all workers is also very important.

Uniformly, in North America, Europe and Asia, management philosophy in the area of radiation protection is based on the ALARA principle. Numerous national and international guidance documents exist on this subject. Based on this philosophy, the key points of the structure of a programme to maintain doses ALARA are common to most countries. These points include the existence of such a programme at each plant, the appropriate assignment of responsibilities, the creation of and role definition for what is called in many countries an "ALARA Committee", the creation of and role definition for an "ALARA Engineering Group" to review work procedures, and the establishment of criteria as to when and to what level jobs are sent to such a group to receive "ALARA Reviews".

Worker Involvement

A topic which influences many of the stages of a job is worker involvement. By engaging the worker in the task being performed, the worker is more likely to be motivated to perform the job to the best of his/her abilities. This will be reflected in lower job doses as well as in higher job quality.

Worker motivation can take many forms. In the spirit of Work Management, the worker should be involved as much as possible in the multi-disciplinary job team which performs the task planning, scheduling, training, implementation, and feedback.

There are many important factors which contribute to the creation and maintenance of good worker involvement. Many of these factors centre around worker motivation. For example, the general behaviour of management and senior staff should reflect their belief in and acceptance of a Work Management approach to jobs. Further, their behaviour should reflect a willingness to listen to and respond appropriately to worker suggestions. This can be reflected in the work process by "planning" for the unexpected, that is, by leaving a certain flexibility in the work procedures, such that the "expert judgement" of the worker can be allowed to function during the training for and performance of the task.

The education and training of workers in techniques for applying Work Management and the ALARA principles to their work is also important, stressing that such techniques are in the interest of the worker, and not simply to gain time and money for the utility. In this regard, the involvement of workers in job planning, in post-job reviews, and in the setting of job goals will reinforce the reflex to "Think ALARA" which is taught during training courses.

Other forms of "communication" with the worker are also important to maintain motivation. For example, the use of information sheets, hand outs, and posters to remind workers of basic principles can be effective. In addition, workers should be reminded of the various goals which have been set, and should be shown the progress towards reaching these goals. This can include posting of graphs and diagrams showing the evolution of various projected dose and/or man-hour goals as compared to actual dose and/or man-hour expenditures. Periodic worker briefings, by senior staff, radiation protection personnel, and job supervisors can also be used to update workers as to current work status, reinforce job objectives, and to discuss dose and quality goals.

Incentives, such as awards, gifts, and worker recognition have been shown to be effective tools to maintain worker motivation. The use of challenging or stressing factors, such as increased management and radiation protection presence at work sites, can also motivate workers to perform better as long as the previously mentioned management behaviour, willingness to listen, discuss and respond appropriately, is maintained.

Finally, once established, worker motivation must be maintained. Management commitment to the above approach, the periodic reinforcement of the Work Management approach through training, and by management following through on commitments to workers will all aid in maintaining worker motivation.

Work Selection, Planning and Scheduling

The objective of work selection is to identify those tasks which are "necessary". Work which can fall into this category includes regulatory requirements, work related to the reliable operation of the plant, and work associated with refuelling. Unfortunately, not all jobs are obviously "necessary" or "unnecessary", and it is here that the concept of Work Management must be applied to appropriately select jobs to be performed. Once jobs have been selected for performance, the process of planning begins, and again the multi-disciplinary Work Management team approach should be applied.

As part of work selection, one technique which has proven effective in some countries (Finland, Sweden) has been to defer tasks to longer, future outages (5 year outage, 10 year outage). Although this does not alter the amount of work to be performed, postponing work can allow the regrouping of similar type jobs, or jobs on the same equipment or system, into a single outage, which, if properly scheduled, should result in time and dose savings. Postponing work, taking plant safety and maintenance requirements appropriately into account, can result in a reduction of work if, for example, annual jobs (inspections, calibrations) are performed only every other year.

Another technique which saves outage time but not necessarily dose, is to reschedule work from the refuelling outage period to the normal operation period. This is, of course, not always possible due to physical and regulatory constraints, however if the option is available it should be considered.

Finally, although it is difficult to identify generic selection criteria, the appropriate selection of work to be performed can significantly reduce the duration and dose of a refuelling outage. The necessity to perform each job should be questioned systematically, as mentioned above, and should be based on plant condition - is the proposed job necessary to make the plant safer, more reliable, or more efficient? Is the necessity for the job based on overly conservative calculations? It should also be noted that such questioning should continue, based on changes in schedule or other work to be performed, until the job is actually begun.

In terms of planning and scheduling, Work Management would require that a multi-disciplinary team be used to plan jobs, including representatives from plant management, scheduling, maintenance engineering, safety, and radiation protection, as well as from the contractor as applicable. This approach will assure that all appropriate measures are taken into account during the job planning process (preparation of procedures and contracts, ordering of equipment, etc.), as well as the scheduling process. This takes some time to perform "correctly", and utilities in most countries establish their planning and scheduling effort well before (generally 7 to 9 months) the beginning of a maintenance outage. During this process it is very important to consider lessons learned.

Other planning and scheduling considerations are also important. For example, the physical proximity of various groups involved in planning and scheduling (schedulers, plant maintenance engineers, radiation protection, etc.) can facilitate communications and decision making processes. Scheduling jobs when the maximum amount of water shielding is available (from components being full) is important, and the consideration of resource use (resource-based scheduling) and area use (area-based scheduling) can greatly reduce unnecessary loss of time and dose. The use of scale models, photo libraries, video-tour systems, and mock-up training will also help to appropriately plan for jobs to be carried out efficiently.

Typically, in planning the efficient use of resources, particularly human resources, many plants tend to concentrate their efforts on particular jobs which are historically "hot". Such jobs are often common to many different plants such that there generally exists much experience which should not be ignored (reinventing the wheel should be avoided). This experience includes previous maintenance outages (historical data), as well as numerous exterior sources (the NEA ISOE Programme, phone calls to "sister" plants, WANO, INPO, national user's groups, etc.). The expansion of such a "data base" of information should also be assured, for use in subsequent maintenance outages, by the collection of detailed information regarding the number and type of workers, and the number of work hours (staging, performing work, post job cleanup).

Work Preparation

As with the other areas of Work Management implementation, multi-disciplinary communication is one of the keys to work preparation. In this case, work preparation refers to tasks performed to prepare the worker, the work site and the piece of equipment or system to be worked on for the job.

To begin with, the work site can be optimised, in terms of the placement and availability of support equipment (scaffolding, temporary shielding, ventilation, area decontamination, insulation removal, etc.). Personnel selection and training are also, obviously, very important. Often, however, training is only effective for large and/or complicated tasks. It should be noted that as little as 25% of a worker's time is actually spent at the work site, such that even the best training will only save a limited amount of scheduled time (although this may be important for critical path jobs). Even so, work can be optimised by selecting for the high-dose portions of a task, those workers who perform best during training, including accounting for the encumbrance related to the use of protective clothing. For example, the temporary shielding installation and removal team should be a skilled and experienced group, familiar with their equipment, with the areas where they will place temporary shielding, and with the desired dose-rate reduction goals. Contamination control, through work-site decontamination, equipment decontamination (either at the work site or in a hot shop), through system flushing, or through chemical decontamination, can reduce the need for cumbersome protective clothing and thus increase worker efficiency and accuracy.

In certain situations, the use of specialised tooling and/or robotics can be both economical and effective. This can include tools used at the work site, as well as tools used in specialised "hot workshops". In particular, it has been noted that the availability of a well-equipped hot workshop can improve maintenance quality as well as save time and cost. The effective use of supporting equipment, such as ventilation and filter systems, or remote communications and monitoring equipment, can also work to save dose, time and money.

Finally, process work control can be very important. The use of electronic dosimeters and access control systems are effective at providing sufficient data for the real-time review of worker doses, as well as dose follow-up. The use of some sort of work permit system can also assist in the real-time co-ordination of work, and in assuring that all necessary job prerequisites (valve line-ups, electrical circuit set-ups, hazardous work permits, etc.) have been fulfilled prior to the start of work.

Work Implementation

The most important concept for the implementation of Work Management during the phase of work implementation is the control of work and the work environment.

To begin with, while the role of radiation protection personnel varies from country to country, as does the degree of radiation protection responsibility assigned to workers, one of the key functions of radiation protection personnel is to provide assistance and advice to workers. To facilitate this task, in some countries particular radiation protection personnel are designated to follow particular tasks (work on the steam generator secondary or primary side, work on the reactor coolant pump, work in the dry well, for example). Also, the use of radiation protection "hold points" assures that advice will be sought and given at particularly dose-intensive portions of a task (for example, requiring a radiation protection survey of the steam generator channel head after opening of the manway). Assigning individual worker dose restrictions can also assure that advice is sought and given at important points.

Moreover, to effectively control work supervisors must spend sufficient time at the work sites to be aware of progress and problems, and to be aware of the radiological status of their work. To resolve any problems encountered, inter-service communications must be quick and efficient. To this end, the French have experimented with the use of a full time reactor building chief, who is the central contact point for any problems encountered, such as lack of electric current, problems with elevators, questions about permits, etc. In the United States, "Make-It-Happen-Managers" and "Dry Well Work Co-ordinators and Managers", assigned to particular tasks or classes of tasks, have been used to accomplish the same type of inter-service communications to facilitate the completion of jobs. Daily outage meetings can also be effective for resolving inter-service problems or conflicts.

The control of access to and time spent in the controlled zone is also important. The Americans have experimented with a "reactor building gorilla" who is responsible for assuring that all workers entering the reactor building are properly authorised and will not stray from their appointed tasks. The reduction of "transit doses" (received by workers going to and from, or looking for their place of work) can increase work efficiency. By familiarising workers with their work site prior to entering the controlled zone (by the use of photos, survey maps, computerised building "surrogate tours", etc.) significant doses can be saved. By assuring that workers spend their "dead time" and break time in low dose areas, dose savings can be further augmented. To this end, in Finland, break rooms have been installed where workers do not have to remove uncontaminated protective clothing in order to eat, drink, or smoke. In France, designated "Green Areas", in the reactor building annulus, are low dose areas where workers can wait between working periods.

In order to assure that sufficient data is captured for follow-up analyses, data collection during work implementation is very important. Such collection is most efficiently performed automatically, via computer systems linked to electronic dosimeters, work permits, radiation area surveys, etc. With the now common use of electronic dosimetry, such systems are becoming more and more available.

Finally, as previously noted in the section on worker motivation, it is during the work implementation phase that such motivation will have the most visible effects. Again, the use of collective dose goals for tasks, groups, areas, etc., and the display of those goals against actual daily collective doses, has proved to be motivational in several countries. Attaching some sort of reward to the achievement of these goals has also proved to be effective.

These simple examples illustrate the importance of maintaining control, in all senses, of the work being performed. Again, communications and multi-discipline co-ordination are the keys to successful implementation of Work Management.

Work Assessment and Feedback

The final stage of work is that of assessment and feedback. However, when applying the Work Management philosophy to jobs, this is also the first stage because, in essence, the process is continuous. As with the other stages, the multi-disciplinary approach is stressed.

In terms of work assessment, the indicators used to assess work, and the bench marks against which these indicators are judged, must be multifaceted. For example, collective dose and individual dose distribution must be joined by other indicators such as person-hours, number of workers, work duration, rework required, delays and problems, etc. For such bench marks and indicators, data from pre-job ALARA analysis, historical data and data from other sites is essential.

Feedback should be as direct as possible. That is to say, the workers having performed the work should directly provide their suggestions as to how the work could have been improved, or how the problems encountered could have been better addressed. This may involve paying the contractor to remain at the site after the completion of the work.

To "close the Work Management loop", a mechanism for assuring the implementation of the job feedback is necessary. Such formalised systems as suggestion tracking lists, or more informal systems such a simply maintaining the Assessment/Feedback team in tact for the preparation and planning of subsequent work, have been utilised.

Finally, the entire system of Work Management implementation should be audited periodically to assure that it is functioning properly. Again, many systems, from very formal to very informal, have been tried.

Conclusions

Work Management is a holistic, start-to-finish, multi-disciplinary approach to jobs. The objective of Work Management is the optimisation of work such that its successful completion - on schedule, within budget, with a sufficient level of quality, with minimum cost, and with a maximum chance of fulfilling the originally desired goal - can be assured. The attainment of this objective requires the active participation of everyone involved in the work. It is hoped that the "Handbook of Good Practice", which will be published by the NEA, will be a useful tool for Work Management implementation.

1. INTRODUCTION

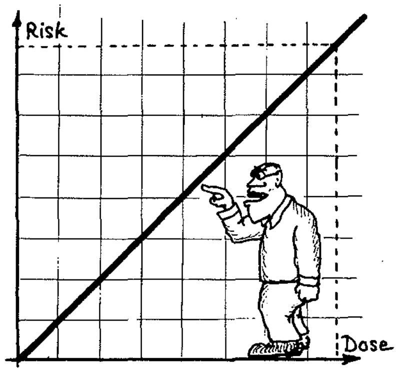
As we near the beginning of the 21st century, the industrialised world continues to change. More and more, in all facets of modern industry, economic pressures have made productivity and cost competitiveness essential concepts to the very survival of companies. In response to these pressures, many companies have adopted a very global approach to their work, stressing the importance of approaching jobs from the multi-disciplinary team perspective, and of following jobs completely through the stages of conception, design, planning, preparation, implementation, and follow-up. By focusing such attention on jobs, their successful completion – on schedule, within budget, with a sufficient level of quality, with minimum cost, and with a maximum chance of fulfilling the originally desired goal – can be assured. This multi-disciplinary, start-to-finish approach to jobs can be broadly termed ***Work Management***.

The nuclear power industry is experiencing the same economic pressures as most other modern industries, and is working to increase revenues and to reduce costs, all while maintaining a sufficient margin of safety for the public, and while reducing the risks to which its workers are exposed. In the case of the nuclear power industry, increased revenues means maximising the operation time (or minimising the outage time) of nuclear reactors. Reducing costs means lowering expenditures for maintenance during normal operation and during refuelling outages. While these two goals may at first seem to be in conflict with the goals of maintaining a sufficient margin of public safety and reducing risks to nuclear workers, forty years of nuclear power plant operation with continuing feedback and improvement of radiation protection performance have resulted in significant experience. Particularly, the past ten years of so have demonstrated that the application of the above mentioned Work Management principles in the nuclear power industry can simultaneously fulfil all these goals.

The objective of this report will be to focus on the application of Work Management principles to the reduction of occupational exposure, which is only one part of one of the goals mentioned in the previous paragraph. However, because the reduction of dose is often accomplished by the reduction of the number of workers in the radiologically controlled zone, by the reduction of the time spent by workers in that zone, and by the reduction of the amount of rework (due to faulty design, planning, preparation, implementation, or follow-up) the goals of reducing costs, as well as classical safety risks, and the goal of minimising the time required for an outage, can often also be simultaneously fulfilled. These simultaneous savings will be noted during the course of this report as applicable.

To accomplish this objective, several broad areas where Work Management can be applied in the nuclear power industry will be discussed. The specific aspects of Work Management applicable to each of these broad areas will be illustrated by actual case studies, and techniques for the quantification of the impacts of these Work Management initiatives will also be illustrated. In that the above mentioned increasing economic pressures have touched all aspects of the nuclear power industry, and that radiation protection is no exception, in order to initiate new programmes to assure convince plant management that any new programme or project to reduce occupational exposure is justified. In the true sense of ALARA, this means that the dose savings must be optimised with respect to monetary expenditures. In some cases, monetary savings can actually be realised while obtaining dose savings simply by applying good radiation protection practice. It is hoped that the techniques illustrated in this report will be used by radiation protection personnel in just this fashion; to justify expenditures for the implementation of Work Management initiatives to reduce occupational exposures.

2. REGULATORY ISSUES



2.1 Introduction

This chapter briefly discusses international radiological standards and the means by which they are implemented in regulations in various countries. Regulatory frameworks aim to secure the maintenance and improvement of standards of safety at civil nuclear installations and the protection of workers and members of the public from ionising radiation. Regulation provides for an effective radiological protection infrastructure which includes a "safety culture" shared by those with protection responsibilities from workers through to management.

One of the key regulatory influences on work management in relation to control of occupational exposure is the ALARA principle. The concept of keeping exposures "**A**s **L**ow **A**s **R**easonably **A**chievable" is fundamental to the current application of radiation protection. In implementing this principle, there is a clear need for balance between measures aimed at further reducing public doses from routine operation, for which individual levels of exposure are generally very low, and those affecting occupational exposure, which may have the potential for achieving genuine reductions in exposure to a relatively small number of people. For example, the installation of ventilation filters or liquid effluent treatment plants might lead to radiation exposure of the staff who would install, maintain, operate and decommission that plant.

There is a further need to ensure that the exposure of operators performing maintenance and inspection is warranted by the perceived benefit in plant reliability and in further minimising the very low probability of a catastrophic failure. Depending on the safety significance of a particular device, a regime of plant condition monitoring and breakdown maintenance may offer advantages over a more rigid system of preventative maintenance to a pre-determined schedule. In practice a certain proportion of plant failures are known to follow scheduled preventative maintenance, in which there is scope for error in dismantling and re-assembly.

An effective regulatory regime should recognise the need for balance in these areas and enable the operator to apply flexibility in the application of the ALARA principle. It should be the operator's duty, in the first instance, to satisfy *him or herself* that a particular operation is safe and meets the ALARA principle. Regulatory regimes vary in their level of prescription. A prescriptive regulatory regime runs the risk of compromising this flexibility and placing an inappropriate burden on both the operator and the regulator. On the other hand, implementation of a non-prescriptive regime requires a high level of expertise, judgement and specialist resource to monitor and ensure that appropriate standards are being proposed and met by the licensee. A licensing regime thus provides one of the means of control available to a regulatory authority.

2.2 International Standards

The international organisations which have a major bearing on the safety standards adopted in managing work at nuclear installations are the International Commission on Radiological Protection (ICRP), the European Union (EU) by virtue of the European Atomic Energy Community (EURATOM) treaty, the International Atomic Energy Agency (IAEA) and the Nuclear Energy Agency (NEA) of the Organisation for Economic Co-operation and Development (OECD). The roles of these bodies are discussed below.

ICRP is a non-Governmental scientific organisation which has been functioning since 1928 when it was established by the Second International Congress of Radiology. It is regarded as the world's foremost body issuing recommendations from time to time on which radiological protection measures can be based and has continued to provide guidance within the radiological protection field as a whole. For more than 50 years, ICRP recommendations have been the basis of underlying national standards and controls governing the use of ionising radiation. ICRP authority stems from the standing of its independent members, who are drawn from a range of scientific disciplines, and from the merit of its recommendations.

ICRP recommendations for limiting the detrimental effects of ionising radiation are issued in publications and through subsequent statements clarifying or extending those recommendations. Three basic principles for protection are involved. Firstly, all operations involving exposure should be justified; secondly, all exposures should be optimised; and lastly, individual doses shall not exceed limits. The recommendations in ICRP Publication 26 (ICRP, 1977) form the basis for many national regulations, such as a portion of the Code of Federal Regulations, 10CFR20 (CFR, 1993), which deals with radiation protection in the United States. ICRP Publication 60 (ICRP, 1990) provides the Commission's latest recommendations, and these form the basis for the recently issued European Union (EU) Directive on basic radiation safety standards (Euratom), which are binding for the member states of the EU.

EURATOM came into being on 1 January 1958 following a treaty signed in Rome in March 1957, having the same Member States as the European Economic Community (EEC). Its task is to promote common efforts between its members in the development of nuclear energy for peaceful purposes. The EURATOM treaty provides for the establishment of basic safety standards for the health protection of workers and of the general public against the dangers of ionising radiation. These standards, which reflect the recommendations of the ICRP, are specified in a European Union (EU) directive and are therefore legally binding on member states. A revision of the EU directive on basic safety standards for radiological protection, which was mentioned in the last paragraph, was adopted in June 1996, and takes into account the recommendations of ICRP Publication 60. Member States of the EU are thus required to enact national legislation within four years, implementing this new directive.

The IAEA was formed in 1957 as an independent, inter-Governmental organisation within the United Nations Network. Its main objective is to promote atomic energy in the interests of peace, health and prosperity throughout the world. The Agency produces standards and other guidance covering all aspects of the safe use of radiation . Basic safety standards in the form of codes and guides are produced under the nuclear safety standards (NUSS) programme, and in the programme on radiation safety a comprehensive set of safety series documents, representing international consensus, is produced. The new International Basic Safety Standards for Protection against Ionising Radiation and for the Safety of Radiation Sources (the BSS for short), which turns the recommendations of the ICRP in Publication 60 into internationally agreed safety standards, is jointly sponsored by six international organisations [Food and Agriculture Organisation of the United Nations (FAO), the International Atomic Energy Agency (IAEA), the International Labour Organisation (ILO), the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (OECD/NEA), the Pan American Health Organisation (PHAO), and the World Health Organisation (WHO)] and will be published by the IAEA in early 1996. Whilst the codes are not binding on IAEA member states, they are expected to be considered in formulating national safety standards and regulatory requirements.

The Nuclear Energy Agency of the OECD was originally established in 1958 with the aim of promoting co-operation among the governments of its participating countries in furthering the development of nuclear power as a safe, environmentally acceptable and economic energy source. Although the NEA does not issue the same type of recommendations and guidance as the ICRP or the IAEA, it does much work in the areas of nuclear safety, nuclear regulation, radioactive waste management, radiation protection, nuclear development and nuclear science. Reports from the committees, expert groups and workshops of the NEA represent consensus opinion on topics of interest to the participating NEA Member countries. Generally, the topics addressed by the NEA are specific, state-of-the-art technology or philosophically new areas, from which the guidance documents produced by the IAEA and the European Commission can be developed.

2.3 Regulatory Policy

World-wide regulatory policy for the implementation of international standards generally has only an indirect influence on the application of Work Management. The type and nature of national regulations can, however, be tailored to promote the use of Work Management by the regulated facilities. To explore the influence that regulations can have, it is helpful to consider regulations in three categories: those issued to respond to nuclear safety concerns, those issued to respond to radiation exposure concerns, and those which are historical in nature.

2.3.1 Regulations to Respond to Nuclear Safety Concerns

Although all nuclear regulations are intended to protect workers and the public from the harmful effects of radiation exposure, one aspect of this protection is the prevention of nuclear accidents. Regulations which address nuclear safety issues have, as one of their primary objectives, the prevention of nuclear accidents. As previously mentioned, classic examples of such regulations are those relating to system inspection and maintenance, including their extent and frequency. Because it is not obvious what the extent and frequency of such programmes should be, the flexibility of such regulations varies from country to country.

If the extent and the frequency of an inspection and maintenance programme is high, the application of work management may be constrained. For example, if every year or every outage much inspection and preventative maintenance must be performed, there exists little freedom to combine some inspections, *i.e.*, to perform them together only every third year under optimised radiation-protection conditions. Postponing inspections until, for example, after the completion of a system decontamination would save dose and allow optimised inspection and maintenance scheduling. If many inspections are prescribed every year, the number of measures available to optimise the application of Work Management is limited.

The same can be said of regulatory requirements imposed following unexpected discoveries, for example cracks or failures in components found at one or more nuclear power plants. Regulatory bodies may tend to enforce other nuclear power plants under their direction to check if similar situations in those plants exist, often on very short time schedules. In these cases, reasonable steps must be taken to optimise exposures even though there may not be time to construct optimised tools to perform the work or to provide full-scale mock-up training.

Recent trends in regulation have, however, been more towards "performance standard" type rules as opposed to more prescriptive type rules, and this tendency follows well the principles of Work Management. For example, a performance standard type rule would require that secondary side water contamination concentration remain below certain limits (statutory in nature), reference levels (such as technical specifications), and action levels (levels above which some action is required). Such performance standards would not be related to plant, but to overall dose/risk to workers and members of the public. A prescriptive rule would require systematic steam generator tube inspection during every refuelling outage. The former type of regulation, which allows more flexibility, fulfils the regulatory authority's obligation to protect workers and the public while providing the operator with the flexibility to optimise occupational exposure.

There are many examples of the regulatory application of Work Management. In the UK, the regulator has accepted safety cases, prepared by some operators, justifying an increase in the interval between statutory outages of power reactors from two to three years. These safety cases have presented a thorough analysis of plant reliability and, where appropriate, have sought to justify a transfer from scheduled maintenance to plant-condition monitoring. Subject to adequate safety management, this reduction in the frequency of statutory outages has the potential to reduce occupational exposure. As another example, in the United States a licensing change was submitted to the Nuclear Regulatory Commission (NRC) for the Susquehana plant, a 1100 MWe BWR, to reclassify main steam piping snubbers as a separate test population. Each outage a certain fraction of snubbers are required to be tested, and the fraction tested is enlarged if a certain failure rate is discovered. It was noted that the main steam piping snubbers were more prone to failure than other classes of snubbers, and by dividing the large class of all snubbers into sub classes, those classes experiencing higher failure rates could be appropriately treated, while those with lower failure rates were not penalised unnecessarily.

A similar example, again at Susquehana, concerned a prescriptive regulation regarding the leak rate testing of valves. The allowed leakage of valves from the drywell was regulated valve by valve. It was noted that a particular class of residual heat removal (RHR) valves was prone to failing their leak rate tests. It was also noted that, even with some RHR valves surpassing their prescribed leak rates, the total leakage from the drywell was less than the sum of the allowed leakage from all valves. The NRC thus allowed the use of the total leakage of all valves, and not just the leak rate from individual valves, to be the action level above which valve maintenance would be required. This allowed the utility to better select which valves it would service, and at what frequency, to meet the new less prescriptive requirement.

2.3.2 Regulations to Respond to Radiation Exposure Concerns

In addition to the above described regulations for nuclear safety, many regulations refer directly to radiation exposure issues. These can include dose limits (for workers and for the public), dose constraints (for use when considering the design of a new process or facility), and operational restrictions (such as technical specifications, action levels, investigation levels, etc., for use in the monitoring of activities at existing facilities of processes). One objective of such regulations is to ensure that, as statutory limits are approached, measures will be taken to prevent them being exceeded or to ensure that occupational exposures remain ALARA. In this regard, the application of Work Management by regulated facilities can be promoted, again, by the use of performance based regulations, particularly in the form of operational restrictions.

In the UK, the principal dose limit for occupational exposure is currently set (IRR, 1985) at 50 mSv y-1, with a subsidiary "investigation level" of 15 mSv y-1. Employers are required to ensure that exposure to ionising radiation is kept "as low as reasonably practicable" ("ALARP"), a term which is a precedented phrase in UK statutes on which a significant case law has been established. For any exposure above the "investigation level", the employer is required to carry out an investigation to determine whether all necessary steps have been taken to restrict that individual's exposure within the ALARP principle. The Commission of the European Communities has taken the view that there is no practical difference between "ALARP" and "ALARA". Practical guidance with respect to these Regulators was issued in 1985 in the form of an Approved Code of Practice (HCS, 1985). Further guidance was later published to set an additional investigation level of 75 mSv per 5 consecutive years (HSC, 1991).

A clear delineation is drawn between "statutory limits" and other terms such as "constraints" and "investigation levels". Under the regulatory framework in the UK, the number of classified radiation workers exceeding the investigation level of 15 mSv y^{-1} has fallen from nearly 2000 in 1986 to 143 in 1992.

Non-statutory guidance has also been published in the UK to advise on practical steps which managers and employees can take to restrict occupational exposure associated with normal work practices in accordance with the SLARP principle (HSE, 1992). This suggests a framework to develop and maintain a safety culture in which clear commitment to the objective of restricting exposure is stated and reflected in the day-to-day practices of senior management and all those in the organisation. Further non-statutory guidance relating specifically to management of safety at nuclear installations has also been issued (HSE, 1996). This outlines a framework against which safety management systems operated by nuclear licensees can be judged, placing particular emphasis on planning and implementation, risk assessment, the control of risks and the application of operational controls.

In the UK, licensees are required to submit to the regulator a written demonstration of safety (the safety case). The regulator judges the adequacy of safety cases against a set of published "safety assessment principles" (HSE, 1992). These principles include quantitative upper and lower levels of consequences or probabilities. The upper level (the Basic Safety Limit) defines the boundary between risks which are just tolerable and those which are intolerable. below this limit, the ALARP principle comes into play to further reduce the risks from the plant. The lower limit (the Basic Safety Objective) defines the point below which the regulator need not seek further improvements from the licensee in his quest for ALARP. The numerical values of these limits and objectives reflect the finding of an HSE paper on the "Tolerability of Risk from Nuclear Power Stations" (HSE 1988, revised 1992). This provides guidance on the levels of tolerability by comparison with other risks which are borne by society in return for certain benefits.

It is proposed, in the UK, to implement the key features of ICRP 60 which are included in the new EU Directive. This new legislation is expected to be enacted around the year 2000. One approach under consideration is to set a statutory limit of 20 mSv y^{-1} with flexibility allowing planned special exposures of up to 50 mSv in any one year within an over-riding limit of 100 mSv per 5 consecutive years.

In other EU member states it is intended to implement the recommendations of ICRP Publication 60, which are incorporated in the new EU Directive, in legislation imposing a worker dose limit of 100 mSv per 5 years, with a 50 mSv limit in any one year.

In Sweden, while the recommendations of ICRP Publication 60 have not been enacted into law, the Authorities now have imposed an individual dose Operational Restriction of 100 mSv over 5 years. Another Operational Restriction which has been imposed in Sweden is that the collective dose accumulated during any 5 consecutive years shall as an annual average not be greater than 2 person-Sv GW^{-1} (installed) on any single site. For example, for the Oskarshamn site, the three units have a total installed capacity of 2.297 GW, leading to an Operational Restriction on the average annual total collective dose for the site of 4.6 person-Sv y^{-1}.

Finland is the first country to adopt into law the recommendations of ICRP Publication 60. Since 1 January 1992, the individual dose limits in Finland have been based on a five year total not to exceed 100 mSv, with no single year exceeding 50 mSv, thus resulting in an effective average annual dose of 20 mSv. In addition to these limits, operational restrictions are also used in Finland. A restriction supplied by the regulators is applied whereby "if in one power plant unit the collective occupational radiation dose, calculated as the average for two consecutive years exceeds the value 2.5 man Sv per 1 GW installed net power", the reasons for the exceeding and, when applicable, also possible actions to improve the radiation protection shall be reported to the regulator. In addition, for any task which is expected to involve a collective worker dose of 0.1 man Sv or a "remarkable" risk of internal contamination, a document describing that task and the associated radiation protection measures is required to be submitted, in advance, to the regulator. As another example of the performance-based approach to regulation, the Finnish Centre for Radiation Protection and Safety (STUK) requested, and Finnish utilities agreed, that any large or high dose jobs should be reviewed and approved by the plant radiation protection manager.

Switzerland is one of the first countries in the world to adopt into law the recommendations of ICRP Publication 60. As of the beginning of 1995, an individual annual dose operational restriction of 20 mSv, and an annual Operational Restriction for each unit of 2.5 person-Sv have been imposed (Loi fédérale du 22 mars 1991, and Ordonnance du 22 juin 1994). It should be noted that the Swiss Restrictions were identified in 1991 such that plants had several years to adjust their programmes for compliance.

Whilst regulatory operational restrictions do not carry with them civil or statutory punishments, as do regulatory limits, they do carry sufficient regulatory weight to assure that they will be complied with appropriately. In a Work Management sense, this non-prescriptive type of regulation leaves the utilities with a certain flexibility to optimise their operations within the applied restrictions, while at the same time fulfilling the regulator's role of protecting the worker. It is likely that more and more national authorities will adopt this type of performance based constraint and operational restriction system into their national regulations.

2.3.3 Historical Regulations

Finally, in spite of the fact that regulations are periodically reviewed as to their continued applicability, it may be the case that regulations exist simply because of historical reasons which are no longer valid or no longer agree with current philosophy. In a Work Management sense, the review of such regulations is important, and many utilities are now interested in applying this approach in order to demonstrate to regulatory authorities that some rules may be too restrictive.

As an example of this, in Germany it has been suggested that work on redundant safety systems should be allowed during normal operation, as opposed to only during refuelling outages. This would allow more flexibility in outage scheduling, and is being considered by the Authorities on a case by case basis.

Current radiation protection philosophy emphasises "total risk management", whereby internal and external exposures should be treated equally. Focusing on the avoidance of internal exposure may give rise to overprotection, *i.e.* to use respirators and full protective suits, which in turn leads to a longer stay in the radiation field and by this to higher external doses. In the US, under the new 10 CFR Part 20 regulations, licensees are required to maintain programs to keep doses to workers ALARA. Part 20 embodies ICRP 26 and 30 concepts which currently define dose as the total effective dose equivalent (TEDE). This includes the sum of internal (Committed Effective Dose Equivalent, or CEDE) and external dose (Direct Dose Equivalent, or DDE) (NRC 1993). In order to implement TEDE ALARA (reduce total risk to workers) licensees have to evaluate the increases or decreases in a worker's total dose as a result from wearing respiratory protection. "The nuclear industry has generally recognised that the use of respiratory protection equipment reduces worker efficiency by as much as 25 percent" (Lee 1994). TEDE evaluations intuitively must be made during the work planning process or ALARA pre-job analysis to determine in advance what additional dose if any a worker will receive while performing the job in a respirator. Changes in work practices (*i.e.* keeping contaminated component surfaces wet) may be a simple way to reduce airborne concentrations and reduce the need for respirators. Other means of reducing airborne levels of course included ventilation units. Since January 1, 1994 when Part 20 implementation was required, plants are finding in many cases that all that is required to achieve TEDE ALARA is allowing workers to perform a task without respirators with no additional mitigating devices and total dose is reduced.

2.4 Summary

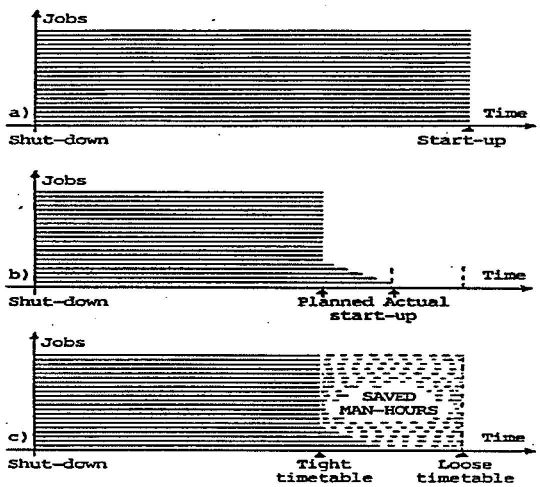
While regulations are a necessary check on the system of public and worker protection, it is important to remember that their nature and application can help or hinder the global optimisation of work. As such, and in terms of the application of Work Management principles for the optimisation of the dose, time, and cost of work, current consensus around the world seems to be leaning toward the use of performance based regulations, as opposed to prescriptive regulations.

2.5 Regulatory Issue Case Study

The previously cited operational restrictions on total annual collective doses per unit or per GW of installed capacity (Sweden, Finland, and Switzerland for example) regulations to respond to radiation exposure concerns have taken a new turn. Only the experience of the coming years will demonstrate the value of this approach, however the inherent flexibility of techniques to attain these operational restrictions is perfectly in line with a Work Management approach to regulations.

3. WORK MANAGEMENT POLICY

Saving radiation doses does not always cost money. Saving man-hours means saving money and doses at the same time. Jobs will always take all the time they are allowed to take. Therefore, with a loose outage timetable, all jobs will last longer than with a tight timetable! So, we can save man-hours simply by choosing the strategy of planning a timetable that is tight instead of a loose. Small runovers don't matter, because by tightening the schedule money and doses are saved.



A loose timetable (a) will always result in more man-hours than will a tight timetable (b). The saved man-hours (c) mean saved costs and collective dose.

3.1 Introduction

As with the implementation of any initiative, success depends upon motivation and support originating at the highest levels of the organisation. Work Management is no exception to this rule, and requires that plant management be willing to support, in policy and budget, the idea that multi-disciplinary teams will be required to plan, schedule, implement, and follow-up jobs. A type of "customer / client" relationship, in other words a service oriented relationship, should be fostered between these teams and the plant.

Management commitment to any project is always demonstrated by management presence. Management policy should thus encourage managers to make frequent visits to the work site(s), and to have first-hand knowledge of project status and problems. Plant tours should be conducted with a specific purpose or area of concentration (e.g., housekeeping, cleanliness, worker procedural compliance, tool staging adequacy, support group timeliness, specific repair task progress, etc.). This can be facilitated by the appropriate delegation of authority, which will free manager's time to accomplish thorough plant observation tours.

In addition, management policy can require that work be performed within specified limits (dose, man-hours, time, etc.). This can be implemented via contractual requirements for contractors, and by management's willingness to fund, in terms of money and personnel, the projects necessary to meet the assigned goals. The communication of these goals to all workers, and of management's commitment to goals, is also very important.

3.2 ALARA: A Philosophy of Radiation Exposure Management (Management Basis)

Occupational dose limits are set at levels considered to be safe as established by national and international scientific bodies. Both annual and lifetime accumulated dose are taken into consideration to assure all occupational doses are safe. Such limits provide operational flexibility as well as adequate safety as long as a highly visible and aggressive radiation protection program is also in place. Dr. G. A. M Webb, currently with the IAEA and formerly of the National Radiological Protection Board, UK, described ALARA as the optimisation of radiological protection: "A developing way of thinking." Optimisation of protection, as developed by ICRP, has a sound philosophical basis. It promotes a management philosophy that associates quality assurance and excellence with safety and productivity, so that they are complementary rather than conflicting goals (Webb, 1993).

Richard E. Cunningham, U.S. Nuclear Regulatory Commission (NRC), states that legislation and implementing regulations should avoid prescriptive specifications related to optimisation methodologies and constraints. In part, this is due to methodologies and technologies usually changing faster than legislation and regulations which would result in sub-optimal conditions. High quality optimisation at the plant level is a continuing process of improvement with no endpoint but an increasing standards of performance curve (Cunningham, 1993).

Dr. Don Cool, also of the NRC, notes that ALARA has saved the industry a great deal over the years. This has included lower dose resulting in lower risk of litigation, fewer workers resulting in lower labour costs and in general better operational performance (Cool, 1995).

3.2.1 Scientific Guidance & ALARA Regulations

The International Commission on Radiation Protection (ICRP), Publication 60, addresses ALARA in paragraph (112):

The system of radiological protection recommended by the Commission for proposed and continuing practices is based on the following general principles. Details of the system in relation to practices are given in Chapter 5. The system for intervention is discussed in the next paragraph and in Chapter 6.

a. *No practice involving exposures to radiation should be adopted unless it produces sufficient benefit to the exposed individuals or to society to offset the radiation detriment it causes. (The justification of a practice.)*
b. *In relation to any particular source within a practice, the magnitude of individual doses, the number of people exposed, and the likelihood of incurring exposures where these are not certain to be received should all be kept as low as reasonably achievable, economic and social factors being taken into account. This procedure should be constrained by restrictions on the doses to individuals (dose constraints), or the risks to individuals in the case of potential exposures (risk constraints), so as to limit the inequity likely*

to result from the inherent economic and social judgements. (The optimisation of protection.)

c. *The exposure of individuals resulting from the combination of all the relevant practices should be subject to dose limits, or to some control of risk in the case of potential exposures. these are aimed at ensuring that no individual is exposed to radiation risks that are judged to be unacceptable from these practices in any normal circumstances. Not all sources are susceptible of control by action at the source and it is necessary to specify the sources to be included as relevant before selecting a dose limit. (Individual dose and risk limits.)*

From these paragraphs it can be inferred that ICRP Publication 60 places the responsibility for the justification of practices, and for performing the associated radiation protection evaluations to determine what doses should reasonably be avoided based on all work management factors, with the licensee of the nuclear facility.

The European ALARA Basis

As mentioned in Chapter 2, radiation protection in the European Union Member States is governed by the EURATOM Treaty, and implemented by the European Commission's Directive on Basic Safety Standards and subsequently by national legislation enacted by the member states. In that EU member states have a period of up to four years from approval of the new BSS during which to enact national legislation implementing the new BSS, regulations stemming from the previous BSS (CEC Basic Safety Standards Directive, L246 of 17.9.1980) are still in force throughout the EU. Title III, Article 6 of this previous directive states the following:

"The limitation of individual and collective doses resulting from controllable exposures shall be based on the following general principles:

a. every activity resulting in an exposure to ionising radiation shall be justified by the advantages which it produces;

b. all exposures shall be kept as low as reasonably achievable;"

The new directive, [L159 of 29.6.1996], reflects the concept of ALARA as presented in ICRP 60, and Title IV, Chapter I, General Principles, Article 7 states the following:

3. "In addition, each Member State shall ensure that:

(a) in the context of optimisation, all exposures shall be kept as low as reasonably achievable, economic and social factors being taken into account;"

Based on the directives of the EC, EU Member States individually enact national legislation implementing the requirements of the directives. For example, in 1988, the Health and Safety Executive (HSE) of the United Kingdom published guidelines on the tolerable levels of individual and social risk to workers (and members of the public) from nuclear power stations (HSE, 1988). In this document, HSE states that:

The main tests that are applied in regulating industrial risks are very similar to those we apply in day to day life. They involve determining:

i. *whether a given risk is so great or the outcome so unacceptable that it must be refused altogether;*

ii. *whether the risk is, or has been made, so small that no further precaution is necessary; or*
iii. *if a risk falls between these two states, that it has been reduced to the lowest level practicable, bearing in mind the benefits flowing from its acceptance and taking into account the costs of any further reduction. The injunction laid down in safety law is that any risk must be reduced so far as is reasonably practicable, or to a level which is "as low as reasonably practicable"(ALARP principle).*

The legal application of the ALARA principle (ALARP in the U.K.) in the United Kingdom requires an employer to do what is reasonably practicable to reduce risk. This means that, unless the expense which would have to be undertaken is in gross disproportion to the risk, the employer must undergo that expense.

The Asian ALARA Basis

The philosophy of ALARA has been adopted in the licensing review of nuclear facilities in Japan. As an example, "The Guidance on Safety Design Review for Light Water Power Reactor Facilities (adopted by the Japanese Nuclear Safety Commission)" contains the guidance that facilities should be designed such that the release of radioactive effluents (quantity and concentration) are ALARA, as well as the guidance that dose rates is work areas should be ALARA.

Although there are no numerical dose objectives for ALARA for workers in Japan, every effort has been made to reduce occupational exposure as recommended by the ICRP. With regard to public exposure, in an effort to reduce environmental emissions of radioactive material, an objective of 50μSv per year, for annual individual effective dose, has been adopted in "The Guidance on Safety Design Review for Light Water Power Reactor Facilities (adopted by the Japanese Nuclear Safety Commission)".

In addition, the Japanese Radiation Council has been discussing practical implementation of the recommendations contained in ICRP Publication 60, namely an individual occupational exposure limit of 100 mSv per 5 years, with a 50 mSv limit for any one year.

The U.S. ALARA Basis

The Preamble to the Federal Guidance on ALARA contains the following guidance to NRC licensees:

> *These recommendations are based on the assumption that risks of injury from exposure to radiation should be considered in relation to the overall benefit derived from the activities causing the exposure.*

This approach is similar to that used by the Federal Radiation Council (FRC) in developing the 1960 Federal guidance. The FRC said then:

> *Fundamentally, setting basic radiation protection standards involves passing judgement on the extent of the possible health hazard society is willing to accept in order to realise the known benefits of radiation.*

This leads to three basic principles that have governed radiation protection of workers in recent decades in the United States. Although the precise formulation of these principles has evolved over the years, their intent has continued unchanged. The first is that any activity involving occupational exposure should be determined to be useful enough to society to warrant the exposure of workers; *i.e.*, that a finding be made that the activity is "justified". This same principle applies to virtually any human endeavour which involves some risk of injury. The second is that, for justified activities, exposure of the work force should be as low as reasonably achievable (commonly designated by the acronym "ALARA"); this has most recently been characterised as "optimisation" of radiation protection by the ICRP. Finally, to provide an upper limit on risk to individual workers, "limitation" of the maximum allowed individual dose is required.

In the United States, the new rule on ALARA contained in the revised 10 CFR 20.101 regulations (***C***ode of ***F***ederal ***R***egulations), Radiation Protection Programs, provides the current regulatory requirements for ALARA:

a. *Each licensee shall develop, document, and implement a radiation protection program commensurate with the scope and extent of licensed activities and sufficient to ensure compliance with the provisions of this part.*
b. *The licensee shall use, to the extent practicable, procedures and engineering controls based upon sound radiation protection principles to ensure that occupational doses and doses to members of the public are as low as is reasonably achievable (ALARA).*
c. *The licensee shall periodically (at least annually) review the radiation protection program content and implementation.*

3.3 Industry Guidance Documents

After many years of reactor operational experience, and equally many years of dose management experience, there is much available in the way of guidance documentation, both on the national and international level.

For example, in the United States, the Institute of Nuclear Power Operation (INPO) publishes in limited distribution for plant radiation protection managers, "Guidelines for Radiological Protection at Nuclear Power Stations". External and internal radiation-exposure control, and radiation-exposure reduction are discussed in this industry guidance document.

The General Electric BWR Owners Group established an "ALARA Subcommittee" in 1988 which holds three meetings per year. Minutes from these industry meetings contain a wealth of dose and cost reduction information. American PWR plants have organised a similar Group (the PWR ALARA Group) which occasionally sponsors joint meetings with the BWR subcommittee. Minutes from the PWR ALARA Group are also an important source of applied dose reduction technology and field results. In addition, other industrial groups periodically organise seminars and workshops. The Westinghouse REM Seminar is one such example.

Many other examples of such organisations providing similar types of guidance exist in other countries around the world. For example, in France, the electric utility, EDF, has written what they call "The White Book" (EDF, 1993), which describes the role, function and structure of radiation protection in French nuclear power plants. This represents a statement from EDF's highest management concerning their corporate approach to radiation protection. In the United Kingdom, the National Radiological Protection Board (NRPB) has issued numerous documents on the implementation of the ALARA principle. Internationally, organisations such as the Nuclear Energy Agency (NEA) of the OECD, and the International Atomic Energy Agency (IAEA) of the United Nations have also generated a wealth of information on ALARA, the implementation of the ALARA principle, and dose management.

3.4 Plant ALARA Organisation

In order to properly implement the ALARA principle, plant management must put in place a management structure, or organisation, to assure that radiation protection is appropriately considered in all work. Although such structures vary from country to country, many of the key points of these organisations are common to many countries. This section discusses these common points.

3.4.1 Plant ALARA Programmes

An "ALARA Programme" should exist at all nuclear power plants. Such programmes express the commitment of management to appropriately implement radiation protection measures, and describe the means available for such implementation. Station administrative procedures and instructions can serve as implementing tools for these programmes which generally include full descriptions of the operation of the station "ALARA Committee", functions of an "ALARA Engineering Group", descriptions of when, where, and how "ALARA Reviews" of modifications and plant maintenance jobs are implemented, as well as such things as the use of temporary shielding, robots, remote camera, etc.

Specifically, the plant ALARA Programme should describe the objectives and define the specific structures, as well as procedures and tools, necessary for its implementation. These generally include:

a. the setting of program goals and objectives; for example, requirement for establishment of collective dose objectives for the year, for outages, and for specific jobs,
b. a definition of resources available to meet the program objectives,
c. a description of the role and functioning of an "ALARA Committee",
d. the specification of radiation protection structures (outage co-ordination, specific radiation protection work groups, etc),
e. the assignment of responsibilities,
f. articulation of an education policy,
g. working methods requirements/recommendations for preparation, implementation and post-job analysis of operations (for example: exposure reduction techniques, project reviews, pre-job briefings),
h. means to measure the success of ALARA efforts; for example, a monitoring system which provides timely, periodic feedback up and down the management chain as to the status of meeting Programme goals and objectives, and
i. the measures to necessary to effect corrective action when feed-back information indicates program failures and shortcomings.

3.4.2 Assignment of Responsibilities

All workers and managers must share the responsibility for the implementation of the ALARA Programme in their field of activity. These responsibilities must be clearly delineated, particularly for:

- the plant manager,
- department managers (particularly the radiation protection department manager), and
- plant and contract workers.

For example, the "Updated Safety Analysis Report (USAR)" for each station in the United States specifies the following organisational responsibilities for ALARA:

- In general:

  a. the Vice President directs the implementation of the ALARA Programme and is responsible for its overall effectiveness,
  b. the Plant Manager is responsible for the overall ALARA Programme,
  c. plant department managers are responsible for assuring work is performed in accordance with ALARA principles and procedures, and
  d. each individual is responsible for maintaining his or her exposure ALARA by following radiation protection training and procedures, and by identifying dose reduction opportunities to management.

- Plant managers are responsible of the implementation of the ALARA Programme in accordance with the policy and objectives of the utility. To this end:

  a. they participate in the formulation of the station ALARA Programme goals and objectives,
  b. they support plant personnel in terms of the implementation of radiation protection measures, particularly the radiation protection manager,
  c. they ensure that open channels of communication exist to the corporate level, and
  d. they review the status of the plant's efforts to reduce exposure.

- Department managers are responsible of the implementation of the station ALARA Programme in their field of activity. To this end:

  a. they define the contribution of their department to the station ALARA Programme,
  b. they establish the dosimetric goals of their department,
  c. they validate and control the procedures and methods elaborated to reach the objectives,
  d. they support their personnel in the implementation of the ALARA principle, and
  e. they review periodically the performances of the department with respect to the ALARA Programme objectives.

- The radiation protection manager must have the authority to "go up management chain" to resolve radiation protection issues and concerns. The responsibilities of this position include:

  a. the development of methods and procedures for implementation of the ALARA principle,
  b. the identification of conditions and operations that can cause significant exposure,

c. the implementation of an exposure control program,
d. providing feedback data to other departments (radiological data, exposure levels,...), and
e. the implementation of initial radiation protection training, and continued input to plant's training programme.

- Radiation protection technicians are responsible for following operations in the field to help assure that radiation protection policies are carried out, and that jobs are implemented in accordance with the ALARA principle. Their responsibilities include:

  a. providing assistance and advice to workers to incite them to adopt an "ALARA behaviour",
  b. following jobs to ensure the respect of security and radiation protection procedures, and
  c. in some plants, stopping work in case of serious deviation from dosimetric objectives, or when there is a significantly increasing radiological risk for workers.

- Finally, each individual worker also has specific responsibilities, such as:

  a. maintaining their level of individual exposure, and that of the workers around them, as low as reasonably achievable by applying good radiation protection procedures and practices, and
  b. identifying and suggesting improvements and good practices for the reduction of exposure.

3.4.3 Role and Composition of an ALARA Committee

The Plant or Station ALARA Committee is typically responsible for approving and reviewing the ALARA Programme proposed by the Plant Manager, of setting annual occupational exposure goals, and of assuring that the Programme is appropriately implemented. Members are generally selected to provide a board range of technical background to the committee, including individuals from maintenance, operations, plant engineering, planning & scheduling, licensing, and ALARA Engineering. The station radiation protection manager should also be a member of the Committee.

The ALARA Committee should meet periodically to review station ALARA performance, evaluate individual dose reduction suggestions, and make recommendations to management regarding the effectiveness of the ALARA Programme.

The minutes of each meeting should specify who is responsible of each action decided by the Committee, and should be diffused to all departments.

3.4.4 Role and Composition of an ALARA Engineering Group

In order to co-ordinate ALARA Reviews of work procedures and programmes, and of the centralise radiation protection data bases, it can be useful to create a specific ALARA Engineering Group composed of radiation protection professionals and engineers.

For example in United States, the ALARA Engineering Group is generally composed of several health physicists and technicians who conduct the routine ALARA Reviews, and who perform dose accounting functions. Typically, the group performs 200-300 ALARA job reviews annually, recommends annual and outage person-Sv goals to the ALARA Committee, administers the exposure data base, the photo library and robots, and designs/recommends temporary shielding installations. This Group should work closely with all phases of job planning, scheduling, and preparation to assure that appropriate radiation protection measures are included, in an ALARA fashion, in all work.

3.4.5 ALARA Reviews

In general, to assure that the ALARA principle has been appropriately built into work, planning, scheduling, preparation and procedures for specific jobs are reviewed by the ALARA Engineering Group. This can include participating in job planning, scheduling, and preparation meetings, detailed review of work procedures, design of temporary shielding, etc.

In applying the ALRAR principle to particular jobs, it is evident that not all jobs require the same level of review. Depending upon the level of radiological risk associated with the job, the level of effort put into reviewing the job for the purpose of reducing doses will vary. Normally, dosimetric criteria are established which define this level of effort, and which also specify the hierarchical level of approval necessary before the job can be implemented.

These criteria are often set such that if the predicted level of individual dose, and/or the predicted total collective dose for the job, pass a certain point, than a defined level of review and approval is required. For example, at some plants in the United States, if maintenance work activities that are projected to receive more than 0.1 person-Sv, then a special review by the plant ALARA Committee is required. Other such criteria are discussed in Chapter 4, under the section "Worker Involvement in Planning of Actions".

3.5 Summary

As with ideas such as quality assurance and quality control, or occupational safety culture, the idea of good implementation of the ALARA Principle and of Work Management techniques must come from the top down. Management must be committed to the implementation of Work Management, must back up such commitment with time, effort, and monetary support, and must put in place a structure to manage this implementation. Every level of the management chain, from the company precedent to the worker on the floor, must know that Work Management is a company priority, and must be willing to make an honest effort to follow the logic of such an implementation to the end. To arrive at such a situation, management demonstrate its willingness to listen to employees feedback, taking advantage of their first-hand knowledge, and to make adjustments to the system based on this feedback.

3.6 Management Policy Case Study

Changes in management policy generally occur slowly, and require significant justification. In the case of implementing the principles of Work Management, several types of justification are possible. For example, to begin a programme of management commitment to Work Management the types of costs to be considered might include the cost of maintaining an ALARA Committee, and of funding various ALARA projects at the station-wide or utility-wide level. As an example of what to consider, one approach is to first examine larger projects (steam generator replacements, full-system decontaminations, etc.). The policy tools necessary for the implementation of Work Management at this level could then be more finely focused to apply to the entire outage. This is the process that has been followed in France over the past 5 years or so.

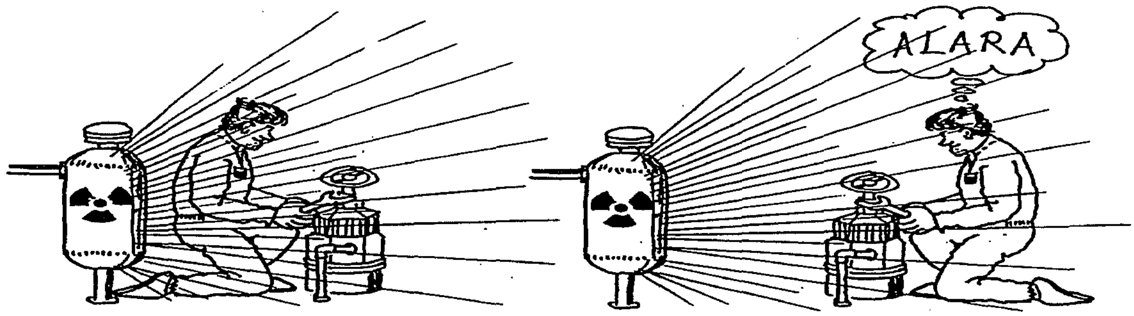
Since the early 1990's Ontario Hydro has been making changes which recognise the need to employ Work Management to reduce occupational doses. Most of Ontario Hydro's nuclear facilities now have an ALARA Co-ordinator and a formalised ALARA program. The initial motivation was provided by ICRP 60 and the recognition that the Canadian regulator, the Atomic Energy Control Board (AECB), will soon be reducing legal dose limits. In addition, in 1994 the AECB published a proposed regulatory policy statement, The Requirement To Keep All Exposures As Low As Reasonably Achievable, which will basically enshrine the concept of an ALARA program.

One of Ontario Hydro management's initiatives has been to adopt performance indicators for radiological worker safety. these include a measure of the total dose per unit as well as the total number of personnel contamination incidents as indicated by the whole body exit monitors.

In conclusion with this is the 1995 revision of Ontario Hydro's Radiation Exposure Management Policy. This policy not only outlines the principles and rules to ensure legal limits are not exceed but it also provides incentives for continuous improvement in collective and individual dose performance. It does this by setting collective radiation exposure performance benchmarks and collective dose targets, as well as individual dose limits. The effect of this policy can be seen at the station level where outage dose targets and even job dose targets are now being employed in efforts to keep doses as low as possible. As Ontario Hydro reactors continues to age, and the amount of dose intensive work increases, these dose control measures will only gain in importance.

4. WORKER INVOLVEMENT

Radiation doses are received only where the workers stay, i.e. "on the floor". Therefore, much exposure can be avoided by training both utility staff and contractors. We should not feel comfortable before every radiation worker has understood the main principles of ALARA-thinking. Lots of dose can be saved simply by knowing the best place to stand, where to rest, places to avoid, best route to use, etc. The workers must also be aware of the main radiation source.



NOT SO! **BUT SO!**

Doses are automatically saved, all the time in all jobs, if the worker is adequately trained in ALARA-thinking.

4.1 Introduction

A topic which influences many of the stages of a job is the performance of the worker. The worker is the last link in the chain between the management and the work to be performed, and is charged with putting into practice the work plans. It is thus very important to involve workers in their jobs. By engaging the worker in the task being performed, the worker is more likely to be motivated to perform the job to the best of his/her abilities. This will be reflected in lower job doses as well as in higher job quality.

Though the presentation here is focusing on the worker who was addressed as the last link of the chain, it must be considered that there is a hierarchy of personnel, ranging from department-level management, to section head, to foremen, to the worker. Many of the aspects discussed later will be valid for personnel of all levels.

Considering work management for the implementation of radiation protection concepts, there are many features that will contribute to the excellent performance of the worker, and which can be supported or improved by worker involvement. These features will be summarised in this chapter.

4.2 Features Defining Worker Performance Based on the ALARA Principle

Good workers are expected to contribute to dose reduction by performing their jobs with high quality, low dose, and if possible with low cost. For this, the worker must be well educated and trained in the technical aspects of the job. This education and training is taken as a given prerequisite and will not be discussed here.

Considering good performance of workers with respect to ALARA concepts, features other than technical knowledge and experience are important:

- Personnel must know the ALARA principle to understand management intentions, to be able to reflect these general ideas and to put them into practice in the local work area during jobs.
- Personnel accept the ALARA principle for their own safety and the benefit of the utility.
- As a "tool" to aid in the application of the ALARA principle, everyone must know and apply good radiation protection practices nearly automatically in the work place. Good practices will be to keep distance from sources, to work efficiently and quickly, to seek low dose rate areas during breaks, to apply local shielding, to keep the work place clean, to communicate with other personnel and foreman to avoid delays, to transfer important information and to avoid problems and re-work.
- Workers must act in accordance with their assignments in the job to be performed and work in co-operation with the team in the case of larger jobs.
- Workers are expected to think about the work to be performed and to try to improve performance within procedural requirements, using their own experience. This <u>may</u> be done during the job in co-operation with the foreman, but <u>should</u> be done during job preparation, or even better in planning of the job to be performed. Workers should contribute to post-job reviews to derive improvements for future activities.
- Workers should propose new tool designs or modifications to existing tools, facilities, or components, drawing on their experience and considering radiation safety aspects to improve work during the outage.
- Workers should be aware of potential problems and should be able to react to the occurrence of unexpected problems in a safe and efficient manner according to their knowledge and assignments.

These are some of the more important practical factors which may be considered to contribute to the good performance of a worker and to improved application of the ALARA principle in a plant. One of the essential building blocks necessary to ensure worker behaviour along the lines described above is personal motivation to perform according to these precepts. De-motivation will hinder their application and worsen performance. As such, the motivation of personnel will be the most important factor in worker involvement, and will govern the application of the ALARA principle to work management.

4.3 Important Contributing Factors

With motivation considered to be an important factor in worker involvement, the factors and modes of behaviour previously discussed will call for conditions and practices in the utility:

- to implement worker involvement, and

- to maintain worker involvement ,

having the long term goal of improving the performance of the work force, and of the utility, under the ALARA concept.

4.3.1 Prerequisites and Conditions to the Implementation of Worker Involvement

General Behaviour of Management

Work management to optimise work, in terms of dose and cost, is an approach which must be supported and applied by all levels of staff at the plant. To involve workers in this approach, it is important for them to see that management at all levels is convinced of work management as the most important – if not the only – tool for keeping doses ALARA. It is also important that all members of the management chain apply this tool to improve the performance of the plant. It is a good example that will bring personnel to agree to the implementation of work management, and will involve and motivate workers. Very often, practice in plants has shown that a good example and the consequent application of work management and radiation protection by plant managers will support the involvement and motivation of the worker. In other cases, personnel will not accept or support work management practices if managers, or even persons at the senior staff level in the plant, are reluctant and are not concerned about the implementation of work management or the application of the ALARA principle.

As often most of the work in outages is performed by contractors, it is similarly important to involve the contractor personnel in work management and radiation protection. Regarding management, here two areas have to be addressed:

- First of all, the management of the contractor company has the task of involving its personnel in work management and radiation protection.
- Additionally the utility is
  - to support the involvement of the contractor's personnel during the work in the outage; and
  - to review the contractor with respect to their attitude toward work management and radiation protection.

If necessary and possible, the utility is to motivate contractors to co-operate in the work management and ALARA-approach. There are a variety of ways to accomplish this, from training the contractor up to selecting contractors according to their attitude towards work management and radiation protection.

General Behaviour of Senior Staff

It has already been mentioned that the implementation of work management as a tool for radiation protection will necessitate the co-operation of a chain of persons from management to the level of the worker, with the senior staff engaged. It should be stressed here once again that many of the topics discussed in this chapter will address senior staff in a two-fold way, as quite often senior staff will have to fulfil the tasks and the demands resulting from work management, from the manager's side as well as from the worker's side. For example, senior staff

- should motivate workers, but must be motivated by the managers, and
- should accept reports of the workers, and to report to the managers.

So in this sense senior staff are an important conveyor in work management and worker involvement, as will be further discussed later.

To be able to fulfil the previously summarised demands, personnel must be educated, and to a certain extent, trained in the ALARA philosophy and its tools.

As already mentioned, education and training regarding worker involvement in work management and ALARA-approaches here does **NOT** mean basic technical education, workmanship, training on the job, specialised training for the job to be performed, or mock-up training. This kind of training certainly is important for work management under work preparation or work implementation aspects but will be addressed in the relevant chapters addressing those aspects.

Education, in the case of worker involvement in the ALARA approach, is meant to deal with basic concepts of ALARA and good practices in radiation protection, and to provide personnel with the important knowledge of their responsibility to maintain exposures ALARA.

This education must be adapted to the type of personnel concerned and to their level of responsibilities. For example, a specific training course may be given to the managers, presenting the importance and the justification of implementing an ALARA Programme, the basic principles of an ALARA Programme (as previously discussed, the need for establishing goals, the importance of involving multi-disciplinary teams in the preparation and implementation of outages, etc.), and the procedures for assessing the efficiency of the programme.

In addition to the basic ALARA principles, radiation protection workers' training must include the presentation of radiation protection tools (pre and post-job review, dose reduction techniques), the definition of the responsibilities of each worker, and an explanation of the radiation protection worker's specific role as assistant and advisor to the other departments and to workers.

It is also important that maintenance and operation people be aware of the radiation protection techniques specific to their jobs. For example, it is necessary for them to know the possible impact of working conditions on the duration of exposure, and therefore to take them into account when defining new working procedures or developing tools which will be used in restricted areas or while wearing "cumbersome" protective suits.

In detail, the basic philosophy and the important arguments for working with doses and cost ALARA should be conveyed, increasing the awareness of personnel for the reduction of doses, improvement of their own safety, and to reduce costs for the benefit of the plant, balancing both aspects for the safety of the plant. In addition to these basic concepts, tools and advice must be given to personnel so that they will be able to succeed, from their side, in work implementation and will be able to perform well under this approach. Here, workers must be trained in the basic concepts of radiation protection, and in good radiation practices to protect themselves and to protect other personnel by reducing exposure during work and during breaks. Workers should learn and accept the application of certain special ways of personal conduct during work to reduce the dose and to perform work with high quality, as previously mentioned, regarding the expected behaviour of personnel.

Training and education also should contain some aspects of conduct regarding unexpected events during work to give personnel guidance as to how to act in these situations.

Worker Involvement in Planning of Actions

Due to the experience of personnel specialised in outage work it is important to integrate personnel in the planning, scheduling, and preparation phases of jobs in an outage. This aspect may cover the consideration of tools and techniques to be applied during jobs, the harmonisation of actions to be performed, and improvement of procedures during work preparation. Special mock-up training for specific jobs may also be considered.

In that most jobs are performed by contractors, the possibility of worker involvement in planning and scheduling is somewhat limited because contractor workers are normally not physically present on the site much before the beginning of work. However, for specific jobs it is clear that the plant and the contractor must work together during the planning and scheduling stages to prepare the job. It is also clear that contractors must be present on the plant site for some job/plant specific training before the task, and for the job review after the task (see the next section). Triggers such as collective dose, individual dose, critical path person-hours, etc. should be chosen to select those tasks which require such special treatment and allow worker involvement.

> For example, at Diablo Canyon, in the United States, ALARA code 1 jobs (< 10 mSv collective dose) are approved uniquely with a radiation work permit (RWP) reviewed by the ALARA Group. ALARA code 2 jobs (> 10 mSv and < 100 mSv) receive official ALARA Reviews, performed by the Radiation Protection Work Planning Group. ALARA code 3 jobs (> 100 mSv collective dose, or > 10 mSv to any individual) are referred to the ALARA Co-ordinator for official ALARA Review. Finally, Unclassified jobs (> 250 mSv collective dose, or > 10 mSv to any individual) receive code 3 reviews, and must be presented to the Station ALARA Review Committee for approval.
>
> At Ontario Hydro, work which involves a significant risk of exposure in excess of administrative dose limits and which requires specially planned and executed control of radiological exposures classified as high hazard work. Some of the conditions which are indicative of high hazard work include:
>
> - external whole body dose rate at working distance >30 mSv/hr (> 3 rem/hr)
> - skin dose rate at working distance > 150 mSv/hr (>15 rem/hr)
> - extremity whole body dose rate at working distance >300 mSv/hr (30 rem/hr)
> - concentration of airborne particulate or radioiodines > (1000 MPCa)
> - concentration of tritium oxide > (10,000 MPCa)
> - existence of collimated beams in excess of 300 mSv/hr (30 rem/hr)

Part of the high hazard work preparation phase includes a meeting co-ordinated by the job director with everyone connected with the job to ensure familiarity with the entire plan, as well as specialised training for workers and practice using mockup where required.

> In addition, some of Ontario Hydro's nuclear facilities have formally included collective exposure triggers as part of their radiation exposure management program. Work including collective exposure > 20 mSv (>2 rem) requires a detailed exposure estimate for the work to be completed, measures to minimise exposures must be determined and recorded on a pre-job ALARA review record. For work involving collective exposures > 50 mSv (>5Rem), a detailed workplan and procedure must be prepared, the pre-job ALARA review record must be reviewed, a meeting of the job review team must include representatives from all workgroups performing the work as well as Health Physics and Radiation Control, the results of the meeting are recorded and included with the workplan, and a dose target for the job must be defined. Work involving collective exposures >100 mSv (>10 rem) requires all of the preceding measures as well as approval of the responsible Health Physicist and Manager.

It should be noted here that most contractors have additional motivation to maintain their exposures ALARA in that their availability for their next job depends upon their total dose (annual, rolling five-year total, etc.).

By "planning", and preparing personnel for the unexpected, that is, by teaching personnel a certain way of conduct for such cases, and by leaving a certain flexibility in the work procedures, the "expert judgement" of the worker can be allowed to function during the training and performance of the task. This will allow for the most effective completion of the task within whatever circumstances exist at the time and place of task execution.

Involving Personnel in Reviews

For the planning of actions, work management can benefit from the experience of personnel through post-job reviews, and where appropriate, at specified stages (hold points) during a particular job. This is supportive in two ways: on one hand, workers involved in post-job reviews will be motivated to improve as their knowledge and their experience is accepted and requested. On the other hand, use is made of a job performance experience. Areas which could benefit from post-job reviews may include planning, preparation and training to work procedures, tools, co-operation, scheduling and support during the work phase.

Here the precept is that the person closest to the job task best understands the work and is best able to suggest time and dose saving changes to improve the job or process being performed. It is appropriate that the average worker believes that valuable ALARA ideas have an avenue for management consideration, development and implementation into the plant's work methods.

Post-job review is most important for tasks which will be repeated. This can include such routine, non-specific tasks as scaffolding assembly and disassembly, pipe insulation removal and replacement, decontamination and shielding, which can account for 15% to 30% of a plants outage collective dose, as well as specific tasks such as reactor vessel head removal and replacement. For all such reviews, it is very important to keep contractor employees at the work site so that their direct input can be obtained and fed back into the next task planning stage. This requires the management commitment to pay contractors for their review time, as well as to maintain site task review and feedback teams.

An additional tool for feed back of experience, on a less official level than the post-job review, may be the radiation protection "suggestion box", which can also be a useful motivational tool. This generally requires some sort of a periodic prize (*e.g.* best suggestion of the week, month, etc.) to draw the attention of the workers.

Assignment of Personnel

Assignment of personnel may address work planning and implementation factors as well as personnel involvement. Considering the latter, assignment of personnel should assure that workers know their tasks and are able to perform their duties with competence, efficiency, low dose, high quality and in a short time. This could also increase the motivation of the workers involved.

It should be noted that by contractually specifying the required worker qualifications, which often will result in higher personnel costs, the use of high-quality personnel can be assured, thus theoretically resulting in more effective completion of the job.

Involvement of Personnel by Setting Goals

The use of goals for the workers can be motivational and challenging, and so will increase involvement. Such goals as job collective dose, daily dose, individual dose, total man-hours, etc. can encourage workers, particularly if a system of rewards for workers who attain these goals is used.

Common types of ALARA goals include long-term, annual and job-specific goals.

- Long-term goals, typically included as part of a long-term department plan, define the vision of where a facility wants to position itself over the next 3 to 5 years in terms of its cumulative personnel dose. To maintain visibility of long-term goals, performance indicators are published, charting current performance in relation to the goal. For example, at EDF, the "White Book", published in 1993, fixed an annual average dose per unit goal of 1.6 person-Sv for 1995. In 1993 the average annual dose per unit was 2.04 person-Sv, 1.74 person-Sv in 1994, and 1.63 person-Sv in 1995.
- Annual dose goals are established prior to the beginning of each year, reflecting anticipated and/or expected personnel radiation dose for all planned work activities. An annual goal, whether defined according to work task, physical work group receiving the dose, or the responsible implementing group, is most effective when all work groups either participate in goal development or are part of the approval process. Long term and annual goals will mainly involve senior staff and planning teams.
- The last major type of goal is the job-specific goal, which is often managed through the use of a radiation work permit (RWP). Such a goal is established for a particular job evolution, normally just prior to the start of the job. This generally makes RWP goals the most accurate type of goal, and the most important for workers as this goal directly addresses them and their performance.

Performance tracking mechanisms are also used to chart progress toward achievement of annual and job specific goals.

It may be interesting and may contribute to the motivation of the personnel to benchmark where their plant performance falls relative to industry performance. For instance in the United States the Institute of Nuclear Power Operations (INPO) has assisted in establishing industry performance indicators. Each year nuclear utilities submit collective dose data to INPO which performs statistical analysis and reports yearly and three year rolling average dose data. Data is available for both PWR and BWR groups on a one year and three year rolling average basis. Plants with top performance are said to have best quartile status. Based on industry projections, INPO has established long-term three year average goals, by reactor type, for the US nuclear industry.

In this same area, the Nuclear Energy Agency (NEA) has established the Information System on Occupational Exposure (ISOE), co-sponsored by the International Atomic Energy Agency (IAEA). This system annually publishes various collective dose statistics for over 300 participating units from 17 countries around the world. These statistics, include total annual collective dose, total outage collective dose, total operation dose and outage dose, and are for various tasks and operational groups. They can thus be considered in setting collective dose goals (for example, on an annual basis) for the plant and/or for specific tasks.

Different methodologies are used in goal development based upon the type of work being evaluated. Goals must be challenging but realistic, and should be based on solid ALARA analyses and on previous "good practice". Exposure goals must reflect known dose reduction items scheduled for implementation and should consider the qualification, status and experience of the worker. Workers, or at least senior staff, should be integrated into planning at this stage, and should participate in the development of goals.

Swedish nuclear power plants are required by their authorities, the Swidish Radiation Protection Institute (SSI), to have an "ALARA Programme", that is, a programme to keep exposures ALARA. The SSI has emphasised the importance of having plant management engage themselves in radiation protection issues, and of maintaining an open dialogue with the entire work force, including those outside workers who participate in the maintenance of the plants, particularly during the outage periods. The importance of education and training as well as setting up systems allowing analysis and feed back of experience has also been pointed out by the SSI. The regulator thinks that it is necessary to review all components contributing to dose rates in the working areas, one by one, and judge their dose reduction potential in relation to costs. In terms of specific guidance, the SSI has established the general goal that each site should maintain exposures at less than 2 Sv per year and per GW of installed capacity, as averaged over a five year period.

At Oskarshamn NPP, the ALARA programme consists of four sub-programmes, one each from the three Operational departments (Units 1, 2 and 3) and the General Service department. The programmes, which are revised annually, contain one year and five year statements concerning those planned activities which would cause worker doses, dose budgets and planned dose reduction measures. For Oskarshamn, the translation of the SSI exposure goal is an annual dose budget of less than 4.6 person Sv. This figure is distributed among the Units based on experience, not on installed power, as follows: Unit 1: < 2.6 person Sv/yr; Unit 2: < 1.3 person Sv/yr, and Unit 3: < 0.7 person Sv/yr. The dose of Service department personnel is included within the doses of three Units when the result is calculated.

These collective dose budgets for the departments are calculated based on budgets for each group within the departments in order to be as precise as possible, and to involve the staff in the process. The groups/departments are responsible for producing their own programmes and dose estimates, and the Radiation Protection group acts as support. The annual budget should be as realistic as possible, but at the same time should be challenging. The predicted collective dose may be higher than the general goal, but in this case must of course be accompanied by a justification, because the overall goal of 4.6 person Sv must still be met. The collective dose results are compared with the dose budget on a monthly base, and are displayed to the staff.

A special dose budget is developed for each outage. As the circumstances may have changed from those of the preliminary estimate, there may be a difference between the preliminary and final predictions. The final budget is of course used during the outage, however divergence with the preliminary estimate must be explained and justified for the end of the year when the "accounts" are scrutinised.

In addition to the overall dose goals, individual dosimetric goals are also set, generally applying to groups of personnel. As a tool for planning, goals for individual doses have been established to assure that no individual exceeds 3 mSv/day, 10 mSv/month or 20 mSv/year without having discussed and evaluated the situation from an ALARA standpoint. Regulations currently require only that doses should not exceed 100 mSv/5 year and 50 mSv/year.

The Swedish nuclear industry has responded positively to the initiatives of the SSI. All nuclear power plant have taken constructive actions, administratively as well as technically. Administratively, the responsibility for radiation protection has been clarified by delegated it to line management. Technically, the industry has initiated a number of development projects aiming at dose reduction, and is in the process of developing the ALARA programs referred to above, including explicit goals and targets for radiation protection for all the reactors. Finally, one has to emphasise that a number of technical actions have been taken, or are in the process of being taken at each individual power plant, *e.g.* finding replacement material for stellite, optimisation of water chemistry, decontamination of components and systems and development of improved strategies for fuel burn up and handling of fuel failures.

A key factor for workers and management in achieving radiation protection goals is how realistic they believe the goals are. If they do not believe a goal is realistic they will not respond with a serious effort to achieve the goal. Challenging a group's performance by simply establishing a goal is not sufficient. Workers must be provided with the tools which enable them to meet their challenge. When management does not do its part in providing these tools, they may be setting the stage for worker frustration and failure.

It should also be noted that the success of such a system rests partly on having and assigning sufficient radiation protection staff to correctly perform work and follow the doses received during jobs.

Information and Communication to Improve Involvement and Motivation

Workers should be regularly informed of the intentions of management, and open questions should be answered as soon as possible. This may be done by regular information sheets, hand outs, posters, or on a case by case basis as for example discussions or information work shops depending on the importance of the topics. If goals are set for specific jobs, personnel should be informed of the performance of workers on this job by the posting of charts, graphs and/or results on a periodic basis.

To this end, dosimetric results should be displayed in a "visible" place, for example at the entrance of the reactor building or in the dressing room. Some key messages can be added to reinforce the motivation of workers to reach the outage goals. Two examples of this are as follows:

> At Clinton (USA), at the beginning of the outage, the ALARA group spends 1 hour with the maintenance contractors in order to brief them on the outage goals. Each worker receives an outage guide, providing the phone numbers of the people responsible for the major activities, the outage objectives and goals, the daily meeting schedule, recommendations on security, quality assurance, industrial safety, scaffoldings, chemical control, housekeeping, radiation protection, etc. This guide also includes 25 maps of the major areas and the location of the main systems.
>
> In France, some plants have experimented with the daily display of the evolution of actual and predicted collective dose for the outage, and such practice is very well perceived by the workers.

Prior to task performance, a short worker briefing provided by the task managers and/or Radiation Protection personnel can be useful to remind workers of the dosimetric objectives for the job, as well as of the job's main characteristics. This can also be an occasion to spread the messages as to the importance of quality, the fact that radiation protection is a "Quality issue", the need to avoid rework, and so on...

> For example, at Clinton nuclear power plant (United States) workers assigned specific tasks are briefed by the Radiation Protection Shift Supervisors and by ALARA Group representatives. These briefings are documented by a specific form and include:
>
> - a review of work procedure,
> - a review of work area conditions,
> - a discussion on the necessary tools and equipment,
> - a radiological briefing (review of all the specific requirements of the radiation work permit, and a discussion on personnel responsibilities for their conduct in radiation areas).

On-the-job training and briefings, with the support and participation of senior management in motivating workers through the use of information and communication/discussions, is also essential. Simple things such as motivational training sessions for workers, where goals and the means for achieving them are spelled out, and visible senior management presence at the job sites are very encouraging. Showing workers that they are not the only ones participating in the process and that management will listen to their suggestions, is essential. For example, in order to stress appropriately plant management's desire to avoid problems which might lead to fuel failure (machining filings, small mettle pieces, etc. left within the primary piping after work) the senior vice president at Clinton Power Station organised a series of half hour meetings whereby ALL site workers were briefed and told be careful to avoid such problems. This level of management commitment to an issue is well received by workers, and adds significantly to their motivation to perform well.

Communication at the worker and senior staff level, on a team basis, will support intentions to implement radiation protection procedures by information transfer and exchange of experiences. This especially holds for communication between utility staff and contractor personnel to disseminate the ALARA approach and to integrate contractor personnel into the information transfer, feedback and review process to the extent necessary. The need for communication between utility and contractor personnel also shows that it may be important and worthwhile to have integrated teams formed by contractor personnel but which include utility personnel, though this may not be "normal" in all plants.

> As an example, at Oskarshamn in Sweden, when a contractor is in the process of contract preparation for a job which might involve considerable individual and/or collective exposure, it is expected that estimates of expected doses as well as costs will be calculated by the contractor and included in the information supplied to the utility for contract evaluation. To facilitate the contractor's job, and to assure accurate calculations, the contractor is supplied with all necessary data (photos, dose rates, drawings, etc.). The results of the contractor's calculations are reviewed by the utility radiation protection professional assigned to follow that particular job, and the contractor is required to explain how following the proposed procedure will assure that exposures are maintained ALARA. By following this procedure, the contractor fully understands the problem, and is able to propose solutions based on past experience, resulting in a better product for the plant, and lower exposures.

Incentives to Motivate and Involve Workers

Incentives or recognition programs for maintaining exposures ALARA are another technique used to motivate groups of employees or contractors toward achieving dose reductions by linking goals set for jobs to competitions, such as prizes for good performance, for the best teams, or for comparisons with results at sister-plants or from previous outages. This positive motivational technique has reportedly been effective in commercial nuclear power plants at reducing personnel dose (Miller, 1992). Company awards which include merchandise, gift certificates or cash positively reinforce management's message to workers of a job well done.

A survey of American BWRs, performed at their 1994 BWR Owner's Group meeting, shows that the majority have implemented some type of ALARA incentive programme, or use a company-wide recognition program to award employees for meeting "ALARA Goals". Some of these programs allow workers to earn "ALARA dollars" good towards the purchase of merchandise. Other award options include company-provided trinkets (hats, shirts, pen-knives), prominent parking spaces or dinner certificates. One advantage of awarding merchandise over monetary awards, according to psychologists, is the length of time a worker will remember the award and thus its impact on attitude and morale (Miller, 1992).

> Other award systems are also used. For example, in Sweden, annual salary bonuses are tied to the achievement of annual dose objectives (annual collective dose less than some target number, for example). At the Gundremmingen nuclear power plant, in Germany, if the dose objectives for a particular outage are met, then the plant management commits NOT to schedule the subsequent outage during the national vacation period (in many European countries, outages are performed during the summer period, which also corresponds to the period of national school holidays, which are thus traditional vacation periods). At the Diablo Canyon plant, in the United States, workers are up to 52 hours of additional annual leaves if outage goals are achieved (10 hours of this time is awarded for meeting radiation protection goals). At the three Tokyo Electric Power Company (TEPCO) nuclear power stations, competitions of good practice in work management, reduction of radiation dose and radioactive solid wastes have been held once or twice per year for the past several years. More than ten groups from various maintenance contractors participate in these competitions, which are hosted by the station Engineering Division Manager. Presentations of good practice are made by participants, and awards for excellent presentations are made by TEPCO management.

Awards and incentives are not only used to recognise good dose performance on jobs but have also been used, with equal or greater benefit, in encouraging suggestions from workers to make exposures ALARA. Review criteria can be established to limit awards only to those suggestions with merit. Caution should be exercised to not too quickly discount honest efforts and discourage workers from using the program. It may be more beneficial to award a worker for a suggestion than to risk the consequences from assuming suggestions without merit were submitted only for an award.

Involvement of Workers by Challenging or Stressing Factors

This kind of involvement may help to engage personnel in improving their implementation of the ALARA principle, though care should be taken in considering this method of involvement as in some cases and for some means there is a great danger of moving from motivation and engagement to de-motivation resulting in frustration and potentially in lack of quality, increasing doses and in some cases increasing cost for example due to re-work. Examples of putting this additional emphasis on the implementation of work practices would be:

- an increasing presence of radiation protection staff at the workplace reviewing the behaviour of the workers with respect to radiation protection performance, and
- an increased senior staff presence at the work place.

It should be noted, however, that care should be taken to such that this increased presence is balanced such that all exposures, including those of senior staff, are maintained ALARA.

Both examples may help if they are handled cautiously, if the workers can identify the presence as supportive and if communication may be improved. But frustration and demotivation of involvement may be expected if the presence is interpreted as checking performances or questioning qualification.

Another point of potentially problematic challenge may be setting goals which contain a "challenge factor" specific to the company and to the work. For example, a company may choose to set a goal at 90% of the dose expected based on previous jobs, believing that continual process improvements for the work will lead to that level of dose reduction. History may suggest, however, that such a reduction may be too high (or low) for a particular work evolution. Job analysis in such a case may result in a goal closer to (or farther from) the expected dose without consideration of a challenge factor.

This procedure may interfere with the need for a reliable and acceptable goal for the job, and may again result in frustration and de-motivation.

4.3.2 Prerequisites for Maintaining Worker Involvement

After having motivated workers to participate in the work management approach and to contribute to efforts to perform work with doses ALARA, it will be important to **keep** personnel involved or even to increase involvement, and especially to get new workers – and new contractor workers – in line with ALARA philosophy application in the plant during the outage. Basically, conditions and means to involve workers will not be very different from means to maintain involvement, and mainly address ongoing communication and information transfer.

Repetition of Education and Training in ALARA Topics

Education and training in topics important for the ALARA approach at the utility should be repeated periodically in the plant, *e.g.*, as a refresher course before the next outage to inform workers of the important aspects of radiation protection and special aspects of conduct in work. Special consideration should be given to:

- new personnel not yet sufficiently familiar with the ALARA approach and its tools,
- the consideration of previous experiences from recent education and training sessions, especially from reviews and recommendations from participants, and
- avoiding training sessions which might repeat trivialities and unimportant information and thus might frustrate and de-motivate workers.

Maintaining Motivation of Personnel

To maintain the motivation of personnel over time, several aspects may contribute and should be considered by management, and in cases by the senior staff, at all times and with an increasing intensity. These aspects are summarised here, and have been previously discussed in more detail:

- Management should set a good example for the application of ALARA in work preparation and planning as well as in presenting an increasing involvement in these topics and applying good radiation protection practices when present in the plant
- The competency of personnel should be acknowledged and supported for both utility and contractor personnel. This especially should be done:
  - by integration of the personnel into the planning process for work steps and for goals,
  - by passing responsibility to the personnel, to the extent possible and necessary, with support provided by the utility in the form of appropriate planning and tools,
  - in performing post-job reviews for all personnel in the areas of experiences and necessary improvements in planning, education, and job training, and regarding tools for the job, procedures or protective measures and working conditions during the job, and
  - by accepting proposals for improvements for all aspects in which workers are involved.

It is especially important that personnel recognise that consequences will be drawn from reviews and that proposed improvements will be implemented.

- Rewards may contribute, depending on company policy. There is, however, some need for periodic review of incentive systems. To avoid various system problems which may develop, *e.g.*, suggestions coming from and awards going to the same people, resulting in frustration and demotivation of the others, or typical rewards becoming "dull" or uninteresting with time resulting in a loss of the beneficial effect of rewarding personnel.

4.3.3 Passive Involvement of Workers in Decisions Taken by the Utility – A Warning

Worker involvement may also be understood as "involving personnel by the utility" in the sense that the management of the utility makes use of the personnel in planning and managing without integrating them into the planning process, and especially without involving them actively in a motivational way. Planning for the management may be easier in this way and challenging plans may be derived without consideration of worker's attitudes and special experience.

An example may be taken from the development of goals. Different methodologies are used in goal development, based upon the type of work being evaluated. After work has been categorised (outage activities, plant modifications, or routine operations for example), goals are derived using historical job performance data, project cost and estimates and man-hour projections provided by work groups, or information from other facilities which have performed similar work. Estimates which are based on historical data, usually for repetitive maintenance tasks or similar modifications to a comparable unit, generally show little divergence from actual figures. When detailed work plans are unavailable for the approaching year, either because of a lagging planning process or work groups placing a lower level of importance on providing information, the goal making process becomes more uncertain and additional management attention is warranted. Sometimes management may try to implement additional challenging factors into planning to try to improve worker performance.

This practice, which is summarised here as a negative example, and which is considered not to be a normal practice in preparing a planned outage, should be avoided as it will be a major step towards demotivation, and most probably will not support the implementation of ALARA-approaches in a plant.

4.4 Summary

The involvement of workers at all levels is one of the most important aspects of a Work Management programme. By engaging the worker in the task being performed, the worker is more likely to be motivated to perform the job to the best of his/her abilities, and this will be reflected in lower job doses as well as in higher job quality. To assure the full involvement of workers, conditions must be correct to create and then to maintain such involvement. A programme to reach these goals should stress the correct behaviour of senior and mid-level management, as well as of senior staff members (job Forman, shift supervisors, etc.), and should involve an appropriate level of training such that workers posses the correct tools for the implementation of ALARA. It should also implicate workers at all the stages of a job (planning, scheduling, preparation, implementation and follow-up), and should assure that there is a mechanism for matching individuals and their skill levels with appropriate tasks. Workers should also be included in the process of setting goals, and good communications between different levels of the hierarchy and among the different disciplines should be a management priority. Finally, worker incentive and "challenge" programmes should be used to create and maintain worker involvement, and periodic refresher training in work management and ALARA should be used to reinforce good habits. Such a programme will help to assure an appropriate level of worker motivation and involvement, and should pay for themselves in terms of time, dose, and costs saved, and in terms of job quality.

4.5 Worker Involvement Case Study

In the case of worker involvement, again, several types of information are necessary to justify the implementation of a new programme. For example, to begin a programme of pre-and post-job review with the job planning team and including the contractor, the types of costs to be considered would be:

- some number (one or two) of person-days of time for the contractor job Foreman,
- some number of days for one or more contract worker with experience in performing the particular job,
- some number of days for the entire interdisciplinary job-planning and preparation team to assemble for the pre-job planning meeting, and for the post-job follow-up meeting, and
- some number of days (up to a few weeks, depending upon the job) of time for the entire interdisciplinary job-planning and preparation team to review the job follow-up meeting and to determine which task modifications and changes are appropriate, and to determine the cost-benefit of such changes.

In an effort to address long-standing interdisciplinary communication problems, Commonwealth Edison Company's Zion nuclear power plant held a "team-building" workshop. As elsewhere, when one of the two Zion 1040 MWe PWRs is taken off-line for refuelling, maintenance outages or for plant modifications, many major activities occur. These can include full core offload, steam generator inspections, reactor coolant pump maintenance, turbine rotor inspections, in-service inspection, motor operated valve tests, technical surveillance, snubber testing, leak rate testing, system operability and valve exams. The work is accomplished by a refuelling outage team comprised of numerous groups. These include groups such as utility electrical, instrument, and mechanical maintenance departments. The station technical operating staff, and construction contractor workforce, and speciality teams for non-destructive testing of steam generator components and critical piping welds. In addition, the radiation protection department provides full scope radiation protection support to each of these work groups.

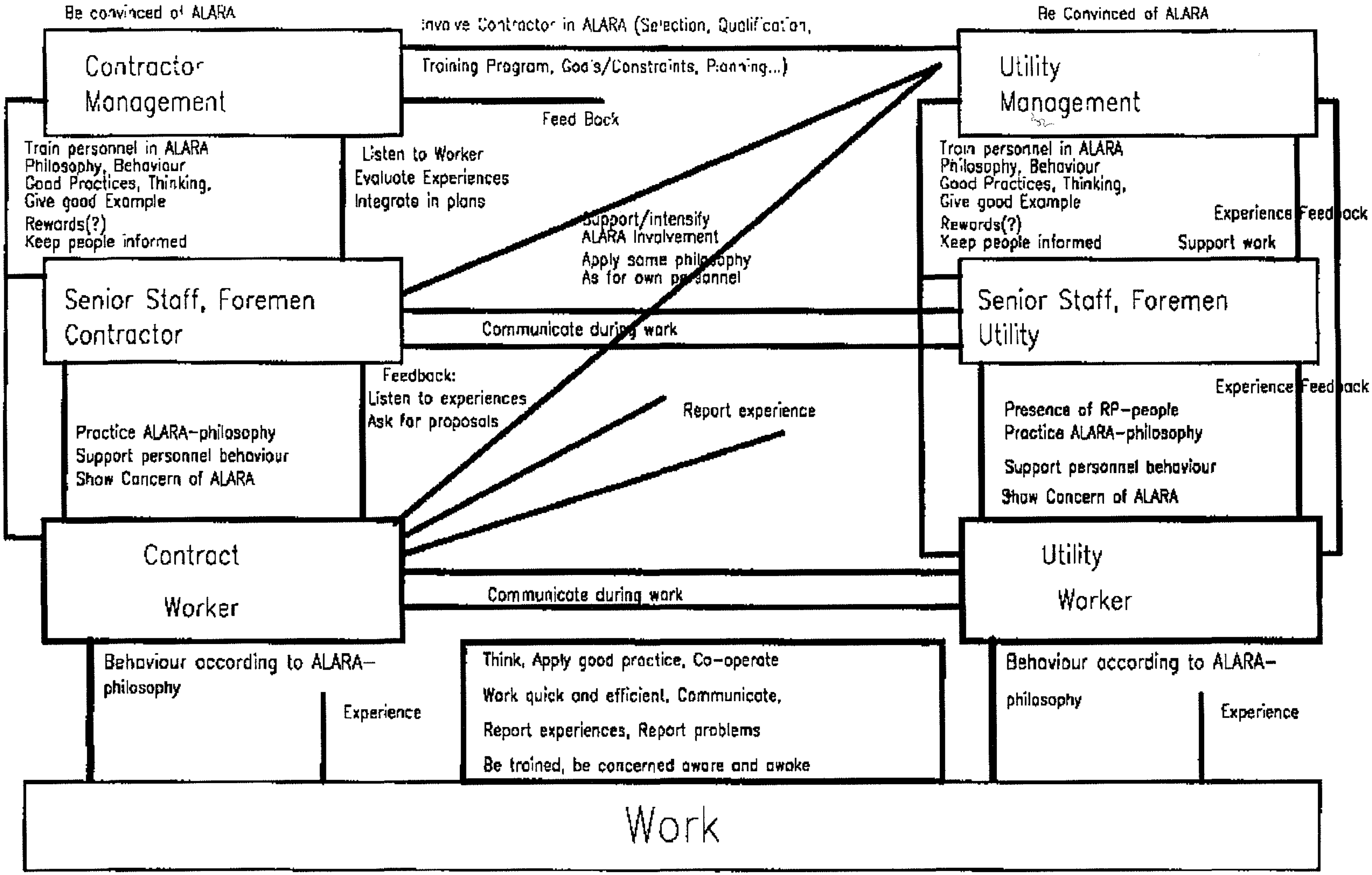
WORK MANAGEMENT PRACTICE DESCRIPTION:

Radiation protection support of the refuel outage team and radiation exposure optimisation actions cannot be taken independently or in isolation from the front line work groups. A workshop to solve lingering problems between the radiation protection department and primary refuel outage team work groups was held. This two day workshop involved the radiation protection staff and the main contractor workgroup performing contracted maintenance. The workshop was run by an organisation specialist who guided discussion between the two groups. Two sides were taken comprised of; side one – radiation protection personnel and, side two – construction contractors. Each side discussed within their group the question "What is working?" answering first 1. "What are we doing right?" and next 2. "What are they doing right?." Each side presented to the other side their list of answers and explained their responses. Next the question "What isn't working?" was answered from the standpoint of 3. "What are we doing to hold back progress?" and 4. "What are they doing to hold back progress?" Each side presented their responses by swapping their answer lists. Finally each side voted on the top priority problems to resolve and improvement ideas were developed, as were lists for corrective action steps. Assignments were made for implementing solutions prior to the next refuelling outage. This served as a valuable exercise in forcing the two sides to understand and appreciate the others' role in completion of outage team tasks. This resulted in improving the co-operation and partnership for future outage tasks.

COMMENTS ON EXPOSURES AND RADIATION PROTECTION ACTIONS:

Although no specific dosimetric data is provided as a result of this workshop, it was recognised that this was a positive effort to integrate radiation protection and ALARA actions into the work of the outage team. When radiation protection and ALARA elements are accepted as part of the work practices, the radiation protection department is better connected to the work and can provide better services and support of the work groups.

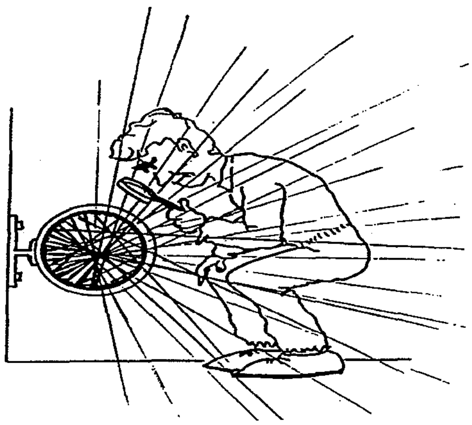
This workshop resulted in improved communications and co-ordination of radiation work. These improvements can result in reduced stay times in radiation areas and lower collective exposures.



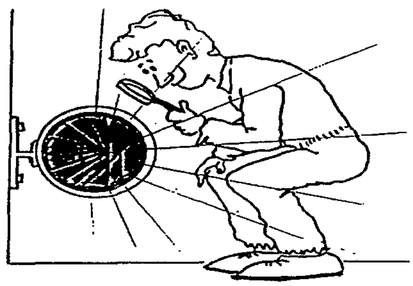
Be convinced of ALARA
Involve Contractor in ALARA (Selection, Qualification,
Training Program, Goals/Constraints, Planning...)
Be Convinced of ALARA
Contractor Management
Feed Back
Utility Management
Train personnel in ALARA
Philosophy, Behaviour
Good Practices, Thinking,
Give good Example
Rewards(?)
Keep people informed
Listen to Worker
Evaluate Experiences
Integrate in plans
Support/intensify
ALARA Involvement
Apply same philosophy
As for own personnel
Train personnel in ALARA
Philosophy, Behaviour
Good Practices, Thinking,
Give good Example
Rewards(?)
Keep people informed
Experience Feedback
Support work
Senior Staff, Foremen Contractor
Communicate during work
Senior Staff, Foremen Utility
Feedback:
Listen to experiences
Ask for proposals
Report experience
Experience Feedback
Practice ALARA-philosophy
Support personnel behaviour
Show Concern of ALARA
Presence of RP-people
Practice ALARA-philosophy
Support personnel behaviour
Show Concern of ALARA
Contract Worker
Communicate during work
Utility Worker
Behaviour according to ALARA-philosophy
Experience
Think, Apply good practice, Co-operate
Work quick and efficient, Communicate,
Report experiences, Report problems
Be trained, be concerned aware and awake
Behaviour according to ALARA-philosophy
Experience
Work

5. WORK SELECTION, PLANNING AND SCHEDULING

The minimum duration of a refuelling outage is defined by 1) opening the reactor vessel, 2) refuelling and 3) reactor assembly. The goal of outage planning should be to schedule all other jobs in an optimal way within that time frame. Computer-aided planning programmes can assist in assigning jobs to various systems when their dose rates are at a minimum. Doses are saved at no extra cost if, for example, jobs are scheduled during periods when systems or components are filled with water rather than drained.



Inspection of a drained system



Inspection of a water filled system

5.1 Introduction

Work activities in nuclear power plants are carefully planned to assure that exposure to radiation is optimised. Planning must recognise not only the sequence of job steps on a time line but also the support services necessary to successfully complete work in an efficient fashion. Also, the scheduling of jobs in relation to each other, and the identification of potential work interferences and hazards in the plant zone where the work is occurring, are often critical to the success of job performance without delays.

The objective of this section is to identify the key elements in planning and execution that permit work in nuclear power plants to be accomplished efficiently and with optimised dose to the workers. Radiation protection planning, strategy and technology will be discussed.

5.2 Work Selection

Selection of work to be included on a plant's outage schedule has become an area of increased management attention as nuclear utilities prepare for deregulation. Cost containment is critical to a utility's survival in the highly competitive electricity source market of the future. In this regard, many American utilities have examined the European approach to outage management, specifically, work scope selection. Finland is the global leader in terms of minimising outage duration. At Loviisa nuclear power station (two PWR units), the annual "short outages" (years 1, 2, 3) take 3 weeks, and the so called "long outage" (year 4) takes 6 to 8 weeks. After this, the next four year cycle starts again with three 3 week outages. Outages at the Olkiluoto nuclear power plant (two BWR units) are normally also short, lasting only 2 weeks.

Mr. Björn Wahlstrom, Radiation Protection manager at Loviisa nuclear power plant, provides the following insights on evaluating the work scope for these short outage durations:

a. *"Every job will always take all the time it is allowed to take."*

Suppose a job could easily be finished within four days, but the work supervisor tells the workers on Monday morning that this work should be finished by Friday afternoon. Be sure that the work will not be ready in four days! It will take *all the time it is allowed to take*, and be finished on Friday. It is the same with the annual outage. A loose timetable will result in all jobs taking more time to finish than with a tight timetable. So, by simply *choosing the strategy* of making the timetable tight, person-hours, money and radiation doses will be saved.

b. *If an outage is prolonged by a single job, it will cause excessive radiation doses, because other jobs will also proceed more slowly.*

This thesis is connected to the first one. More time would "be allowed" for other jobs if a single job caused significant delay in the outage timetable. This situation can arise even if the time table is planned in an optimal way. If one unexpected job causes significant delay to an outage (for instance, because spare parts have not been delivered on time), make every effort to postpone the work to a future outage. If the system can be left in a safe mode until the next scheduled outage, the safety authority should allow this based on dose reduction projections.

c. *Many jobs will be suggested which should never be authorised.*
   and
d. *Never perform "Nice But Not Necessary" (NBNN) jobs.*

At some point most people who are responsible for initiating work will suggest modifications or new installations or changes to existing systems. Even if a suggested job at a first glance seems *nice* it should be evaluated to ensure that it is also *necessary*. Within the organisation, there should be a group that meets periodically to do such evaluations. Different interests and aspects should be represented on the group. This group should only make YES/NO decisions, "go" or "stop". Performing NBNN jobs costs money and causes radiation doses to no avail.

e. *The optimum size of a work team is the smallest number of workers that can perform the work on time.*

Generally it can be said that the fewer the number of workers, the smaller the collective dose. This means that if the *individual doses* are *not* a problem, no more workers than the *necessary minimum number* should be assigned to a job. For instance, if the number of workers is *doubled*, the duration of the work will be shorter, but it will *not be halved*. So, *adding* more workers will *increase* the total number of working hours, thus increasing the collective dose and the cost.

Another example of how the collective dose will increase with the number of workers is the *exchanging* of workers. The dose received from a job is the sum of three parts, 1) dose received in transit to the work site, orientating and putting the tools in order, and getting started, 2) dose received while performing the job, 3) dose received while finishing the job, securing the work site, removing protective equipment and leaving. The dose in phase 2) is relatively constant and independent of the number of workers exchanged, but doses in phases 1) and 3) will increase each time a worker or work team is changed. So, the exchanging of workers should be used only when it is *necessary* for controlling individual doses.

It should be remembered that technically appropriate work, which clearly contributes to nuclear safety and equipment reliability, should be scheduled and performed. Avoidance of such "necessary, even if not nice" tasks may lead to unnecessary plant shutdowns, with their associated costs, risks and doses. The key question here is the ability to make proper technical judgements regarding the value of proposed work; to be able to distinguish between "nice but not necessary", and "necessary".

f. Jobs which are not performed cause no doses.
and
g. Recalculate overly conservative presumptions.

For instance, the 60 large bolts (weighing 180 kg each) of the reactor vessel head of Loviisa 1 were to be changed in 1993 according to the original lifetime maintenance program. However, when the straight calculations made by the manufacturer were reviewed by the power company, significant conservatism was found. *New calculations using more exact data* showed that the bolts could be used at least five years more. Thereafter new calculations should be made. This result was presented to and accepted by the nuclear safety authority. So, this *work has been avoided,* and so have the doses and costs it would have caused.

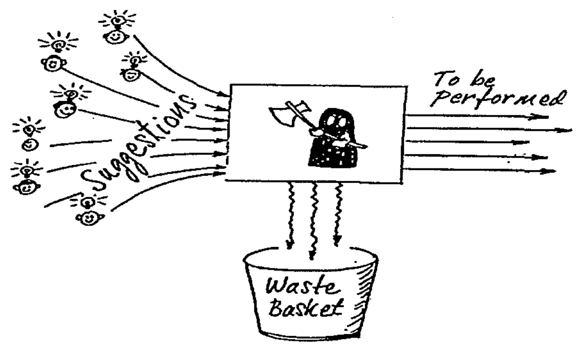
h. Doing a job fast and well may mean doing it twice (if you do it too fast): First fast—then well.

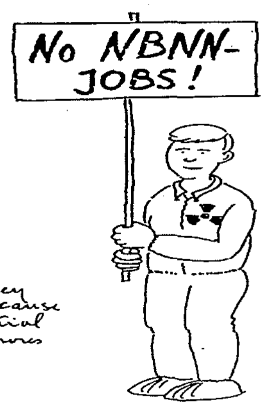
It is difficult to give exact figures for how much extra radiation doses are caused by so-called *rework,* work which was first performed incorrectly and thereafter corrected. Estimates between 5 and 15 percents are often given. Rework will be discussed in more detail in Chapter 7. Here are a few examples: A welding seam may need to be ground up and re-welded because inspection revealed welding errors; a valve may need to be dismantled, opened and closed once again because a gasket was improperly mounted resulting in leaks. Leakage in any primary system which are found only during the *start-up phase* of the plant are likely to prolong the entire outage. The delay may be several days, if the reactor must be cooled and the pressure taken down before the rework, after which the temperature and pressure must be raised. This delay will also cause "secondary" doses from other jobs. Such jobs are, for instance, plant operations that must be repeated upon every start-up, and any job which will progress slower because of the additional available time.

The Finnish approach is clearly where some aggressive US nuclear utilities are heading. A management team from Philadelphia Electric Company's (PECO) Limerick Nuclear Power Plant visited several European BWRs in 1994 and returned to plan and execute a 22.9 day refuelling outage in 1995 and a 24 day outage in 1996. Adoption of a European approach to efficiency, and their work selection and planning processes contributed significantly to this achievement by a US BWR.

5.3 The Job Planning Process

Many jobs, which should never be performed, will be suggested. However, if a job is not necessary – why do it? It only costs money and dose. Never perform NBNN-jobs, i e. jobs which are "Nice But Not Necessary". It will pay off to have a routine that separates the necessary jobs from those which are only nice. That mechanism may be a group of persons who question and "try to resist" every initiative of extensive work or modification, even those initiated by the authorities.





Jobs which are not done cause *no doses* and *no costs*.
If a job isn't necessary, don't do it, even if it seems nice.

but they could cause potential exposures

Effective work planning is essential to minimising operating and maintenance (O&M) costs at nuclear facilities. Such improvements in planning processes and interfaces with radiological protection personnel have resulted in reduced O&M costs and collective doses in the nuclear industry since the early 1980's. Integrated work planning allows proper review of work in radiation areas and provides an opportunity for necessary controls to be factored into work plans. One approach to the process of integrated work planning has been to assign maintenance planners, rather than radiation protection personnel, the responsibility for radiation protection planning right down to the job level. It is, of course, essential to maintain the involvement of radiation protection personnel in this process, for instance, to provide input as to radiological conditions at the work site, feedback experience as to contractor and material selection, and as ALARA reviewers of procedures. However, assigning radiation protection responsibility to maintenance planners puts the responsibility in the hands of line management, closer to the actual work, and fosters interdisciplinary communications. This approach is currently used in many European, and a growing number of American nuclear plants.

In terms of planning, it is important that a multi-disciplinary team be created to plan jobs. Such a team should include representatives from plant management, scheduling, maintenance engineering, safety, and radiation protection, as well as from the contractor as applicable. The co-ordination of work between all work groups involved in the outage is encouraged by the organisation of regular meetings during the planning stage.

For example, in Ringhals (Sweden), a specific schedule is established to outline the steps in the outage preparation with, among others, the specific dates:

- *7 months* before the outage: definition of the final organisation, first outage meeting, list of all the jobs to be performed during the outage,
- *6 months* before the outage: first estimated schedule
- *5 months* before the outage: definitive schedule
- *2 or 3 months* before the outage, detailed schedule for every maintenance section.

At Philippsburg (Germany), the following schedule is adopted for the outage preparation:

- *9 months*: The list of all routine jobs to be performed during the outage is established.
- *8 months*: The list of maintenance jobs is approved by all departments.
- *7 months*: The list of jobs had been discussed with the engineers responsible of the outage. The list of the jobs needed for the operations preparation is established.
- *7 months*: All services involved discuss the details of the operations. The jobs are scheduled together.

Health physicists of Planning and Preparation Section discuss the jobs with the other divisions.

- *6 months*: The full list of jobs is given to all departments.
- *6 months*: First outage meeting. First complete schedule.
- *5 months*: Second outage meeting. Second complete schedule (improved).
- *5 months*: The detailed schedules for each department are finished. The responsible engineers give their approval.

The main task of the division of Preparation begins : all the jobs are integrated in the computer system (1000 to 2000 tasks). They write the first part of the Work Permits (technical description of the jobs).

- *4 months*: Third outage meeting.
- *3 months*: Final schedule: no new job can be added without the agreement of the plant manager.
- *2 months*: Meeting with the Safety Authority (State ministry) and with independent TÜV experts (a German inspection and testing organisation which works for the regulatory authority) to discuss the main jobs to be performed during the outage. All are informed of the global schedule for the outage, and a list and description of all jobs with safety significance is prepared for the meeting.

An important consideration for job planners is the review of lessons learned and the application of corrective actions from these lessons learned to future job evaluations (see Chapter 8). A system to identify problems and challenges to work crews in the field, and to track corrective actions for future application is necessary. Some facilities use ALARA post job review meetings for this purpose. Other mechanisms include in-progress job reviews performed by the job foreman or radiation protection personnel, or post-outage critique reports. Once deficiencies are identified and assigned to a responsible organisation or individual for resolution, periodic management review should be performed to ensure schedule commitments are met, and to resolve differences.

The geographic location of job planners is a key factor to the success of a planning organisation. Grouping planners together in one location opens communication lines and enables more efficient interfaces. Sometimes two flights of stairs present enough of an obstacle to discourage seeking out the right person for important information. Radiation protection planners should not be excluded from any centrally located planning team. Most plants which have been successful in incorporating effective radiation protection consideration into their planning process have also integrated radiation protection personnel into the planning organisation.

Careful work scheduling and scheduling reviews are also important in maintaining doses ALARA. The majority of dose-significant maintenance work at nuclear facilities is performed during the refuelling outage in PWRs and BWRs, and during maintenance outages in CANDUs, when radiation fields are substantially less in most places than during power operation. Other opportunities for maintenance work occur, however, during power downs used to perform control rod sequence adjustments, when dose rates are lower in areas such as BWR steam-affected locations. Scheduling work during a particular period within the outage is also important. Doses can be saved without any costs just by "putting jobs in right order" and performing them at the right moment. Here are some examples:

- As far as possible, work should be avoided when the system, pipe, tank or other component is drained. Even if the process water is contaminated it absorbs radiation. The dose rate at the surface of a pipe, valve or pump is almost always much lower when the system is full than when it is drained. So, whenever possible, schedule jobs to those periods when the system is water filled. Generally, keep water in the systems whenever possible. Flushing of systems, where possible, can also contribute to dose reduction by removing hot spots or crud deposits.

- If the time table does not require that jobs on radioactive systems are done immediately at the start of the outage, then schedule them later. The dose rates will be lower towards the end of the outage than at the start. Coolant purification and natural radioactive decay will also contribute to this effect.

- Schedule work to take advantage of other work about to begin, already in progress or recently finished. In this way the same local arrangements, e.g., contamination containment and boundary designation material, can be efficiently used. If an unrelated job in a particular location requires scaffolding which had been erected previously for another job, the scaffold can remain for the next work crew in turn saving dose to the scaffold builders. This is often called "Resource-Based" scheduling.

- If a scaffold or a temporary radiation shield was first constructed and used for one job, then removed – and later constructed again because of another job in the same location, a major mistake in scheduling was made!

- In order to take advantage of work in progress and save dose to workers, to avoid situations where one job creates a radiation or contamination problem for adjacent work crew or to prevent such congested areas that safety and productivity are diminished, radiation work planning groups have developed a system called "Area-Based" scheduling. An area-based scheduling system divides work areas into grids and allows schedulers, planners and work foremen to visually depict all work in each grid sector. Multiple transparent grids (one for each type of work; valves, scaffolding, in-service inspection, etc.) can be marked and laid over one another to understand the concentration and type of work in each sector. Simpler approaches use engineering maps of buildings. Some plants have reported development of a computerised data base with the precise position of all reactor building components in order to prevent unnecessary interaction between different tasks performed in the same room.

When all the work and corresponding schedule/priority is known, potential problems are anticipated in the planning stage, and corrective actions can be taken to prevent conflicts.

> Another dose saving planning tool, reported at several Commonwealth Edison facilities and Liebstad nuclear power plant, in Switzerland, is a physical scale model of the containment structure. Scale models have been used for more effective planning and pre-job meetings, contractor employee orientation, and to eliminate the need for engineering walk-downs. Like most radiation protection tools, a scale model saves time. Physical models are uniquely capable of providing complete visual information and provide at a glance what would otherwise require the cumbersome evaluation of many drawings.

In addition, some aspects to consider as part of the up-front job planning process are the prefabrication/pre-assembly of equipment/parts, the removal of in-plant components to low dose rate staging areas or machine shops for maintenance, and worker mock-up training. Planners as well as design engineers and maintenance technicians are responsible for identifying components which can be fabricated in machine or electrical shops outside of radiation zones prior to installation. This technique has been used successfully, for instance, for prefabrication of pipe spools, flange welds, pipe struts and electrical wiring for valve actuators. Another useful technique is the removal of components from higher to lower dose-rate areas for maintenance. Good examples are removing of valve actuators for service, valve disks for machining and pump motors or pumps for inspection. Equipment can simply be moved to a nearby low dose-rate area, or to an on-site hot-shop for maintenance work.

> For example, at Laguna Verde Unit 2, an 1100 BWR, 0.14 person-Sv was saved by moving valve actuators from their high-radiation area locations inside the drywell to a low radiation area, outside the containment, for maintenance. It should be noted that this savings includes the exposures necessary for equipment decontamination.

Mock-up training also saves doses. Workers who receive training on mock-up equipment may perform their tasks over and over again in a clean environment, which prepares them to work more efficiently in the radiation area. This training allows workers to ask questions, to become familiar with the maintenance or inspection process, and to work out any "kinks" before entering radiation areas. Mock-ups are used for work such as installing ultrasonic scanners or temporary shielding, removing and replacing control rod drive mechanisms, and valve disassembly and re-assembly. Very notable dose saving mock-ups are used for training workers who replace PWR steam generators, one of the most complex and exposure-intensive projects that a nuclear plant will undertake. Finally, proper execution of a mock-up training plan includes two important aspects:

1. the mock-up replica should be full size (if at all possible) and in an environment similar to the field location and,
2. the physical constraints and conditions(scaffolding, lead shielding, insulation etc.) should be installed as they would be when actually performing the job.

A good example of the effective use of mock-up training is the use of the CETIC Training Centre, run by Electricite de France and FRAMATOME. This 4000 m^2 facility houses full-scale mock-ups of all major PWR components (pressure vessel, vessel head, steam generator, pressuriser, reactor coolant pumps, refuelling machine, fuel assemblies, reactor cavity, etc.) and is used for worker training and new equipment testing. As a specific example, the training of "steam-generator jumpers" to perform tube plugging work reduced the worker's time in the channel head from 45 seconds to 20 seconds. For such jobs in high dose-rates environments, FRAMATOME, EDF and the CEPN have jointly performed studies which indicate that adequate mock-up training can reduce the worker's time in the high dose-rate environment by up to 40%.

At Pennsylvania Power and Light's Susquehanna nuclear power plant, a snubber mock-up has been developed worker training, and all snubber inspection and maintenance workers are trained prior to each outage. At the American Electric Power Company's D.C. Cook nuclear power plant, training, security and radiation protection personnel have actually visited contractor sites to perform worker training prior to outages, to save worker site-entry time during the outage.

Like a physical scale model of plant buildings, pictures provide a good visual reference for work planners, radiation protection pre-job planning and worker pre-job meetings. Many plants have identified the need to record and access images of various plant areas and components not normally accessible due to plant operation and/or high radiation levels (Newman, 1992). Providing visual references in a centralised image data base reduces redundant and inconsistent individual efforts by various groups to record photos or videos of selected components. It also provides uniform and consistent information which helps reduce dose through familiarisation with plant layout and minimising visual inspections. The following advanced imaging tools are being used at U.S. PWRs and BWRs:

- videodisk-based image storage and retrieval systems
- still video and digital photography
- multimedia
- image transmission technology
- photogrammetry

Of all the advanced imaging systems addressed in a 1992 study by EPRI, videodisk-based image storage and retrieval systems are the most widely used in nuclear power plants (Owen, 1992). Evaluation and selection of a digital technology over more conventional technology (35 mm or videotape) should include cost, desired image quality, and intended retrieval availability. Products are commercially available under a variety of trademarked names as well as by general terms such as walk-through tours, video mapping systems and surrogate travel systems. As indicated by their names, some of these systems provide real time navigational (walking tour) capabilities. Some plants have developed digital image libraries in-house using still video cameras selected for their high image quality. Advantages of using digitised computer images of plant areas include widespread retrievability if computer networks are in place. Those who have access to the computer network could realistically access up to 100,000 images contained in a typical plant data base. In a surrogate travel mode, a keypad, joystick or mouse is used to move through the plant as if one were walking and allows speed control or pausing to look up, down, left, right or behind (Owen, 1992).

5.4 Tracking "Hot" Jobs

In radiation protection, too, the *"80-20 law of nature"* holds true: 80 percent of the jobs will cause 20 percent of the collective dose, and 20 percent of the jobs will cause 80 percent of the dose. In order to direct and use resources in an optimal way it is important to identify those 20 percent dose intensive jobs. Even though each nuclear power plant has many unique aspects, they all have much in common. For instance, removal and replacement of *insulation* causes significant exposure to radiation at *all* plants, as does *in-service inspection*. On the other hand, jobs as *refuelling* or *plant modifications* cause no problems at some plants but major problems at others.

In Table 5.1, typical high dose jobs at light water reactors have been listed. Each plant is likely to find their own high dose jobs, the critical "20 percent which cause 80 percent", among those in this table. These are the jobs which should primarily be included in some type of radiation dose management information system. One useful approach to taking advantage of the vast collective experience of the nuclear industry for those critical 20 percent jobs, is to use the ISOE data base and communications network to "benchmark" the collective dose of a job against that seen at other plants around the world for similar jobs.

Table 5.1. Typical High Dose Jobs at Light Water Reactors

Cavity Decontamination
Chemical and Volume Control System Maintenance
Control Rod Drive Maintenance
In-Service Inspection
Insulation Removal and Replacement
Instrumentation Calibration and Repair
Local Leak Rate Testing
Main Steam Isolation Valve Maintenance
Operation-Surveillance Routines and Valve Line-ups
Plant Modifications
Pressuriser Valve Maintenance
Radioactive Waste System Maintenance
Radioactive Waste Processing, Storage, Shipment
Reactor Water Clean Up Pump Maintenance
Reactor Coolant Pump Maintenance
Reactor Head Work
Recirculation Pump Maintenance
Recirculation System Piping Replacement
Refuelling
Residual Heat Removal System Valve Maintenance
Safety Relief Valve Maintenance
Scaffold Installation and Removal
Snubber Inspection and Repair
Steam Generator Maintenance
Steam Generator Replacement
Calibration and Repair of
- Transversing In-Core Probes (TIP)
- Power Range Monitors (PRM)
- Start-up Rante Monitors (SRM)
- In-Core Radiation Monitors (IRM)

Torus Inspection and Repair

One efficient technique for reducing the exposures for such high-dose jobs is to familiarise workers with the work over more than one entry. At the American Electric Company's D. C. Cook nuclear power plant, radiation protection technicians have been assigned specific tasks and areas for several outages in a row, thus familiarising them with the area and the work. This has been particularly effective in high dose rate areas such as the upper and lower containment, and particular areas in the auxiliary building. Sending radiation protection technicians to the vendor, Westinghouse, for training with work crews for particularly high dose jobs, such as reactor coolant pump repair, has also proven to be effective at building interdisciplinary communication ties on the work crews.

Radiation protection controls are most efficiently incorporated at the job planning stage, and their implementation during work performance can be assured if this information is included with work procedures and plans. This can be accomplished most effectively with a computerised planning process which maintains historical data. Within a computer-based integrated information management system, collective dose and dose rate information can be stored with the work planning document and easily retrieved each time the work is performed. Here are examples of questions which may be answered by use of a historical file:

- Is the scheduled time sufficient? Is it optimal? Should it be cut down? Saved time means saved doses and saved costs.

- What support services are needed? Scaffolding, shielding (duration of construction/removal?), insulation work etc.

- Is the manpower optimal? Contractors like to use too many men. This will increase the collective dose. Too few men will result in higher individual doses than necessary.

- What doses can be expected? Use your own historical file, not estimates given by contractors. They use data from other plants and they may not include all necessary support work.

- Is there another similar component that could be inspected in place of the originally planned "hot" one?

- Can the component that needs service be moved to a another place to be repaired and serviced in a lower ambient dose rate?

- Should radiation shields be installed? Temporary or permanent (repetitive jobs)? In some cases, construction of a radiation shield will *increase* the total collective dose! Is this the situation?

- What personal protective equipment was used before? With what success? Was the use beneficial? Use of protective equipment *prolongs the duration* of the work. In certain situations the additional external dose will be larger than the internal dose saved.

- Can you gain anything from flushing the system? What was the result last time? If flushing costs time but gives no result – don't do it. A good file will advise you.

- Which contractor was used last time? Try to get the same contractor and even the same workers if they did a good job. They know what to do and how to do it.

A good reference system eliminates guess by work planners and radiation protection personnel and prevents historical job information from being "lost" as organisations change and people move into new departments. An important example of such a historical reference system may be ALARA blocking (tagging-out of valves) which is applied for radiation protection purposes. Such blocking is performed on valves or systems each time work is scheduled in a room susceptible to rapidly and widely changing radiological conditions, e.g., in a BWR reactor water clean-up backwash receiving tank room or in a PWR ion exchanger room for coolant purification. The need to perform such blocking is less likely to become "forgotten", with the changing of personnel, if it is appropriately stored in a computer-based reference system. Such a system also enables fast electronic review by radiation protection planners, which is particularly beneficial for critical emergent jobs and can improve cost effectiveness of the process.

5.5 Use of Available Data

Making good use of available data during radiation job planning can result in the maximum dose savings to workers. Many types of information sources are used, such as post-job reports, outage critiques, and deficiency/exposure reduction item tracking lists. Other valuable resources are available for radiation job planners which include job history files, photo libraries, information data bases and outside utilities who have previously performed similar work.

Job history files, if well maintained, provide readily accessible information during planning. Most historical job information is achieved for practical storage space purposes on some condensed media such as microfilm or microfiche which requires a lookup search and retrieve process. Hard copy history files kept near the work location are convenient and helpful to planners, and for the preparation of radiation work permit to establish ALARA goals and appropriate radiological controls, and to reduce reliance on historical job knowledge which changes with personnel.

Photo libraries are useful planning tools. Pictures are an easy way to show workers a job layout and help them gain orientation. Photos and maps can also minimise engineering walk downs and pre-identify interferences. For example, at Pennsylvania Power and Light Company's Susquehanna nuclear power plant, the in-service inspection group developed a series of location drawings for every snubber in the plant to help workers to find and identify the snubber corresponding to their job assignment. Video aided libraries are also available and will be discussed in Chapter 7.0.

Radiation and radiation protection information is available for job planning purposes through industry supported networks. As previously mentioned, the Information System on Occupational Exposure (ISOE) has three databases available (NEA-1, NEA-2 and NEA-3) which can provide various types of occupational exposure data, historical as well as actual. This includes annual occupational exposures for individual units (normal operation, refuelling/maintenance outage, forced outage), individual annual dose distributions for each unit or site, job specific exposures for 18 jobs and 75 sub-jobs, plant configurational information (start-up/shut-down procedures, water chemistry, ALARA programmes, etc.), and specific information for particular tasks, jobs, incidents, etc. which are interesting from an exposure reduction perspective. The ISOE Programme was put into operation and is managed by the OECD Nuclear Energy Agency (NEA), and is co-sponsored by the International Atomic Energy Agency (IAEA). Currently, over 380 units are included in the ISOE data bases, and data back as far as 1969 is available. Although not all of the information mentioned above is provided each year by each plant, participating plant correspondents can be contacted for information to supplement the data bases as necessary. As of July 1996, participation includes 61 utilities from 22 countries, and national regulatory authorities from 16 countries. The three level database system joins utilities and regulatory agencies though the world, providing occupational exposure data for trending, cost-benefit analyses, technique comparison and other radiation protection analyses. Another database of ALARA experience and good practice, made out of information taken from journal and proceedings articles and categorised by key works, also exists at Brookhaven National Laboratory (BNL), Upton, New York, through the ALARA Centre E Exchange (ACE) or ACEFAX. ACE is an on-line database system accessible via computer, modem and the appropriate communications software.

Outside utilities provide one of the best sources of radiation protection information available today. Information exchange throughout the nuclear utility industry has been universally endorsed and well supported, particularly since the Three Mile Island accident. This may begin to change however, as some countries begin deregulation. For example, in the US the 1992 Energy Policy Act which paves the way for the electric utility industry into a deregulated, and opens a competitive market environment. Utility information can be gained from participation in industry owner's groups by sending radiation protection personnel to owner's group meetings to exchange dose information, lessons learned and plant-specific regulatory issues. Utilities can also send personnel to visit other facilities and benchmark their process against those identified as industry leaders or to learn from problems encountered at these plants. One final, convenient and cost effective method of gathering useful information is – *telephone calls to other nuclear power plants!*

Procedures, training documents and of course co-workers can provide detailed plant specific information for radiation protection planning. People are sometimes one of the most frequently overlooked or untapped information resources. Learning who the right people are to contact for certain information usually takes time and should become easier the longer an individual is part of an organisation.

5.6 Summary

The work selection and planning phase of a scheduled outage, or for an in-service inspection campaign, is one of the most cost-effective periods for implementing Work Management. By judiciously selecting work, and by selecting not to perform certain tasks, much time, manpower, and dose can be saved. By effectively planning work, during the phase before procedures are fixed and equipment has been purchased, changes can be affected easily and inexpensively to save time, manpower and dose.

The key issues to the effective selection of work include the implementation of a tight schedule and the postponing or elimination of jobs which adversely effect that schedule, the selection of only those jobs which are "necessary" to the safe and efficient running of the plant, the use of realistic assumptions when deciding upon the necessity for performing work, and the avoidance of rework through tight but not rushed scheduling of tasks. In terms of job planning, the effective incorporation of lessons learned from previous jobs, or from similar jobs performed elsewhere in the nuclear industry, is essential. This sharing of experience, through data bases and communication networks like ISOE, INPO, WANO, the BNL ALARA Centre, etc. can provide very useful experience and help to avoid "reinventing the wheel". Also, for convenience, the location of job planners can be optimised by centralising all appropriate workers (planners, engineers, schedulers, etc.), thus fostering and facilitating interdisciplinary communications. In addition, the proper scheduling of jobs, to co-ordinate the use of services, scaffolding, installed shielding, water shielding in pipes and tanks, etc., and the use of scale models for planning (as well as training and worker orientation) purposes both contribute to the efficient use of resources. Finally, by concentrating on those jobs which are the most dose intensive, for both work selection and planning purposes, and by making effective use of available historical data, work selection and planning activities will be optimally focused and directed.

5.7 Work Selection and Planning Case Study

The implementation of appropriate work selection and planning mechanisms can be justified by looking at the types of costs and benefits associated with such a programme. For example, in terms of work selection, a programme to form a special group to review "standard" jobs which are "required" by plant technical specifications or by regulatory authorities to see which jobs could be eliminated would have to consider the following "costs" and "benefits":

- a certain number of person-hours for a long-term study by a multi-disciplinary team
- interdisciplinary job-planning and preparation team to the person-hours for the inclusion of contractors on that team
- the potential savings involved with the elimination of some "required" tasks.

For a similar team to review all jobs for their necessity would require the analysis of the same types of elements.

Two practical examples of this philosophy can be found at Loviisa plant in Finland. In one case, the 60 reactor pressure vessel head bolts (180 kg each) were scheduled for change in 1993 according to the plant maintenance programme. However, new strength calculations, using less conservative assumptions than the manufacturer had originally used, showed that the bolts could be used for an additional five years. The job was thus postponed until at least 1998. In exactly the same way, the scheduled change of the control-rod drives and fuel-following intermediate rods (specific to the VVER reactor) have been postponed for several years. These postponements have led to temporary cost and dose changes, however the extension of the change-out period leads to real savings by requiring fewer changes during the lifetime of the plant.

In a second example, in 1992, Loss of Coolant Accident (LOCA) analyses showed that certain valves and drives in the pressurising system at Loviisa 1 and 2 would not function properly in case of a LOCA. The decision to replace these valves and drives was made, and then postponed when analysis in the United States showed that even the proposed replacement parts would not function correctly. Meanwhile, it was noted that a significant maintenance/upgrade programme had been envisioned for the main safety valves of the same system, and it was decided to further postpone the valve and drive replacement until the job on the entire job could be performed together. Here again, the appropriate selection of work has led to the grouping of two large jobs into one, thus saving money and dose.

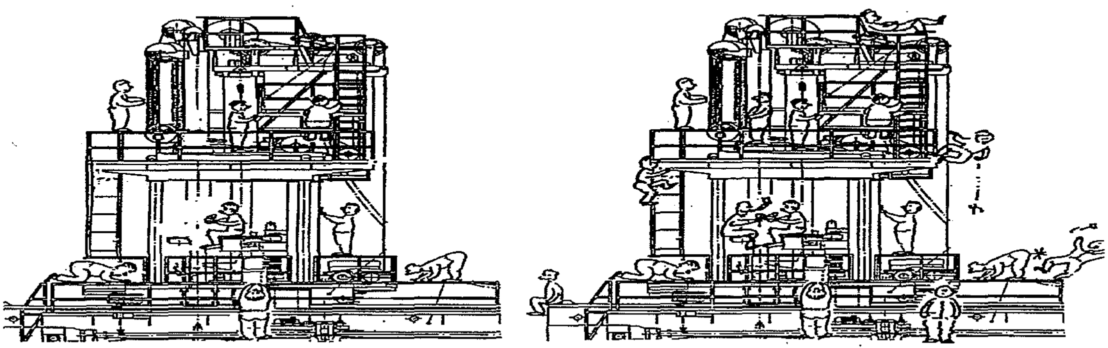
As an example of work selection and planning, an interesting study was submitted by a German nuclear power plant. In PWRs, the heat exchanger of the volume control system is a high radiation source due to the corrosion/activation products in the channel heads and in the pipes. During outages, often much inspection and testing must be carried out in the heat-exchanger compartment. Many of these inspections are related to operational systems, and test intervals left to the utility. While these inspections can result in relatively high worker exposures in a short time, it is difficult to justify protective measures based on only a single task. To solve this problem, and to reduce doses and cost, the plant decided to concentrate all activities in the heat-exchanger compartment in the outage of 1992, during which a large test had to be performed on the heat exchanger. This concentration of work allowed the justification and co-ordination of protective measures, including system decontamination.

Early in the outage, and prior to any of the scheduled work in the heat-exchanger compartment, extensive decontamination of the heat exchanger was carried out, using the CORD process, to reduce the dose rate at the heat exchanger and in the adjacent areas of the compartment. Dose rate reduction factors of up to ten were attained, resulting in significant collective dose reductions for all jobs which were performed in the compartment, including on the heat exchanger itself. Collective dose reduction factors of up to 30 were achieved, and compared to total collective dose estimates for work in the compartment, the decontamination resulted in a dose savings of 150 person-mSv.

The cost for the decontamination was approximately 412 000 DM, resulting in a cost per person-mSv of approximately 2000$/mSv. Note that this value was calculated after the fact, and should not be considered as an agreed-upon value in Germany.

6. WORK PREPARATION

Using protective equipment and radiation shielding improperly can cause a higher collective dose than not using them at all. If personal protective equipment causes the work go more slowly, the extra external dose may be more relevant than the avoided contamination hazard. Lead shielding installation/removal workers may receive a larger collective dose than the dose later saved by the installed temporary shielding. One thing more to remember: increasing the number of workers means increasing the collective dose.



Suppose that N men can do a job in X hours. Adding another N men will most likely result in 2N men needing more than X/2 hours for the same job. So, the cost and the collective dose increase with increasing number of workers.

6.1 Introduction

Work preparation, in the context of this report, is meant to cover all efforts to be considered or performed before and during a maintenance or backfitting job in order to prepare the worker, the site, or the piece of equipment for the job. Thus, a large amount of preparatory work must be done prior to the outage. All these efforts to prepare and to support the task and its working environment are essential if working conditions are to be optimised in order to assure quality results, and to keep the duration, the exposure, as well as the cost as low as reasonably achievable.

Therefore, proper multi-disciplinary preparation for the outage is very important.

There are many important aspects to work preparation. Worker training, using such aids as work station mock-ups, photographs, surrogate tours, etc. can be very useful. Often, however, this type of training is only effective for large and/or complicated tasks. It should be noted that as little as 25% of a worker's time is actually spent at the work site, such that even the best training will only save a limited amount of scheduled time (although this may be important for critical path jobs). Also, in order to facilitate and appropriately manage simultaneous tasks, the use of radiation work permits and/or work permits can be very effective. If properly constructed, these permits will guide workers efficiently through all required authorisations such that all the parties involved in a job will know what they have to do, and plant personnel will know what is going on in the plant, preventing delays and job conflicts.

ALARA reviews and dose estimates, the level of which should be based on job dose (collective, individual) cut-off points, are important and should be discussed with workers prior to the start of work. This assures that all workers are aware of their goals, as discussed earlier, and that the radiation protection staff is prepared to offer work support as appropriate. Actual doses, as compared with dose estimates, can then serve as one of the indicators of the effective implementation of Work Management.

Note that in some of these areas there is overlap with planning activities, which are discussed in Chapter 5. This chapter will discuss these topics from the perspective of work preparation.

6.2 Work Site Optimisation

One global subject in work preparation is, as already mentioned in Chapter 5, the optimisation of the working area to improve working conditions. Work must be scheduled and prepared based on a knowledge of all operations planned in the same area to avoid rework. This is especially important for the optimised use of all supporting activities and equipment, such as:

- scaffolding
- insulation
- mobile air ventilation and filtration
- temporary shielding
- decontamination of area / components / systems/ tools and equipment.
- radwaste removal

The removal of large amounts of radwaste, especially with high dose rate/activity waste being produced during a maintenance operation, has to be appropriately prepared and scheduled in order to help to maintain low dose rates at work locations. Removal of insulation material of larger piping areas, for instance, should be planned and scheduled together with the insulation work. For extremely high dose rate parts (*i.e.* from reactor vessel interior) shielded intermediate storage must be prepared.

Another important subject linked to the working site is to optimise the work load in high radiation areas, for example, transfer steps of a certain job to a low radiation environment. One good example is to use prefabricated piping spools (*i.e.* using inductive bending). If professionally planned, a high percentage of welding can be done outside without stress from uncomfortable conditions and radiation exposure. The result, beside saving dose, will be improved quality and less rework.

One other major factor to be taken into account when optimising the work site is the improvement of working conditions. In France, for example, in order to quantify the impact of some working conditions on dose, a literature search was performed by the CEPN (Schieber, 1994), resulting in an estimate of the impact of the modification of some working conditions on exposed time. These results were complemented by a survey, carried out in five French nuclear power plants, which focused on three types of operations: primary circuit valve maintenance; decontamination of reactor cavity; and some specialised maintenance operations. Eighty persons (workers, foremen, health physicists, planners) were interviewed concerning their perception of the impact of working conditions on the exposed work time, and on the main causes of mishaps. The following table presents a summary of both literature search and survey results.

Table 6.1. Impact Of Working Conditions On The Exposed Time

Working conditions	Impact on exposed time
Inadequate lighting	+ 20 % in comparison with working with adequate lighting
Noisy conditions, or difficult communications due to masks, without Audio links	+20% in comparison with jobs in using audio links to communicate with other workers
Working space : Not very congested area	+ 20 % in comparison with work in an open area
Working space : Highly congested area	+ 40 % in comparison with work in an open area

The direct impact of some factors, such as the general organisation of tasks or the preparation of work, is more difficult to quantify. Nevertheless, the importance of these factors has been underscored by the analysis of routine maintenance and post-incident operations. Indeed, this analysis has shown that on an average 20 % to 30 % of the collective dose associated with these operations could be due to mishaps or poor working conditions.

In the case of mishaps, their main causes where identified as being:

- inadequate preparation of work (for example: scaffoldings not adapted, problems of schedules, etc.);
- ill-adapted or malfunctioning tools, and
- a lack of worker training.

Such a quantification is essential to the performance of optimisation studies for radiation protection actions. These studies can, of course, be used for the evaluation of dose savings, but also for the calculation of cost savings, as the reduction of exposed time sometimes implies a reduction of the operating costs associated with the jobs (reduction of the outage duration, of the number of workers necessary, of the amount of waste when protective clothings can be avoided, or even diminution of training costs if the workers do not reach their individual dose limit and can therefore perform more jobs during the year).

6.3 Personnel Selection and Training

One major preparation or planning task is the selection of adequate personnel. It is of major importance to have motivated, highly skilled workers who are experienced at performing the anticipated or similar jobs.

A good, trained and experienced nuclear worker will do the same job with higher quality, and within a shorter time than a specialist, not used to working under controlled area conditions. To develop an experienced team of qualified workers requires a significant amount of **training**. This training is two fold. On one hand, it involves general items dealing with the special nuclear working conditions (see Chapter 4). On the other hand, often a job specific training must also be done, using the actual (or similar) tools and equipment, and realistic protective clothing.

Working time and quality may be highly influenced by the use of protective clothing and equipment. In France, in order to assess this impact, a specific study on mock-up has been performed by CEPN (Schieber, 1994a). Three different mock-ups were used try to quantify the effect of ergonomic parameters such as the level of effort, the need for precision, or the task duration.

1. The first mock-up was a steam generator channel head where a maintenance spider (20 kg) had to be installed and removed. This was representative of heavy and precise work performed during a short period of time in a very congested area.
2. The second mock-up was a "small" valve (2 inch), modelling a long precise task in a congested area. The workers had to remove, place and adjust 2 limit switches.
3. The third mock-up was a "large" valve (12 inch) where the workers had to unscrew, remove and then replace 12 nuts (of 0,9 kg each). This represented long, heavy, imprecise work in less congested area.

Eight clothing situations were selected, representing protective suits of both French nuclear power plants and from other parts of the French nuclear industry:

- Suit 1: 1 cotton coverall and 1 set of cotton gloves = "Reference"
- Suit 2: 2 cotton coveralls, 2 sets of rubber gloves, 1 respirator, 1 cotton hood
- Suit 3: 2 cotton coveralls, 1 rubber overall suit, 3 sets of rubber gloves, 1 air supplied respirator, 1 cotton hood
- Suit 4: 2 cotton coveralls, 1 rubber coverall, 3 sets of rubber gloves, 1 respirator, 1 cotton hood
- Suit 5: 1 cotton coverall, 1 rubber coverall, 1 set of cotton gloves, 1 set of rubber gloves, 1 air supplied hood
- Suit 6: 1 cotton coverall, 1 air supplied overall suit, 1 set of cotton gloves
- Suit 7: 2 cotton coveralls, 1 air supplied overall suit, 3 sets of rubber gloves, 1 air supplied respirator
- Suit 8: 1 cotton coverall, 1 air supplied overall suit, 1 set of cotton gloves (this suit was used only for the steam generator mock-up)

In total, nine workers were timed on each mock-up, with every suit. Based on this study, an average percentage of time difference has been calculated for each mock-up and each suit, the first suit being used as the reference. The main results of this study are presented in Table 6.1.

The negative influence of various levels of protective clothing, described above in the French case study, can be partly eliminated by realistic training. An excellent instrument for training under realistic working conditions is the mock-up. The worker can become familiar with previously unknown working procedures, special tools or supporting devices, or difficult working conditions. Experience with the more complicated steps of a job can be gained by doing them several times without hazardous influences of radiation or heat, allowing an instant feedback of experiences. The worker can also improve working efficiency which might be hampered due to the use of protective clothing (different gloves, bubble suits, respirator protection etc.). By training several workers for the same job, those with the highest performance can be given the most delicate jobs. Such trained workers will do the anticipated job more efficiently, in a shorter time and thus saving dose.

In Europe, many PWR plants have steam generator channel head mock-ups at the site to train utility as well as contractor personnel. Even some specialised nuclear service companies also have their own mock-up to train their staff. In France the CETIC facility, a high-tech training centre, is operated in co-operation between EDF and FRAMATOME with different mock-ups of steam

Table 6.2. Impact Of Protective Suits On Exposed Time

(as a supplementary time percentage compared to reference cotton clothing)

	Work Type 1 • continuous concentration • precise work • heavy effort • duration < 2 mn • very restricted workspace • uncomfortable posture (ex. Installation of maintenance 'spider' in steam generator channel head)	Work Type 2 • continuous concentration • precise work • heavy/light effort • duration < 10 mn • restricted workspace • uncomfortable posture (ex. remove, place and adjust of 2 limit switches on a '2 inch' valve)	Work Type 3 • non-continuous concentration • imprecise work • heavy effort • duration < 10 mn • not much workspace • comfortable posture (ex. unscrew, remove and screw of 12 nuts on a '12 inch' valve)
Non ventilated cotton clothing			
2. Cotton coverall + mask	34 % (±17)	34 % (±14)	19 % (± 14)
Non ventilated impervious clothing (PVC or Tyvek)			
3. Non ventilated Chadoc + ventilated mask	34 % (± 19)	65 % (±20)	21 % (± 13)
4. Impervious clothing + mask	29 % (± 8)	46 % (± 18)	25 % (±13)
5. Impervious clothing + ventilated hood	28 % (±12)	27 % (±16)	22 % (±10)
Air fed pressurised clothing (PVC)			
6. Air fed pressurised Mururoa®	30 % (± 11)	37 % (± 25)	8 % (± 4)
7. Air fed pressurised Chadoc + ventilated mask	51 % (±12)	57 % (± 25)	16 % (±14)
8. Shrunken air fed pressurised Mururoa®	21 % (±12)	-	-

generator channel heads, a refuelling pool, and some major pumps and valves. A similar facility is operated by Kansai Electric in Japan. Such mock-ups are also used to test newly developed tools or devices before use at actual work sites thus saving time and optimising use and functionality before use during an actual outage.

Another way to get workers as well as technical planners familiar with the working area and conditions is using visual means, such as physical scale models, pictures, video tapes or special computerised digital picture databases (*i.e.* surrogate tour). The pictures may be complemented with information about the radiological status of the area or component. Such systems are described in more detail in Chapter 5, Section 3, The Job Planning Process.

6.4 Temporary Shielding

Temporary shielding especially during refuelling and inspection outages is one of the primary methods used to reduce job specific and general area radiation levels. Areas which receive the highest concentration of temporary shielding are the drywell for BWRs, and steam generators and loop piping for PWRs respectively. Many plants install in excess of 25 tons of portable shielding on such piping as for the reactor coolant, cleanup, recirculation (BWR), and the primary loop (PWR) during outages. Using temporary shielding effectively requires a **flexible system** of different shielding elements in order to obtain the adequate shielding device to get the best results under the local conditions. Often, it is important to save space because of narrow working areas and the need to give sufficient work space to the worker.

Typical examples of mobile shielding elements are:

- lead wool or lead sheet blankets (Pb wrapped in polyethylene for ease of decontamination)
- lead sheets (5 – 10 mm thick)
- concrete bricks (with stainless steel liner)
- water shields (plastic polymer/resin type containers)
- specialised lead / steel shielding elements, tailored for repetitive tasks

and as supporting device:

- special quick connecting scaffolding equipment with shield support hangers
- hooks and belts for direct installation on piping or supports.

All these forms of shielding are effective. Application depends on desired dose rate reductions, plant configuration and allowable pipe loads for direct shielding. Water shields offer some possible dose savings, in terms of installation/removal over lead blankets/sheets since the carboy containers are lightweight and allow remote filling and draining.

Although lead blanket shielding, often supported by scaffold structures, still accounts for the majority of temporary shielding, other alternatives are available. Options for direct shielding include solid lead or steel rings which surround piping or casings of large valves.

A good practice currently used in several plants with high dose rates is to create shielded waiting areas near highly frequented working areas. These "Radiation Shadow Areas" are designated for workers to wait during interruptions of the work process, technical discussions etc. Typical installation areas are in the containment (PWR and BWR) or in/near the drywell (BWR).

In the United States, an innovative shielding technique was discussed during the 1993 meeting of the BWR Owner's Group. Shield containers (sealed steel casings) fitted to the outside of piping/component and then filled by pumping a slurry of lead shot mixed with a fluid material (*i.e.* silicon) into the casing through hosed connections are in a testing phase. The casings are gravity drained and removed when shielding is no longer required. This option, called fluid lead shielding, is in use under a pilot program by a volunteer utility and a vendor firm. Current questions and concerns related to fluid lead include maintaining a low viscosity for pumping, solidification at high temperature, added maintenance interference form steel casings and mixed waste concerns.

Several important aspects of a temporary shielding program implemented during refuelling and inspection outages are work scope review, pre-identification, cost-benefit evaluations, engineering analysis and planning of shielding requirements. One of the problems plants have encountered with installing shielding is early identification to allow for proper analysis. Some American plants have improved their shielding programs and reduced the time required from shielding identification to engineering approval. This has been accomplished through the development of a "cook book" approach for most shielding applications. Basically, engineering analysis has been performed for a matrix of generic shielding configurations which often eliminates lengthy engineering reviews, and allows radiation protection personnel to implement shielding controls in a timely fashion.

On one hand, the availability of a wide range of shielding elements, and on the other hand, a well trained team with sufficient skill to find the optimal solution is needed for installation of the shielding elements in a short time.

In some European countries specialised contractors with staffs of skilled craftsmen and technicians perform portable shielding operations, using precise documentation of installation and the dose rate values together with a photo documentation. These teams have developed optimised tools for temporary shielding installation with experience from performing the job during numerous outages, educated with radiation protection background as well as with practical knowledge, such professional shielding teams have saved some 5 to 10 % of the yearly outage doses at several plants.

An optimal shielding program should be supported by appropriate work scheduling. Filling pipes with water, or draining them at a time when no work is being performed, is cost free and can make unnecessary tons of portable shielding and much collective dose for its installation. This is one of the aspects which should also be kept in mind during the planning and scheduling phase (see Chapter 5). It should be noted, however, that water will not significantly reduce dose rates in piping of less than about 10 cm (4 inches).

Since the mid-eighties a German contractor has offered specialised service for the installation of temporary shielding during outages. A team of 3 to 5 specially skilled craftsmen with health physics training carry out all temporary shielding installation. This team has much experience in this area because it performs only this kind of job during outages at different plants all during the year. As a result of their experience, these experts have developed special tools and equipment to support and install a wide range of shielding elements. In addition, they are trained in and experienced at choosing and installing appropriate forms of shielding, designed to get optimal results, also taking into account the mechanical aspects of the job, such as the possible load on platforms, piping etc.

Since 1990 this contractor has been involved once in the installation of temporary shielding at Philippsburg unit 1 (BWR) during an unusual outages. Most of the workload occurs in the first week, and mainly in the drywell and surrounding areas. Work is performed partly on an ad hoc bases to shield sources (including hot spots) that have been identified by the radiation protection surveys after shut down.

The average collective dose saving from temporary shielding, during a usual outage, has increased from 100 person-mSv before to between 150 and 200 person-mSv since the implementation of this specialised shielding crew, with a collective doses averaging only 10 person-mSv for this team (30 person-mSv before).

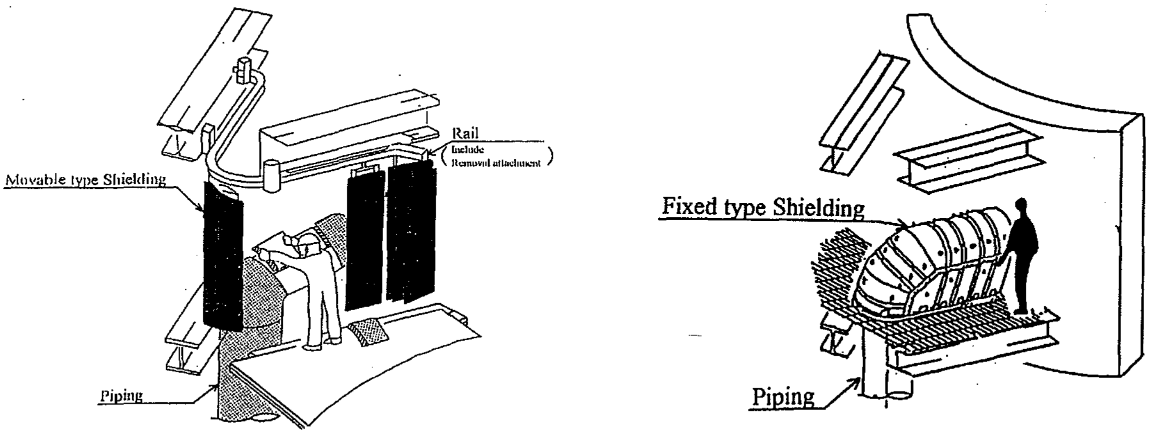
The price for the specialised shielding service during one outage is approximately 220,000 DM, the price for a non-specialised service can be estimated at about 150,000 DM.

At American Electric Power Company's D.C. Cook nuclear power plant, several approaches to the problems of temporary shielding installation have been used. For example, worker transit dose can be a significant problem. For the installation of temporary shielding in the lower containment, the shortest route for workers carrying shielding is through the lower containment airlock, however this path requires workers to pass through several elevated radiation fields. To eliminate this dose, shielding material is now transported from the upper containment hatch by use of cranes and floor hatches. Also, shielding of high transit pathways is performed early in the outage to save as much exposure as possible. The use of quickly installed and removed water shields has also been effectively employed, as has the use of permanent shielding hangers in areas where temporary shields are systematically used in each outage.

In some Japanese BWRs "movable permanent" shielding has been installed to shorten the installation and removal time, and corresponding worker exposures, during maintenance work. Work-time reduction factors of from 10 to 20, and dose rate reductions of up to 20 % have been observed as compared with the use of conventional shielding systems (lead sheets and blankets).

Movable type (permanent) shielding has been designed for easy access to piping and equipment to be inspected. Movable lead blankets are hung from rails installed on permanently installed beams of earthquake-proof design. Blankets are hung side by side and restrained from swinging by the use of bottom fixtures, and can thus be left in place during plant operation. By detaching the blankets from the bottom fixtures, they can be slid along their rails sufficiently far to allow easy access to the work space, but still providing some shielding value. There is no need for a lay-down space for removed shielding (non is removed), and the blankets are compactly arranged to allow sufficient working space. Figure 6.1 shows a work space shielded by conventional shields and by permanent movable shields.

Figure 6.1



6.5 Control of Contamination

The control of contamination is one of the fundamental ways to reduce the radiological risk to workers. Maintaining plant areas as radiologically clean reduces protective clothing and respiratory protection requirements, and this can increase productivity. When productivity is improved, time and dose are conserved. It is widely accepted that protective clothing diminishes dexterity, comfort and mobility and may add a heat stress factor for the worker. Respiratory protection devices (*i.e.* full face, bubble hoods, bubble suits) both impair vision and interfere with verbal communication. Further elaboration of these effects are presented in Section 6.3.

Surface decontamination of loosely adhering contamination can be accomplished with techniques used in non-nuclear professional cleaning. Most decontamination on components is performed by hand, while large floor surfaces can be quickly cleaned by professional cleaning machines . Fixing agents are used in American plants to prevent surface contamination on plant components from being liberated and creating airborne radioactivity problems, in turn reducing the need for respiratory protection. These agents include strippable coatings which have been applied to reactor cavity walls and, more recently, common carpenter's wood glue (known generically as Elmer's glue in the United States) has been used at some plants to fix surface contamination while working on valve internals.

6.5.1 Decontamination Workshop

In some European countries a special decontamination workshops are integrated in the plant design, both for PWRs and BWRs. These facilities, usefully placed close to the hot workshop, are designated for all components or internals that are movable (perhaps after dismounting) as well as for tools. A wide range of equipment, that can not be operated at the working area, is available for decontamination. These facilities have proven to be very effective at reducing both dose rates and contamination to a level which is easy to handle in the hot workshop or at the working area, thus reducing exposure during maintenance work.

Typical equipment includes:

- decontamination chamber for bigger components
- decontamination box for smaller parts
- Several bathes of different size, equipped for ultrasonic cleaning, and also used for (electro-) chemical decontamination
- high pressure water jet system (130—250 bar) for use in decontamination chamber/box
- blasting system for glass, corund, steel beads etc. for use in decontamination chamber/box

6.5.2 Decontamination Technology

Several non-destructive mechanical decontamination techniques are available for removing loose or tightly adhering surface contamination. Some techniques which are commonly used, or are being tested, are discussed here.

Water hydrolasing technology is very effective at reducing loosely adhering contamination on surfaces of components, in tanks or refuelling pools. Pressures up to 250 bar (for manually operated) and up to 1000 bar (for remotely handled) spray nozzles make this a very effective and low cost process.

Abrasive blasting as glass or plastic bead blasting are more destructive types of processes. These can be used to achieve a high decontamination factors, especially to effectively reduce high dose rate at surfaces with oxide layers from primary water. It is not suitable for sensitive surfaces. A recent development allows some reuse of the abrasive medium, for as long as it is technically effective. An automatic separation process removes the contaminated waste fraction from the medium fraction.

CO_2 cleaning is a unique pneumatic dry process that uses dry ice as the decontamination medium (Aldridge et al., 1994). It is similar to conventional abrasive blasting, however, does not use hazardous or abrasive media, and can be used on sensitive equipment such as electronics. The decontamination effect, unfortunately, is lower for hard oxide layers. Although some form of ventilation is required for contamination control, the CO_2 cleaning process does not generate costly secondary wastes such as water or abrasive aggregate. The technology is mainly effective on softer materials like wood, rubber and plastics, or to remove paint or coatings.

Ice blasting is a wet process which uses small pellets of ice as the cleaning media. Disadvantages include slower decontamination rates as compared to conventional methods, and high noise levels [typically 110 dB].

Ice blasting was developed to provide an environmentally safe method of decontamination, and uses a refrigeration unit and ice grinder to produce ice chips which are delivered to contaminated surfaces with compressed air. Systems can be used by robotics, and produce approximately 60-90 litres of water per hour. Inherent safety features of ice blasting were discussed during the 1993 meeting of the BWR Owner's Group, and include lower heat stress concerns, lower airborne levels from a wet environment and lower nozzle thrusts lessening operator fatigue. Decontamination effectiveness for fixed surfaces is reported to be comparable to other methods. This technology is fairly new, however, and industry experience appears to be limited.

6.5.3 System Flushes

Radiation source and hot spot flushing of systems and piping can reduce dose rates by forcing radioactive material inside piping downstream to areas where workers are not affected. Flushes may be performed through different routes, generally ending up in the waste-water handling system or reactor-water cleanup system. Some keys to having an effective flushing programme are early identification, procedure development, operations "buy-in" and ensuring a scheduled window. Consideration should be given to the timing of flushes in relation to the work schedule to optimise dose reduction. Often, the appropriate window is early in an outage if a unit is shutdown. Flushing early in an outage is particularly important for those flushes which can only be performed while the reactor vessel head is still installed. Beside this, system flushing with full system pressure and temperature, and with a maximum flow rate, is most effective.

As an example, at Laguna Verde Unit 1 during the 4th refuelling outage approximately 20 person-mSv were saved by flushing the 23 reactor vessel inlet penetrations prior to in-service inspections of welds. Flushing was accomplished after all fuel had been removed from the core, and at the same time, submersible pumps and filters were used to remove crud from the reactor pressure vessel.

It should also be noted here that the installation of flushing connections, through which partial system flushes and/or decontaminations can be performed, can save doses if the connections are appropriately placed, with work management principles in mind.

Hydrolasing-like piping flushes remove radioactive materials contributing to local area dose rates and either capture them by filtration or distribute them throughout the reactor vessel, out-of-core piping or tank internals. The principle applied here is the opposite of the environmental adage: that the solution to pollution is not dilution, but is redistribution. Hydrolasing utilises high pressure water [ranges from 70 bar (1000 psi)up to 1500 bar (20000 psi)] to force radioactive crud, silt or resin material from reactor pools, nozzle thermal sleeves, tank eductors and other dead leg or crud trap areas. In some German BWRs, the suppression pool is flushed every year after draining at the beginning of the outage. The dose rate in the surrounding containment area, which has a high yearly workload, is reduced by a factor of 2 – 5, thus saving some 100 mSv every outage. Another example is the flushing of primary heat exchangers before maintenance or inspection work, reducing dose rate and dose for the total job dramatically.

Underwater vacuum cleaners are used when hydrolasing piping penetrations inside reactor vessels. Vacuums collect and filter radioactive particles forced out of tight areas by a hydrolaser lance, and limit the impact on vessel water clarity (from resuspension of particulate material hydrolased from an area) and outage critical path time. Drawbacks to flushing and hydrolasing are that most of the radioactive material is only temporarily removed if no filtration system is available, and when redistributed can contribute to higher dose rates for workers in other areas. High-pressure hydrolasing (800 – 1000 bar) by special lances has also proved to be a good means for preparing the exchange of piping. On one hand this reduces dose rate for the exchange work, on the other hand the reduction of loose system contamination allows a reduced level of personnel protective equipment used.

Another interesting contamination control technique is used in Japan. In order to remove the reactor vessel head of a BWR for refuelling, the reactor pressure vessel (RPV) must be full of water. In the process of raising the water level, the main-steam piping, relief valves and isolation valves may become contaminated if radioactive CRUD from the reactor water falls into main-steam piping. If this occurs, radiation levels will increase. To prevent this at Japanese BWRs, clean make-up water is injected into main-steam piping prior to filling the RPV with water for refuelling. The injected make-up water fills the main-steam lines up to the level of their entry into the RPV, thus preventing contaminated reactor water from entering the main-steam lines and possibly causing contamination. This will reduce dose rates in the vicinity of main-steam line valves (relief and isolation) and will allow work on these valves to be less encumbered by the use of personal protective clothing.

6.5.4 Chemical Decontamination

Another effective way to remove radioactive materials and reduce dose rates at nuclear power plants is through chemical decontamination of system internals, or source reduction methods which remove the metallic precursors which become activated and contribute to plant radiation fields.

Chemical decontamination processes have been commercially available for nuclear plant application since the early 1980's. The most common and effective types of chemical decontamination processes today use oxidation and reduction reactions to remove radioactive material build-up from various component internals (*i.e.* piping, pumps, valves and tanks). Although more widely used in reactor recirculation (BWR), reactor water cleanup piping, running gears of main coolant pumps (PWR), there are also applications for these processes in PWR steam generator heads. It is estimated that between 1986 and 1992, chemical decontamination has been responsible for reducing dose to workers at US nuclear plants by approximately 1 300 mSv (Wood, 1994). Recent large-scale system decontaminations at Oskarshamn and Loviisa have had very promising results, significantly reducing primary system piping dose rates. The total estimated dose reduction resulting from these processes are significant.

For example, in 1994, as a result of modifications which were being made at Oskarshamn, a 442 MWe BWR, following a Barsebäck incident in which insulation material clogged filters, it was found that extensive repair work was necessary on the feedwater risers in the reactor pressure vessel. In order to allow this work to be performed in a low dose-rate environment, an extensive decontamination was performed of the pressure vessel using the CORD process. This took place in four cycles of the process, and required 134 hours not including preparation time. Approximately 2.3 TBq of activity were removed, and decontamination factors of from 500 to 1000 were achieved. As a result, workers in the pressure vessel were able to spend 6000 person-hours working or repairs in the pressure vessel, for a total collective dose of only 800 person mSv (Svantesson, 1995).

At Loviisa 2, a full system decontamination was performed in 1994, and again here the CORD process was used. Loviisa is a six-loop PWR, VVER-440 design, and all six legs were decontaminated. Here, the process took four cycles, but required 10 days not including preparation time. Dose-rate decontamination factors at the surface of piping varied, but was on average between 10 and 20. 36.3 TBq of activity was removed, generating 32.5 m^3 of ion-exchange resin waste. It was estimated that over 8 person Sv of collective dose was saved due to this decontamination.

It should be noted that recontamination appears to be less than expected. During a forced outage, four months after post-decontamination start-up of the plant, dose rates on primary circuit piping had grown from 10% of their pre-decontamination levels to 15% of their pre-decontamination levels (Wahlström, 1995).

Finally, a decontamination of the recirculation system at Hamaoka unit 1, a 515 MWe BWR, was performed in 1993 in order to reduce dose rates for the replacement of an inlet nozzle. The volume of the system which was decontaminated was 23 m^3. The CORD process was again used, requiring 5 days not including preparation time. An average dose-rate decontamination factor of 36 was obtained, and an estimated 3.6 person Sv was saved as a result (Kaneko, 1995).

Implementation of the technology has been uneven among nuclear utilities (Wood, 1988). Many utilities today routinely perform chemical decontamination during refuelling outages, while some find it necessary to perform large scale maintenance evolutions before attempting a decontamination. Cost benefit evaluations are generally the basis for decisions whether or not to perform the process. Factors influencing these ALARA cost-benefit analyses are plant-specific dose rates, projected dose savings, value of a person-Sv and the technical acceptance by the organisation.

Three case studies, supplied to the NEA's ISOE Programme by KKP Phillipsburg, are attached as Appendix 1: high pressure decontamination of RHR heat exchanger, Appendix 2: high pressure decontamination of suppression pool walls, and Appendix 3: full-system decontamination using the CORD system. These demonstrate how decontamination operations can be very successful at reducing doses. In addition, a Topical Session on chemical decontamination was sponsored by the NEA ISOE Steering Group in 1994, and the proceedings from this meeting also notes several cases of successful uses of chemical decontamination (NEA 1995).

6.6 Specialised Tooling

Proper tools are essential to workers in the field for maintaining dose ALARA. The planning process and final work plan should direct the work crew to obtain appropriate tools. Tool availability, control and house keeping procedures should prevent problems due to inadequate tool supply and leaving tools in radiation areas which requires cleanup by support crews and results in additional dose. The important aspect of tooling with respect to engineering controls involves identification, procurement or development and training in the use of specialised tools (atypical wrenches, chainfalls, hammers etc.). Good examples of specialised tools which help reduce dose are automated/remote cutting, grinding and welding machines, remote in-service inspection (ISI) devices or snubber alignment/lifting tools. Tool selection can also reduce time and dose.

Many types of such specialised tooling are in common use. Air arc cutting is generally faster than oxy-acetylene torch cutting. Snubber transport carts used in containment areas can prevent worker lifting injuries as well as facilitate movement of equipment. Plants using these carts have recommended large rubberised wheels which swivel to enable easy manoeuvring over metal grating and into tight areas. Small tools like mirrors on reach rods can make inspections in hard to access areas less difficult. Other tools used for easier access are electric lift trucks, ladders which reduce the dose from building scaffolding and video cameras on long reach rods (video on a stick) for visual inspections in overhead areas.

On some occasions, for repair, inspection and exchange work, highly specialised and sophisticated tools have been developed. To test such tools, mock-ups have been used to assure proper functioning as well as personnel familiarisation. Both of these aspects help to avoid mishaps on the critical path and to save dose. A good example here again is the CETIC facility used by EDF and FRAMATOME to test newly developed equipment.

As another example, at Pennsylvania Power and Light Company's Susquehanna plant, worker feedback has lead to several advances in tasks involved with snubber inspection and maintenance. Snubbers are routinely removed from high radiation areas for maintenance, however this used to require significant time and effort for the placement of the snubber into a plastic bag for contamination control. Now, a transport cart has been designed and the snubber bagging step has been eliminated, saving time and dose. In addition, to ease the removal and reinstallation of snubbers, an alignment tool has been developed, and snubber pins have been tapered to make them self seating.

In a Japanese BWRs, the cleaning of condensate demineralisers involves several hundred elements, each of which required cleaning with a hand brush by contract workers with full-face masks and plastic suits. This task used to take four workers up to seven days for two demineraliser resin tanks. As a result of this time and exposure, a special cleaner, with brushes and high pressure water jet nozzles enclosed in a small ventilated box, has been developed and applied at Tokyo Electric Power Company's Fukushima Daiich site. The time required for cleaning elements is shortened by a factor of five, and respirators and plastic (upper) suits are no longer required (see table below). The physical burden of workers and dirty image of the cleaning work have been dramatically improved.

	Hand Brush	**Cleaner Box**
Time to clean 432 condenser elements:	127 hrs	26 hrs
Number of plastic suits and respirators required:	56	0

6.6.1 Hot Workshop

To maintain plant component internals, spare parts, and tools which become contaminated in the controlled area, a hot workshop is necessary. Some plants, for example in the Scandinavian countries, have made great efforts to improve the hot workshop's efficiency by constructing new buildings in order to enlarge the space, and by installing state of the art machinery. Specialised equipment will enable maintenance even of complicated components. Having a well equipped hot workshop of the same quality as the cold workshop may improve maintenance quality and save time and cost. Workshop capacity within the controlled area avoids the need for decontamination and the release of parts for maintenance work to the cold workshop.

Having the hot workshop and decontamination workshop located close to one another will also facilitate part maintenance work, and will reduce worker doses.

6.6.2 Robotics

Mobile robots have been developed for use in the nuclear industry to remove the human element from certain jobs and reduce the risk to workers. Since the cleanup activities at TMI, the applications for robotics in the nuclear power industry has grown and is no longer considered a novelty (Jones and White, 1994). Mobile robots and remote handled devices have found cost-effective uses in the areas of radioactive waste handling, underwater inspections, equipment decontamination, surveillance in high radiation areas and radiation surveys. Often, remote handling is the only solution for repair work in such high radiation fields as the reactor interior. For intervention after severe accidents, robots are available which can negotiate stairs, perform underwater diving activities, and carry lighting, camera and radiation detection equipment. Small tasks can even be performed such as material/equipment retrieval. On the other hand, for routine high work load tasks there is still a large field to adopt industrial intelligent robots to nuclear conditions in areas of higher risk from radiation hazards such as the decontamination of components or piping after replacement.

6.7 Supporting Equipment

6.7.1 Ventilation and Filter Systems

Ventilation, filter systems and temporary containments are effective at controlling airborne contamination. Properly designed and applied ventilation, which typically employs HEPA filtration, can preclude the need for respiratory protection for workers, especially for those working in the neighbourhood of the source area. Placement of HEPA ventilation hoses and hoods, capacity and hood design or capture velocity must be considered when selecting a unit. Specialised filter types (charcoal filters) must be used when iodine activity has to be considered. To operate those filters safely, hazardous conditions that destroy the capability of the filters have to be avoided (high humidity, organic solvents). The type of work to be performed also impacts the type of unit used. Grinding, for example, will require hoods with higher face velocities to capture materials.

6.7.2 Remote Communication and Monitoring

Communication systems make use of the distance principle in maintaining doses ALARA. Remote communication systems include radio and video, and allow information to be conveyed without personnel entering radiation or high radiation areas. Radio headsets are in wide use at nuclear plants, particularly for radiation protection coverage and operations evolutions. Radiation Protection technicians working in the area can communicate radiation conditions to those outside the area. Plant control operators can quickly inform control room operators of valve line-ups or control rod drive uncoupling. Work crews can request equipment, or inform other groups that important milestones are complete. Video surveillance or inspection, using small, high resolution CCD cameras, allows observation of work crews, remote quality assurance inspection, or in-service inspection of in-vessel components. A special means for the transfer of information in documented form is the use of fax machines between in and outside the controlled and uncontrolled area. In the case of measurements, values, or critical procedures a fax is one way to avoid misunderstanding.

Remote monitoring systems, e.g. for dose (rate) or airborne activity, provide an excellent, reliable means of real time monitoring of the radiological conditions to which a worker is exposed. Remote monitoring reduces dose primarily to radiation protection technicians, and affords adequate monitoring. A radiation protection control room may gather all information on the radiological conditions at various working areas with a minimum of presence in radiation areas, being alarmed when pre-set levels are affected. The same principle works in other areas to survey critical parameters, or for camera observation from a place outside the radiation field (*i.e.* survey of automatic welding, cutting, in service inspection).

6.8 Work Process Steering and Control

6.8.1 Electronic Dosimetry/Access Control Systems

Electronic dosimetry systems are rapidly replacing the self-reading dosimeter or pocket ion chamber at nuclear power plants. Electronic dosimeters or pocket alarming dosimeters allow dose monitoring and tracking for jobs on a real time basis when used with real-time dosimetry hardware and software systems. These systems can, combined with an electronic access control system, confirm radiation protection education, training and respirator qualifications as well as up-to-the-minute cumulative dose for each worker. Therefore, a form of access control into the radiological controlled area or local work locations is provided. Access control, in combination with a (radiation) work permit system, is also suitable to keep unnecessary personnel out of controlled areas, giving access only to people in combination with an authorised work permit. The same may be done for local restriction to separated areas (*i.e.* refuelling floor). These restricted areas with access control combined with electronic dosimeter reading are also useful for job/area related dose recording and follow up.

Electronic dosimeters provide dose rate, total dose and stay time alarm levels as well as a high level of data integrity and retrievability in the work place (data can be retrieved even after a dosimeter has been damaged, particularly for newer models). Errors associated with workers reading analogue scales on self-reading dosimeters or pocket ion chambers, and from data entry of RWP dose data is eliminated since a computer automatically updates a worker's dose when exiting the area and "signing out" on the real-time dosimetry reader stations. Reduced error allows a better correlation between electronic dosimeters and official dosimetry of record (typically TLDs or film badges). Some plants, however, are currently pursuing changes to their radiation monitoring program to allow the use of electronic dosimeters as the dose of record.

> At the American Electric Company's D. C. Cook nuclear power plant, the use of electronic dosimeters has saved time, money and doses in several ways. First, the electronic alarm points on the dosimeters are set by radiation protection personnel, taking into account the individual worker's dose status, and the work to be performed. Upon alarm, the worker will leave the work area, and upon checking out of the controlled area another alarm will indicate that the worker should contact radiation protection. The alarm and the dose are automatically recorded electronically for radiation protection records purposes. Second, the electronic dosimeters used at D. C. Cook can also be used in the dose-rate mode, and as such can be used in place of a standard portable dose-rate instrument, which is larger and heavier. These has been found to be more convenient for workers, because of their small size, and they are less often dropped or broken. Note that workers use a second electronic dosimeter for this purpose, their personal dose monitors are NOT used for this purpose.

6.8.2 Work Permit System

Work process controls are critical to success of well planned outages. Radiation workers must be well trained before work in the plant is undertaken. Training needs to involve work process indoctrination for the plant's controlling documents, including the maintenance work order, the radiation work permit, and industrial safety permit.

In some plants, modern computerised work permit systems have been introduced. These systems are in service as work process steering systems giving, an information and responsibility network, including the authorisation process by the different departments for an anticipated job, as well as the system isolation requirements. This system in some plants also includes the radiation work permit using the same data base of information (component, site, working conditions), including information of similar operations done in the past. It is also operated as a tool for working crews, providing guidance and giving knowledge of the state of the operation to all groups involved. This may be supported by information from a radiation protection data base covering dose rate and other values influencing the radiological risk. Such a system is of great advantage during planning and scheduling phase as well as when dealing with *unexpected jobs.* Experience of most plants is that even in the case of unexpected jobs with highest priority, an ad hoc planning often is useful and pays off in terms of dose and time. Even for such events, a planning/scheduling strategy must exist to assure adequate work results and quality, and to avoid rework. Therefore, having (computer aided) tools for quick planning/scheduling is of great importance.

6.8.3 Job Dose Follow Up and Review

To optimise efforts and radiation protection actions for jobs with high radiation exposure potential, a step by step estimation of working time and associated dose is accepted as good practice. The results of such calculations are a good instrument to follow the work proceeding, and to allow the early recognition of possible problems. For this purpose, an on line computer based dosimetry system is required, and should interface with the work permit system, giving the dose and status of ongoing work.

All large-scale, high-dose jobs should be reviewed when finished and all results are available. The different teams involved (mechanical, electrical, scaffolding, health physics, industrial safety etc.) should support the gathering of all available experience. This forms a valuable database for the planning of similar tasks.

Proper documentation of all job, component and working area related information, including radiological values, is necessary as input for a operational data base. The data base must be open to all faculties contributing to planning and scheduling. Updating work status must be the responsibility of all organisational groups associated with the job. This system will demand a computerised network system (*i.e.* related to the work permit system). Such systems are in operation or evaluation in some European plants.

6.8.4 Job Co-ordination

Up to 65% of the total outage dose is received from work activities in the drywell (BWR) or in the containment (PWR). Assignment of Drywell Work Co-ordinators and Managers in some US BWR, whose sole purpose is work process control and monitoring, has reduced work duration and dose in this critical plant location after implementation. Reactor building co-ordinators have been successful at expediting work and reducing doses at some French PWRs.

The use of "Make-It Happen" Managers has also been effective in assuring continuous monitoring and field-coaching of the critical path work scope. Finally, dose accountability at the work foreman level is important to ensure buy-in to dose budgets at the task level.

The result of aggressive work process controls is, in part, acceptance by plant personnel that radiation exposure is a "Quality Issue". The accumulation of unnecessary dose will be tracked and followed-up by supervisors to assure reoccurrence is avoided.

In Germany, SIEMENS has made a comparative investigation, ordered by VGB*, of work load and collective doses on the refuelling floor of different German BWRs. One result of this study was that the registered working hours for comparable jobs differed between different BWRs by up to a factor of two, with a linked difference in collective dose. It was thought that this difference may come from different working policies, and that a more restrictive access control to that area would reduce the working time and dose.

Following this investigation, at Philippsburg unit 1 (BWR) an access control system for the refuelling floor was installed in advance to the 1995 outage. During this outage, the number of people entering that area was about 580, compared with more than 800 in previous outages. The related collective dose for the 1995 outage was registered as about 70 person-mSv, compared with 80 person-mSv previously.

*Technische Vereinigung der Großkraftwerksbetreiber e.V. (Technical Association of Large Power Plant Operators)

6.9 Summary

As previously mentioned, work preparation as referred to here means the ensemble of work necessary for the performance of a particular job. For example, the reparation of a valve may involve co-ordinating the valve job with other work in the area, selecting and training the work crew, installation of temporary shielding, performing decontamination of the area and/or various pieces of the valve, the selection, preparation and use of specialised tools, and the use of ventilation or communications equipment. The system of work process control (such as work permits, control of dosimetry, job review, and building co-ordination) also contributes to the preparation of the job. These aspects of the work should be considered holistically, and in co-ordination with the other Work Management aspects discussed in this Manual.

6.10 Work Preparation Case Study

In the case of work preparation, several types of information will be necessary to justify the implementation of a new programme. For example, work site optimisation will require a specifically designated team. The number of required person-hours can be estimated, and the approximate gains could be taken from data on previous bad experiences. While the costs of selecting highly trained workers are fairly clear, the benefits are more difficult to quantify. However some plant experience might point to particular jobs which were well performed because of good worker selection and training. A general review of the temporary shielding programme would require a certain number of person-hours from a multi-disciplinary team, but the dose and time savings could perhaps be estimated. The same type of study for resource utilisation (ventilation and filter units, communications equipment, crane and elevator use, etc.) might also look at the same type of quantitative justification; person-hours of study versus the gain in time and dose due to better planning of resource use. Finally, for work process control, the argument for the justification of such a programme (or a change to an existing programme) would include the amount of time and money necessary to change computer systems, etc., and the cost in person-hours for the implementation of such a programme (job co-ordinator, "make-it-happen-manager", etc.). The benefits of such a programme could be illustrated using other utility's experience as an example, perhaps in a quantitative fashion, but most likely in a qualitative fashion, stressing the improved quality of the resulting work as well as the tendency to maintain or beat schedules.

As an example of a case study in the area of work preparation is given here from the Commonwealth Edison Company's Byron nuclear power plant. During unit refuelling outages In-service Inspection (ISI) is performed on over 300 examination points of piping and component welds, pumps, and valves. ISI is done in three groups of inspections using non-destructive examination (NDE) techniques; volumetric involving ultrasonics; liquid penetrant or magnetic particle; and visual examination. The ISI is often in high radiation hard to access locations of the plant, and scaffolding is often required to reach the point to be inspected. In some cases alternatives to scaffolds exist, such as a motorised lift platform, but in general, ladders are not acceptable for use reaching the ISI inspection point.. Steps involved in performing the inspection include assessing and preparing the inspection point, including the building of any needed scaffolding, removing of insulation and preparing the weld (such as cleaning and buffing), then performing the inspection and restoring the inspection point to original conditions.

From the same scaffolds used for ISI, work is done to remove various snubbers from plant piping systems. Snubbers are removed and tested at a test facility then returned and reinstalled. Proper co-ordination and scheduling is thus necessary in order to minimise total time spent and total radiation doses for this work.

For this purpose, a tracking system has been used to identify quadrants in the plant where ISI examination points and snubbers are located, as well as the type of examination to be performed. One part of the tracking system identifies where (by plant location) and when (installation date) scaffolds will be needed to support either ISI or snubber work. The system tracks all the work to be performed off the scaffold thus avoiding rework of having to remove and reinstall the scaffold in the same location at a later time. All scaffolding for the containment and auxiliary building are tracked using this system. During unit 1 refuelling outage 5 this tracking system was credited with eliminating unnecessary construction of scaffolding. Original work plans indicated that 101 different scaffolds would be built in the containment, however the tracking system showed that 41 of these requests were unnecessary when work was combined to use the same scaffold. Of the 60 scaffolds that were built, 26 were used to perform multiple work tasks. In the auxiliary building, original work plans called for 77 scaffolds to be built, but the tracking and scheduling system showed that 15 requests were unnecessary and could be accomplished by the use of manlifts. For these 15 points, labour savings over the use of scaffolding was estimated to be to be 600 man-hours.

In addition to the tracking of scaffolding, ISI examinations and snubber testing are tracked. Thus portion of the tracking system is called the "Bus Ticket" programme for the co-ordination of the location and dates of work. Details of each inspection location are pre-marked on isometric drawings and located on area grid maps. These maps were highly effective in helping workers to easily and quickly access their work location. A single person, dubbed the "tracking co-ordinator", is responsible for knowing the status of work. The initiation of each job is timed to minimise interference with other work, and to streamline the sequence of work in each quadrant (zone) of the plant. All work flows through the tracking co-ordinator, who has a status board of work which has been completed, work which is ready to begin and work which remains to be done. For each ISI examination or snubber job, when all work package and plans are completed, the tracking co-ordinator issues a "Bus Ticket" that allows work to begin. The bus ticket includes the radiation work permit and maps of the jobsite. As job evolutions continue, the shift to shift status of completion is communicated back to the tracking co-ordinator who keeps the work flow running smoothly.

In the most recent unit 1 refuelling outage, it was estimated that more than 1640 man-hours and 82 person mSv were saved through better planning, scheduling and multiple use scaffolds in the containment building. For the Auxiliary Building, 900 man-hours and 27 person mSv were saved. The use of the fifteen manlifts resulted in exposure savings of 90 person mSv.

Appendix 1

NEA Information System on Occupational Exposure

NEA 3 - Work Related Information Report
High Pressure Decontamination of a Residual Heat Removal System Heat Exchanger: Philippsburg 1

NEA 3 - WORK RELATION INFORMATION REPORT
(To be filled in on an ad-hoc basis)

Please, describe (i) any or all of the following situations (each one separately) involving an unusual radiation protection problem, or/and (ii) a work, routine and non-routine giving a significant contribution to the total plant collective dose, or/and(iii) planned future work of significance to radiation protection.

Please remember when filling in this report that the description should be clear enough to be useful to your colleagues in other utilities/countries. In particular you are asked to define the operations, the systems affected as well as the radiation protection actions by using the attached codes (annex 1, 2 and 3).

1. General

Country:	GERMANY	Region:	EUROPE	
Plant name - Unit number - Reactor type - Cycle number:			KKP BUR:	1 11
Contact person:	JUNG			
	Phone: + 49 7256 95-328770	Fax: 49 7256 95 2029	Telex:	
Address:	Peter Jung, Kernkraftwerk Philippsburg GmbH, Postfach 2240, D-76652 Philippsburg			

2. Description of the work

Date of work (start): 09.05.1992 Date of work (end): 26.05.1992

Description of the work (reasons for doing it, main characteristics, working methods, good practices...)

KKP 1/1/4.94 Inspection of Residual Heat Removal (RHR) sytem's heat exchanger. This included eddy current test, pressure test, visual inspection.
High pressure decontamination as preparation and special radiation protection action.

Codification:

Operation(s) performed (annex 1):	1.1.2	1.1.9	6.2
Systems(s) and component(s) affected (annex 2)	G.C.		

3. Dosimetric information (for planned operations, give estimates)

Collective Dose (man.mSv):	2.90
Maximum Individual Dose (mSv);	0.60
No of People Exposed:	11
No of man-hours to perform the work:	51,00

4. Comments on exposures and radiation protection actions (description, cost, efficiency, break down of work collective dose according to main tasks involved, reference(s) to reports)

The above figures are for the decontamination action only.

Break down of the total maintenance action:

- removal of insulation + opening heat exchanger — 1.1 mSv
- high pressure decontamination — 2.9 mSv
- Eddy current test + inspection, maintenance of linked valves + visual inspection of heat exchanger + pressure test + reassembly of heat exchanger — 11 mSv
- total cost: 15 000 DM for decontamination action
- total collective dose: 15 mSv
- time for action: 10 hours

Codification of radiation protection action(s) (annex 3): 1.1.5.5

References to reports:

KKP 1, outage report '92 (in German)

5. Additional comments

For the RHR system heat exchangers, routine inspections have to be done with a great amount of work in the area of the exchanger, which has an usual dose rate of about 0.7 mSv/h (filled up). For most of the inspection time the heat exchanger has to be drained. The dose rate therefore increases to about 1.5 mSv/h (surface) and 0.2 mSv/h in the main working area.

A high pressure decontamination has been introduced into the preparation of the inspection since the 1990 outage. The decontamination liquid was led by provisional means via the reactor-building-sump to the water reprocessing installations. The dose rate at the heat exchanger where the working area was established was reduced to 0.02-0.07 mSv/h.

The decontamination action took a collective dose of 2.9 mSv. The estimated collective dose reduction was 33 mSv, compared to a total dose for inspection and maintenance work of 15 mSv (including decontamination).

Since the '90 outage, when this kind of decontamination was first performed, it is introduced as routine step whenever a heat exchanger inspection is done due to the good results so far.

Appendix 2

NEA Information System on Occupational Exposure

NEA 3 - Work Related Information Report
High Pressure Decontamination of the Suppression Pool Walls: Philippsburg 1

NEA 3 - WORK RELATION INFORMATION REPORT
(To be filled in on an ad-hoc basis)

Please, describe (i) any or all of the following situations (each one separately) involving an unusual radiation protection problem, or/and (ii) a work, routine and non-routine giving a significant contribution to the total plant collective dose, or/and(iii) planned future work of significance to radiation protection.

Please remember when filling in this report that the description should be clear enough to be useful to your colleagues in other utilities/countries. In particular you are asked to define the operations, the systems affected as well as the radiation protection actions by using the attached codes (annex 1, 2 and 3).

1. General

Country:	GERMANY	Region:	EUROPE
Plant name - Unit number - Reactor type - Cycle number:		KKP BUR:	1 11
Contact person:	JUNG		
	Phone: + 49 7256 95-328770	Fax: 49 7256 95 2029	Telex:
Address:	Peter Jung, Kernkraftwerk Philippsburg GmbH, Postfach 2240, D-76652 Philippsburg		

2. Description of the work

Date of work (start):	10.05.1992	Date of work (end):	11.05.1992

Description of the work (reasons for doing it, main characteristics, working methods, good practices...)

KKP 1/3/4.94 Special high pressure decontamination of the suppression pool walls (suppression chamber) to reduce dose rate outside the containment

Codification:

Operation(s) performed (annex 1):	6.2	5.1
Systems(s) and component(s) affected (annex 2):	C	MA

3. Dosimetric information (for planned operations, give estimates)

Collective Dose (man.mSv):	1.50
Maximum Individual Dose (mSv);	0.20
No of People Exposed:	7
No of man-hours to perform the work:	52,00

4. Comments on exposures and radiation protection actions (description, cost, efficiency, break down of work collective dose according to main tasks involved, reference(s) to reports)

The above figures are for the decontamination action only.

Decontamination action:

1) empty the suppression pool

2) high pressure water jet decontamination in 3 sections (each 120^0 of total pool area) by special decontamination heads.

3) at the same time draining the decontamination water to the water reprocessing installation (about 45 m^3)

Total cost: 12 500 DM

Time for action: 5,5 hours, 13 hours with preparation, etc.

Codification of radiation	1.1.5.5	1.1.1

References to report:

KKP 1, outage report '92 (in German)

KKP 1, report no. 1/GLA/001/001505/92 (in German)

5. Additional comments

During outage, especially when the suppression pool is emptied for inspection work, the contamination layer on the suppression pool wall produces a dose rate in the area around the containment, where a lot of work has to be done.

To reduce dose rate in this outside area a high pressure (350 bar) decontamination with special tank-decontamination-jet heads (300 l/min) has been done, first in the '92 outage. The dose reduction factor was 4 (effective dose rate), from 0.4 mSv/h down to 0.08 mSv/h each in the outside area, while the suppression pool was filed, and 0.6 to 0.15 mSv/h respectively with the pool empty.

The dose saved by this decontamination will differ from outage to outage depending on the workload in the outside area, which is generally about 5 000 man-hours. The approximate saving during the '92 outage is an estimated 100 mSv collective dose.

Lessons learned:

Because of the good results and the benefit of this action it will be introduced in the planning of usual outage procedure in the future, at least if the pool has to be emptied.

Appendix 3

NEA Information System on Occupational Exposure

NEA 3 - Work Related Information Report
Decontamination and Dismantling of a Pressurised Water System: Philippsburg 1
(To be filled in on an ad-hoc basis)

Please, describe (i) any or all of the following situations (each one separately) involving an unusual radiation protection problem, or/and (ii) a work, routine and non-routine giving a significant contribution to the total plant collective dose, or/and(iii) planned future work of significance to radiation protection.

Please remember when filling in this report that the description should be clear enough to be useful to your colleagues in other utilities/countries. In particular you are asked to define the operations, the systems affected as well as the radiation protection actions by using the attached codes (annex 1, 2 and 3).

1. General

Country:	GERMANY	Region:	EUROPE		
Plant name - Unit number - Reactor type - Cycle number:				KKP BWR	1 12
Contact person:	JUNG				
	Phone: + 49 7256 95-328770	Fax: 49 7256 95 2029	Telex:		
Address:	Peter Jung, Kernkraftwerk Philippsburg GmbH, Postfach 2240, D-76652 Philippsburg				

2. Description of the work

Date of work (start):	20.06. 1993	Date of work (end):	18.10.199 3

Description of the work (reasons for doing it, main characteristics, working methods, good practices...)

KKP 1/5/4.94 Dismantling of the pressurized bearing water system (TD) lines for the internal recirculation pumps: Chemical decontamination of the pipes together with the reactor water purification system (TC) to reduce high dose rate in the area of the dismantling work. The lines were dismantled because of a change in the design of the pump bearings, making the system unnecessary. At the same time, the TC line inside the containment had to be exchanged because of the link to the TD system.

Codification:

Operation(s) performed (annex 1):	4.1	4.2	
Systems(s) and component(s) affected (annex 2):	A.J.3	A.D.4	J

3. Dosimetric information (for planned operations, give estimates)

Collective Dose (man.mSv):	775.00
Maximum Individual Dose (mSv);	12.90
No of People Exposed:	454
No of man-hours to perform the work:	4 3855.00

4. Comments on exposures and radiation protection actions (description, cost, efficiency, break down of work collective dose according to main tasks involved, reference(s) to reports)

Chemical decontamination was necessary because of the high dose rate of the piping and components of the TC and TD systems and in the working areas. The decontamination action needed several steps because of the great and complex system area decontaminated. Weighted decontamination factors (average):

for the piping	75
for the components	14
for the working areas	25

For the replacement of the piping at the reactor pressure vessel (RPV) nozzle the biological shielding penetration had to been widened in order to work from outside the biological shielding. A mobile shielding with lead sheets and a lead plug in the nozzel (after cutting) was installed to reduce the dose rate both from the RPV and the piping.

Break down of the (estimated) collective dose:

Chemical decontamination of the systems	38.5 mSv
Dismantling of the TD system	257.8 mSv
Exchange of the TC system within containment	209.1 mSv
Exchange of the running gears at the recirculation pumps	308.1 mSV
Total cost decontamination:	1 350 000 DM
Total duration	67 days

Codification of radiation protection action(s) (annex 3):	1.1.5. 1.1	1.2.2	2.4.2
	2.4.3		

References to report:

KKP1-report no 00226/06/1993 on dose estimation and description of radioprotection actions (in German)

SIEMENS/KWU-report no S733/93/027, Rev.a, technical description of CORD decontamination process at the KKP-1-npp for the TC, TD systems and the pump flange (in German)

Presentation at the CEC meeting, Luxembourg 10-11, Jan. 94, minutes of the meeting.

5. Additional comments

The KKP-1 npp, same as the KWU-BWR KKB and KKI-1, are equipped with internal recirculation pumps that need a pressurized bearing water system (TD). This system is a 3-line high pressure system with a great volume situated outside the containment.

For reasons of nuclear safety this system had to be eliminated by a change of the pump design with new bearings. Thus a total exchange of the pump running gears was necessary.

Inside the containment the total TD piping was dismantled starting at the rpv nozzle and ending outside the containment including the penetrations (reactor side, one line splitting into 3 lines inside the containment), on the other hand the 1 line (high pressure side) from the containment penetration to a sampler line with the links to the recirculation pump bearings.

The reactor water purification system (TC) before was split from the TD-line (reactor side) and left the containment by a separate penetration. The clean side enters one feedwater line in the containment again.

Thus a new TC line had to be installed between the rpv nozzle and the containment penetration. The 4 TD penetrations were closed. The 9 pump running gears were dismounted in a whole under water from the refuelling machine and stored in the spent fuel pool.

Typical dose rates at the working areas (before) after decontamination:

rpv-nozzle	(8)	0.15 mSv/h
TD piping inside containment	(3)	0.05 mSv/h
TC piping inside containment	(3)	0.08 mSv/h
Control rod drive room, pump mounting area		0.07 mSv/h
reactor service floor		0.015

Lessons learned:

The decontamination by the CORD-process was very effective and saved and estimated collective dose equivalent of about 8 Sv

In the meantime the running gears have been transported in shielded containers to the Karlsruhe Nuclear Research Centre, Decontamination Facilities, were they will be dismantled and packed for final storage.

Appendix 4

Specialised Tool Experience

The following two interesting case studies, from Commonwealth Edison Company plants, illustrate the use of specialised tools.

1. Reactor Components Wetlift Equipment: LaSalle County nuclear power plant

Reactor units are taken off-line for refuelling at the end of their 18 month fuel cycle. During each outage the reactor upper internal components are required to be removed to allow for refuelling. Past practice at LaSalle was to flood the reactor cavity with-water up to the vessel flange. The steam dryer was then unlatched and moved "dry" (through the air) to the dryer/separator storage pit. The separator was then unlatched from the grating level. The separator was lifted as the cavity was flooded and moved "wet" (underwater) to the dryer/separator storage pit, which was now flooded.

A new method for removal of the reactor upper internal components was first used with success during the unit 2 refuelling outage 4 in the spring of 1992. This new method has been refined during the unit 1 refuelling outage 5, in the fall of 1992, and during the unit 2 refuelling outage 5, in the fall of 1993. A direct comparison is made here between the unit 2 refuelling outage 3 and 5 activities. The new method involved the use of the WETLIFT 2000 equipment supplied by ABB Combustion Engineering. This equipment allowed the complete flooding of the reactor cavity with water and latching of the steam dryer, from the refuelling bridge, and movement of the dryer "wet" (underwater) to the dryer/separator storage pit. The separator is then latched, from the refuelling bridge, and moved underwater to the dryer/separator storage pit.

The WETLIFT 2000 equipment consisted of a watertight overhead crane hook box, dryer/separator slings and lifting legs and a rigid pole handling system. This equipment allowed the following operations to be performed underwater by operators located on the refuelling bridge or operating deck:

1. Operation of the steam dryer hold downs.
2. Coupling/detaching of the steam dryer sling.
3. Removal of the steam dryer.
4. Unlatching of the shroud head bolts.
5. Coupling/detaching of the separator sling.
6. Removal of the steam separator.
7. Installation of the steam line plugs.

Using the WETLIFT 2000 equipment, the internals removal critical path time was also reduced by approximately twelve hours. The unit 2, refuelling outage number 5, reactor upper internals removal activity was completed for a collective exposure total of 80.28 man mSv. This compares to the unit 2, refuelling outage number 3, reactor upper internals removal activity collective exposure total of 126.47 person mSv. This represents an exposure savings of 46.19 person mSv. In addition, a collective exposure of 49.15 person Sv was saved during the replacement of the reactor upper internals utilising the WETLIFT 2000 equipment. Therefore, the total collective exposure avoided for the disassembly/assembly of the reactor upper internals was 95.34 person mSv, representing a 26.4 % reduction. The dosimetric breakdown for various types of workers involved in this task is attached. Pre-meeting and job procedure reviews were valuable in familiarising all participants with each step of the disassembly process utilising the new equipment.

Reactor Vessel Disassembly/Assembly Comparison
L2R03 vs. L2R05

Work Group	L2RO3 (without wetlift)		L2RO5 (with wetlift)	
	Disassembly Dose (mSv)	**Assembly Dose (mSv)**	**Disassembly Dose (mSv)**	**Assembly Dose (mSv)**
Operators	2.07	2.52	0.26	0.06
Station Labourers	5.23	0	5.46	27.67
Mechanical Maintenance	70.42	188.81	59.65	111.42
Electrical Maintenance	0	1	0.04	0.01
Instrument Maintenance	0	0	1.11	1.66
Fuel Handlers	0.15	15.10	2.37	2.67
Radiation Protection	11.10	12.82	5.45	11.05
Chemistry	0	0	1.28	1.18
Technical Staff Engineers	0	2.65	0.27	0.48
Quality Control/QV	0.35	1.77	0.07	1.98
Training/Reg. Assurance	0	0	1.30	0.41
Offsite CECo Personnel	2.82	5.09	0.89	0.16
NRC	0	0	0.03	0.10
Architect Engineers	0.05	2	0.21	0.08
Contract Labourers	34.28	5.52	1.89	26.23
TOTALS	126.47	234.31	80.28	185.16
		EXPOSURE AVOIDED	46.19	49.15
TOTAL EXPOSURE AVOIDED UTILISING WETLIFT 2000 EQUIPMENT				95.34 person mSv

2. Reactor Vessel Flange Cleaning System: Byron nuclear power plant

During each reactor refuelling outage the reactor vessel O-ring seat/flange surface must be cleaned and inspected prior to reinstalling the reactor vessel head. The cleaning is required to remove any film or debris of foreign matter or oxidation adhering to the stainless steel flange surface. Further, a visual inspection is done to confirm the cleaning. High radiation exposure rates exist in this area ranging from 15 mSv/hr to 30 mSv/hr.

Past practice required up to 12 individuals wearing plastic protective clothing and negative pressure full face respirators to scrub the flange surface by hand. This work typically takes about four hours and collective exposure of 38 mSv.

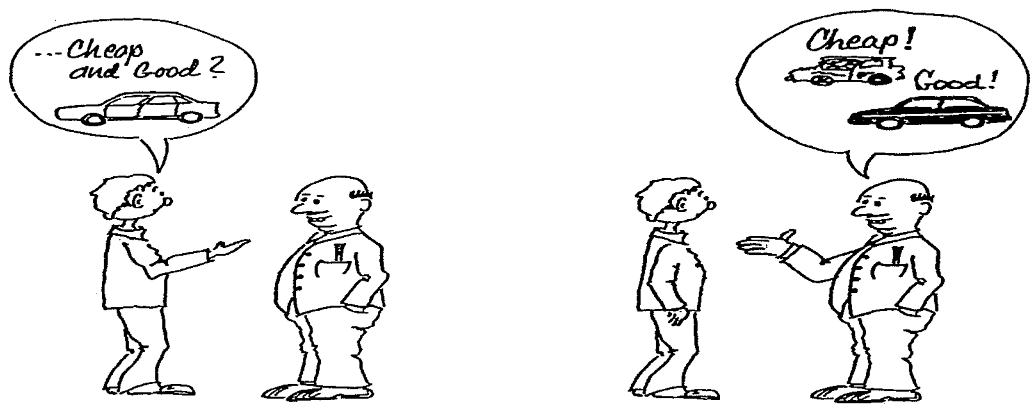
During unit 1 refuelling outage 4, a reactor vessel O-ring flange cleaning machine was used for the first time to replace the manual cleaning. The device is a Model E-2 manufactured by Barron and Associates of Santa Cruz, California USA. The device is tethered to a control box and is remotely controlled by an operator in a low radiation dose area. The device is motorised and self-driving to follow in the groove of the reactor vessel head flange, and tracks in the space between the reactor vessel internals and the flange. The guide wheel propels the cleaning machine along the flange surface brushing clean the surface as it moves. The machine has front and rear 3M® Brand Scotch Brite wheel pads to clean the flange surface automatically, and is controlled from the switch box controls located about 15 metres away in a low radiation dose-rate area.

The flange cleaning machine is simple to use, easy to install and inexpensive, less than $20 000 (USD). What formerly took four hours to complete now takes about one and one half hours, with about 45 minutes of machine time on the flange surface, and only two people are required for the job. One person installs the machine on the flange and leaves the area, the other person controls the machine remotely from the manipulator bridge crane cab outside the reactor cavity area.

Radiation dose saved due to the use of this device during the fourth refuelling outage totalled 23 person mSv. Subsequent use has resulted in similar savings. It is advised that the device should be set up on a mock-up flange and tested prior to use in a radiation area.

7. WORK IMPLEMENTATION

"There is never time enough to do a good job in the first place, but there is always time to do the same job twice!" *A general list of jobs performed twice would include 1) trivial jobs, such as welding a seam, which after inspection must be ground away and re-welded, as well as 2) major mistakes, like unsuccessfully connecting a control rod to its drive, which causes reopening of the closed reactor and an additional week of work. Avoiding rework is avoiding doses and costs.*



If, when buying a car, your criteria are cheap and good, then you may need to buy two cars. It's the same with doing a work fast and well. You may need to do it twice, first fast, then well.

7.1 Introduction

As with the other areas described in this Manual, Work Management plays an important role in the implementation phase of any task. This phase of work refers to the actual performance of the work, and to those actions taken during this time which affect or facilitate the work. In particular, there are four areas where Work Management can most effectively contribute to lowering cost, time, and dose. First, efficient control of the work process will help to assure that the objectives set during the work planning phase are met. Second, the provision of workers with sufficient information, radiological as well as plant and job specific, will reduce "unnecessary" dose as well as transit dose. Third, the collection of feed-back information will assist in the real-time management of the work, and will facilitate the preparation of future, similar work. Finally, Work Management can be very useful in creating and maintaining worker motivation (which is also discussed in Chapter 4).

7.2 Work Process Control

Work process controls are critical to the success of well planned outages. Many people will be involved in these controls, so it is of importance to clearly establish the responsibilities of each, as well as to create a flexible organisation to co-ordinate work and to resolve any problems encountered.

The role of radiation protection (RP) personnel may vary from country to country, as will the degree of radiation protection responsibility assigned to workers. However, the key function of radiation protection personnel is to provide assistance and advice to workers. It is then necessary that the workers be able to identify the radiation protection technician who will follow their job. This identification will of course be made if the workers receive a radiation work permit from the RP group. It is also possible, to designate a particular RP technician for the surveillance of one type of job.

> At Vattenfall's Ringhals nuclear power plant (Sweden), one radiation protection worker is in charge of all operations on steam generators, and another is in charge of the fuel handling work. They are both identified on the organisation chart of the outage which is given to the workers. This type of organisation allows a better co-ordination of work, and ensures that the information related to one type of activity is always given to the right person.

To ensure that radiation protection inspections are made regularly, and especially during work which will modify the radiological environment, "radiation protection hold points" can be included within work procedures. The aim of these points is to "force" the workers to stop the job until the radiological conditions have been checked by a radiation protection technician.

> At Illinois Power Company's Clinton nuclear power plant (USA), a "Radiation Protection Hold Point" is included when an activity within a procedure could cause a significant increase in work area dose rate (e.g., greater than 10 mSv/hour) or create unmonitored release path to the environment. At this stage of job execution, the worker must ask for a signature by a Radiation Protection Technician before continuing work. A radiation protection hold point cannot be by-passed. A "Radiation Protection Critical Point" is a step requiring direct supervisory involvement to ensure that the step or activity is completed satisfactorily. At this stage of job execution, the worker must ask for a signature by a Radiation Protection Technician or by the Radiation Protection Shift Supervisor before continuing work. This critical point cannot be by-passed.

In order to help in the prevention of unplanned high exposures, it can be useful to set individual dose restrictions, and to check worker doses upon their entrance to and exit from radiological controlled areas.

> Again, at Illinois Power Company's Clinton nuclear power plant (USA), if a worker receives a dose greater than 0.5 mSv for one entry/exit, an alarm is printed in the radiation protection room situated near the main access, and the worker must see the radiation protection staff before returning to his/her job. For operations having an estimated dose greater than 10 person-mSv, there is an automatic comparison of the dose received by the worker with the planned dose included in the radiation work permit: if the worker has received a dose greater than 80% of the estimated dose, there is a message onthe computer system. If the worker has reached 100 % of the estimated dose, the

radiation protection staff must be contacted. If the worker's dose is greater than 150 % of the estimated dose, his/her entrance into the controlled area is blocked.

At Vattenfall's Ringhals nuclear power plant (Sweden) and IVO's Loviisa nuclear power plant (Finland), using an electronic dosimeter, an alarm is set at 2 mSv. This alarm represents a hold point for every individual entrance to controlled areas and is set at the same level for all workers. The alarm is, however, raised for operations involving higher dosimetry. If a worker receives a dose higher than 1 mSv during an operation, upon leaving the controlled area the name of the worker is sent to the computer screen in the radiation protection control room.

At Kernkraftwerk Philippsburg nuclear power plant(Germany), the personal dose limit for one entry to a controlled area is 0.5 mSv/day in general, but this limit may be changed by radiation protection depending on the estimated and approved dose for the work to be performed during that entry.

The role of Task Managers or Job Supervisors is also very important because they are directly in contact with the workers doing the jobs. To effectively control work, Task Supervisors must spend sufficient time at the work sites to be aware of progress and problems. It is also necessary to favour a close collaboration between supervisors and radiation protection personnel during the outage. The job foremen, often a contractor, must be able to identify and work closely with the Job Supervisor who is responsible for collecting information concerning the work progress and any problems encountered.

At Illinois Power Company's Clinton nuclear power plant (USA), the Task Managers for activities greater than 10 mSv of projected dose must work with the ALARA Group in establishing a "Final Authorised Dose Budget" for each task. During the outage, they provide daily work status values to the RP Analysis Group for incorporation into the Dose Management Database. Radiation Protection personnel add to this database the radiological status of the individual jobs of concern. It is essential that the Task Managers take individual responsibility for the dose budgets assigned to their tasks and assure that appropriate attention is paid to the reduction of total dose for the job evolution. For this purpose they must work with the RP Group which can assist them with dose reduction opportunities and efforts.

At Philadelphia Electric Company's Limerick nuclear power plant (USA), the use of "Make-It-Happen-Managers" has also been effective in assuring continuous monitoring and field-coaching of the critical path work. Assigned the responsibility for a particular job, or particular jobs, the "Make-It-Happen-Manager" assures that obstacles encountered during the task are overcome. These can include such problems as a lack of institutional support (scaffolding, insulation or shielding groups, polar crane use, maintenance and electrical groups, etc.) procedural problems encountered during the course of the work, or unplanned "emergent" work discovered during the course of maintenance activities (broken/leaky valve, faulty pump, etc.). In each case, the "Make-It-Happen-Manager" is responsible for co-ordinating, in a multi-disciplinary fashion, the response to these problems such that the work is not adversely affected in terms of time, cost, or dose.

To resolve any problems encountered, inter-service communications must be quick and efficient. For this purpose, it can be quite useful to identify the persons who will co-ordinate information and report to the outage structure.

> To this end, EDF, the French utility, has experimented during some of its units' refuelling outages with the use of a full time reactor building co-ordinator, who is the central contact point for any problems encountered, such as lack of electric current, problems with elevators, questions about permits, etc.
>
> In BWRs, up to 65% of the total outage dose is received from work activities in the drywell. In the United States, the assignment of Drywell Work Co-ordinators and Managers whose sole purpose is work process control and monitoring has reduce work duration and dose in this critical plant location. In Sweden, a member of the radiation protection group is generally assigned the task of co-ordinating drywell jobs, and for outages with large drywell work loads official drywell managers have been assigned. In the United States, at Susquehanna Steam Electric Station, both a drywell co-ordinator and a refuelling floor manager have been designated to ensure effective co-ordination of work and prompt decision making.
>
> At CFE's Laguna Verde nuclear power plant (Mexico), and at Kernkraftwerk Gundremmingen nuclear power plant (Germany), Area Co-ordinators are used in this fashion to assure that all the work performed in particular areas is appropriately co-ordinated with all other work in the area, and that problems arising during the outage are efficiently handled. It should be noted, however, that at Gundremmingen these co-ordinators are mostly concerned with industrial safety aspects of problems.

The daily outage meeting must be the place where the problems are solved in "real time". It is then important that task supervisors, RP and the people in charge of preparation and scheduling attend this meeting. If necessary, when specific problems are encountered, it will be necessary to have the participation of contractors. During this meeting, the planning of "unscheduled" emergent jobs must be elaborated together with the outage structure, in the same way as planned jobs (taking account of interference with other jobs, reduction of dose rates by keeping water in circuits ...). It is also important during this meeting to inform the outage management structure of the evolution of the actual dose of the outage and to compare this with the projected dose.

> Interdisciplinary communication is an essential part of work implementation. Pennsylvania Power and Light Company's Susquehanna plant noted the importance of this during snubber inspection campaigns. Previously, daily snubber inspection and maintenance lists were made up and supplied to work crews and to a radiation protection technician. Prior to entry of the work crew into the reactor building, each snubber was surveyed by a radiation protection technician. However, often, the work crews would not complete work on all the snubbers on their list, necessitating the addition of unfinished snubbers to the next day's list. Thus, the survey of the next day's list by the radiation protection technician included snubbers which had been surveyed the previous day but which had not been worked. Better communication between the radiation protection technician and the snubber work planning group solved this problem.

7.3 Reduction of Transit Exposure and Avoidance of Unnecessary Dose

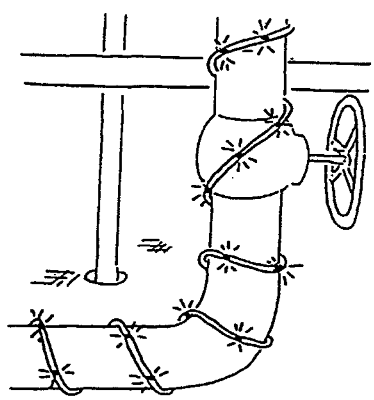
The control of access to, and time spent in, the controlled zone, particularly that part of the controlled zone where workers are exposed to radiation, are important in avoiding unnecessary doses. An "electronic" control at the entrance to the controlled zone can be implemented using radiation work permits (RWP), allowing workers access to the controlled area only if the RWP is planned for the day considered. Sometimes, however, this system may not be sufficient to control access, for example if the period allocated is very long. It can be useful, then, to designate a person who will be in charge of controlling access.

Some American utilities have experimented with a "reactor-building gorilla" who is responsible for assuring that all workers entering the reactor building are properly authorised and will not stray from their appointed tasks.

Another work management objective during work implementation is to provide the workers all necessary information and working area characterisation to reduce "transit doses". The use of detailed maps, available at the entrance of the reactor building and/or at the various levels inside the building, can help to reduce the transit time of workers who can become "lost" and therefore accumulate unnecessary doses while looking for their job location. This is particularly the case for work on small valves which are often difficult to find. These maps can also be included in the work procedures given to the workers, or shown during pre-job briefings. Information as to dose rates is also important, especially if there are hot spots along the transit path.

In Japan, a visual reminder is used to inform workers of high or low radiation doses. Colour light-tubes have been introduced in Japanese BWRs to indicate high radiation fields, red, and low radiation fields, green. These light-tubes are made of flexible, transparent polyethylene and contain small coloured bulbs at approximately 30 cm spacing, which can be hung on equipment, handrails, walls, etc. to indicate areas to be avoided or to use as waiting areas. They can be connected to area radiation monitors and will change colour according to the dose rate. Figure 7.1 illustrates the use of these light-tubes.

Figure 7.1



Another solution is the use of computer systems which allow the use of "films" of the reactor building.

At Kernkraftwerk Philippsburg nuclear power plant (Germany), a map listing of dose rates in the reactor building is available at the radiation protection office (located at the entrance of the controlled area) and open to everyone. On all major elevations, maps of the floor area are available, and include information as to high dose rate rooms (> 3 mSv/h). Moreover, at all rooms with dose rates higher than 0.1 mSv/h, there are surveys near the entrance indicating the dose rates inside the room.

At Illinois Power Company's Clinton nuclear power plant (USA), the ALARA Group runs a computerised photo library with photos of the main systems of the plant. This data base is used for pre-job briefings of the workers, and for the preparation of maintenance work packages. The photo library is also available to systems engineers and work planners through the local area computer network.

At Electricité de France's Paluel nuclear power plant (France), for all activities on valves the working procedure given to the workers includes a photo of the area showing the location of the valve and indicating the estimated or measured dose rates (see Appendix 1).

A few plants in France and in the United States now use "surrogate tours", a laser disk system of thousands of photographs taken of controlled zones. Using a joystick, the worker can "tour" the area of interest; advancing, retreating, and looking forward, backward, left, right, up and down. This system is very useful for orienting workers and for familiarising them with the work site with no cost in dose.

At IVO's Loviisa nuclear power plant (Finland), all rooms are listed in a central computer file along with radiation information (average dose rate, hot spots, etc.). These data can be retrieved by anyone at any computer terminal in the plant. More over, when looking up a single component from the component file (valve, pump, sensor, etc.) the location of the room where that component can be found, as well as radiation information for that room, will also appear on the screen.

In order to reduce the time spent in high dose rates areas, it can be useful to identify low dose rates areas so that the workers can read their working procedure, prepare their jobs, or wait for their part of the work procedure with less exposures.

Electricité de France, the French utility, is identifying "green areas" in the annulus at several levels of the reactor building. These areas are clearly indicated. As an example, such an area is often established just outside the reactor building personnel entrance hatches. It is of course important to educate the workers on the use of these areas to ensure that they are using them as often as necessary, but not too much (they are not supposed to be rest areas!).

To minimise the time spent for coffee breaks, Finish plants have installed break rooms where workers can drink (coffee, soft drinks, water) and smoke without having to change out of their controlled-zone protective clothing and back into street cloths. The break room is situated between a monitoring checkpoint (workers must pass through portal monitors and meet 4 Bq cm-1 contamination levels before entering the break room) and the "step-off pad" leading to the dressing rooms. Toilets are also available in the break room (see Appendix 2). By this technique, the time spent on "coffee breaks" has been reduced from approximately 50 minutes to less than 20 minutes.

Finally, it should be noted that operational dose-rate control is also important. This can be accomplished only with efficient communications. For example, the effective control of "transient" high dose rates, from hot spots in piping systems, requires hot-spot identification (workers and/or radiation protection) followed by line flushing or hot spot shielding. In that these hot spots are, by nature, transient, follow-up surveys are also necessary.

7.4 Collection of Feedback Data

The collection of feedback data is essential during the implementation phase. This collection has a double interest : firstly, to provide a "real-time" feed back allowing the rapid implementation of corrective actions in case of dosimetric "drift", and secondly, to supply data bases which will be used during the assessment phase and for the preparation of the next outage.

In order to create past experience databases that are as complete as possible, it is important not to stick to dosimetric data alone. It is in fact essential to also have information on the general course of operations if it is desired to analyse the unexpected and the deviations (positive or negative deviations) between the predicted and recorded doses.

One of the largest difficulties regarding these data lies not so much in their integration into computerised systems, which can be done fairly easily with database management systems, as in the direct capture of the raw data. For this purpose, one efficient procedure is to use records systematically completed, either by the radiation protection staff or by the job foremen, at the end of the operation. Such things as dosimetric data (total collective dose, individual doses etc.), data describing the working environment (ambient dose rates, contamination, type of protective clothing, "ergonomics of the jobs" etc....) and lastly, when appropriate, precise details of any malfunctions encountered, their causes and a quantification of their impacts in terms of time and dosimetry are useful. Particular attention should be paid to completing these records, as the quality and precision of the final information used for past experience analysis depends on them. While being sufficiently simple not to be seen as a constraint for the responsible person, these records must be designed for easy incorporation into the planned data-processing system: planning of the chronological order of the questions for data capture, prior coding of certain variables when possible, etc. (an example of the data collection system used by FRAMATOME, a French reactor vendor and maintenance contractor, is presented in Appendix 3).

Another way of collecting real-time feedback data is to organise post-job briefings together with radiation protection personnel, task managers and job foremen. The use of check lists during these briefings ensures the collection of all relevant information.

> At Illinois Power Company's Clinton nuclear power plant (USA), the ALARA Group performs post-job briefings with all workers after the major jobs. An "ALARA Post-Job Review Form" is used to collect information. (see Appendix 4). The estimated and actual person-hours and person-Sv are compared, and a set of 10 items which may have contributed to higher than expected person-hour and person-Sv accumulation is provided. Finally, their is a place devoted to suggestions for future improvements.

At EDF in France, during steam generator replacements, a "Mishaps Analysis Grid" has been used which collects information including the description of problems, and their consequences, and proposing a codification of possible problem causes in 6 groups (procedure, work organisation, information/communication/training, working conditions, tools, human factors) (see Appendix 5). During post-job briefings, a check list of 15 items is also used (see Appendix 6).

7.5 Motivation and Education of Workers

Radiation workers must be well trained before work in the plant is undertaken. Training must involve work process indoctrination for the plant's controlling documents, including the maintenance work order, the radiation work permit, and industrial safety permit.

It is also important for the workers to be aware of outage goals, as well as the estimated doses for their jobs. During the outage, the comparison for the workers of the evolution of actual and predicted collective dose encourages their participation in the global effort of the plant. Dosimetric results should be displayed in a "visible" place, for example at the entrance of the reactor building or in the dressing room. Some key messages can be added in order to reinforce the motivation of workers to reach the outage goals.

In France, as in the United Kingdom, some plants have experimented with the daily display of the evolution of actual and predicted collective dose for the outage, and this has been very well perceived by the workers.

At Illinois Power Company's Clinton nuclear power plant (USA), at the beginning of the outage, the ALARA Group spends 1 hour with the maintenance contractors in order to brief them on the outage goals. Each worker receives an outage guide providing the phone numbers of the people responsible for the major activities, the outage objectives and goals, the daily meeting schedule, recommendations on security, quality assurance, industrial safety, scaffoldings, chemical control, housekeeping, radiation protection, etc. This guide includes also 25 maps of the major areas and the location of the main systems. It should be noted that most plants around the world follow this practice (at Loviisa, the radiation protection group spends approximately 2.5 hours briefing workers). Such a practice is highly recommended.

Prior to task performance, a short worker briefing provided by the task managers and/or Radiation Protection can be useful to remind them of the dosimetric objectives for the job, as well as of the job's main characteristics. This can also be an occasion to spread the messages as to the importance of quality, the fact that radiation protection is a "Quality issue", the need to avoid rework and so on...

At Illinois Power Company's Clinton nuclear power plant (USA) the workers are briefed by the Radiation Protection Shift Supervisors and the ALARA Group representatives. These briefings are documented by a specific form (see Appendix 4) and include:

- a review of work procedure,
- a review of work area conditions,
- a discussion on the necessary tools and equipment,
- a radiological briefing (review of all the specific requirements of the radiation work permit, and a discussion on personnel responsibilities for their conduct in high radiation areas).

Finally, dose accountability at the work foreman level is important to the full acceptance of responsibility for dose budgets at the task level.

7.6 Summary

The implementation of work represents the last opportunity to influence the cost, time and dose associated with a particular task. The principles of Work Management, if applied at this phase, can help in optimising these three aspects of work. The use of work process controls, the provision of appropriate information to workers, the collection of feed-back information, and the motivation of workers are all areas where effective Work Management can "optimise" work in many ways.

7.7 Work Implementation Case Study

In the case of justifying the implementation of Work Management principles during the work implementation phase, there are several different approaches. For example, the costs associated with various work process control techniques could be discussed. These would include the person-hours necessary to assign a "make-it-happen-manager" to a task or group of tasks. The benefits could be compared by looking at the same job performed during two outages, one with the manager, and one without.

Another example could be the use of various types of photo libraries, discussing their cost and estimating savings based, again, on the performance of jobs before and after the photo library was implemented.

The appropriate collection of feed-back data could be illustrated by looking at the cost of collecting such information (job foremen time and post-job review time), and the savings associated with its use (job technique improvements, etc.).

An example of an interesting work implementation case study was provided by the Commonwealth Edison Company Braidwood nuclear power plant. Similar to a case study of the Commonwealth Edison Company Byron plant (see Chapter 6, Appendix 6.4), this case study involves an innovative method of cleaning the reactor vessel O-ring seat/flange surface, which must be cleaned before the reactor vessel head can be reinstalled. The cleaning is required to remove any film or debris or foreign matter or oxidation adhering to the stainless steel surface. Past practice was to manually clean the reactor flange following reactor cavity drain down. Work crews would flush the flange using low pressure spray of borated water and the scrub the flange by hand using abrasive pads.

A new method for cleaning the flange was used with success during the unit 2 refuelling outage 3 in spring of 1993. The new method involved the use of an underwater diver to clean the flange using an underwater vacuum system, an underwater brush, and abrasive pads to further clean the flange. This work performed under water was then followed by a minimal amount of work being performed in air (dry) following the cavity draindown.

The cleaning activities included a diver entering the cavity refuel pool with the underwater vacuum system, and carrying a suction line, and the vacuum head equipped with an abrasive pad brush. The diver then works around the circumference of the reactor vessel vacuuming and brushing the flange surface. After the flange is cleaned, the cavity is drained and one worker applies a final cleaning using low pressure steam spray from a hot water steam cleaning machine. The final step is to dry wipe the flange using one worker equipped with a long-handled dry mop. The cleanliness of the flange is then visually inspected from the manipulator bridge crane cab by a Quality Inspector using binoculars.

In the past 16 workers were used to complete the cleaning portion of this activity spending a total of more than 400 man-hours in this high dose rate, >15 mSv/hr area. Using the diver the cleaning time was reduced to approximately four hours total and the remaining work performed dry (following draindown) required three hours. Using this process, the reactor vessel flange cleaning activity was completed for a collective exposure total of 5.59 person mSv. The diver received 1.17 mSv and the workers performing final rinse and drying received a total of 4.22 mSv.

It should be noted that in addition to saving worker exposure, using the underwater vacuum system prevented the stirring up of large amounts of corrosion and debris material into the cavity pool water. Pre-meeting and job procedure reviews were valuable in familiarising all participants with each step of the cleaning process. However, the use of divers requires significant work preparation, as well as a back-up diver in case of emergencies. At Braidwood, however, once trained for this task and for work in radiation areas, the same diving crew was used for other tasks. In all cases, diver radiation exposures were monitored by multiple electronic dosimeters affixed to the outside of the divers suit.

Appendix 1

Example of "ALARA Work Procedure" with Location of Working Area

Paluel Power Plant (France)

This procedure is given to the workers before entering the controlled area. On the first side, it shows the map of the reactor building and the way to follow to get to the working area, as well as the reference number of the valve to be controlled. The reverse side presents pictures of the area and of the specific valve, and the relevant dose rates.

EDF CNPE PALUEL	GAMME D'INTERVENTION ALARA		74
Ordre d'intervention	Intervention sur:	Référence gamme	Indice

Rédacteur	Vérificateur	Approbation	Date
Objet de la révision:			Référence archive

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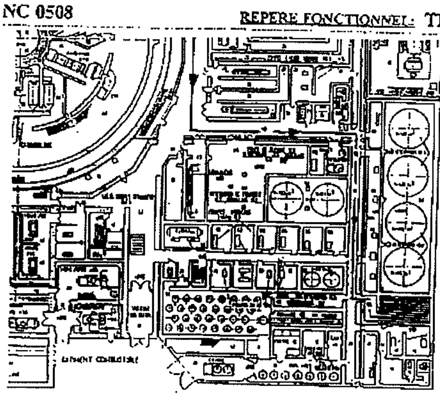
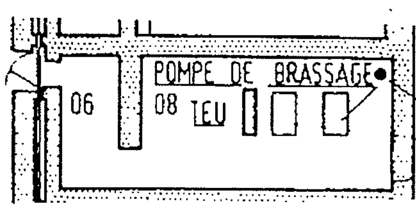


IMPLANTATION



REP	VANNE
1	TEU 031 VK
à	à
6	TEU 036 VK
7	TEU 040 VK
8	TEU 041 VK
9	TEU 101 VK
10	TEU 102 VK
11	TEU 104 VK
12	TEU 111 VK
13	TEU 112 VK
14	TEU 401 VK
15	TEU 402 VK
16	TEU 405 VK
17	TEU 406 VK
18	TEU 415 VK
19	TEU 416 VK

EDF
CNPE
PALUEL

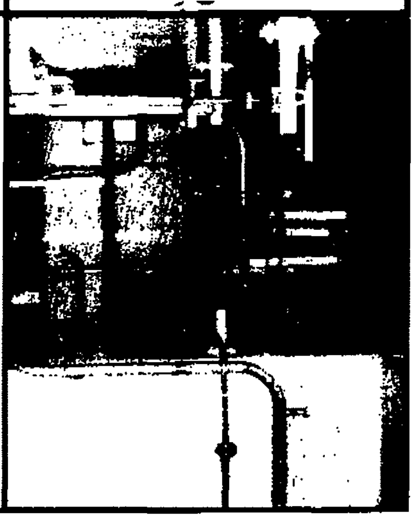
GAMME D'INTERVENTION ALARA

Ordre d'intervention	Intervention sur :	Référence gamme	Indice

LOCAL : NC 0508

DDD mSv/h

Ambiant 0,12



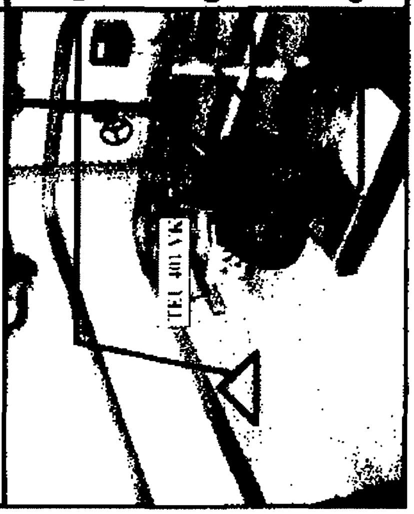
REPERE FONCTIONNEL : 1EL 401 VK

DDD mSv/h

0,70

0,40

0,60



REPERE FONCTIONNEL : 1EL 401 VK

DDD mSv/h

3,50

MOYENS MIS EN PLACE

SUGGESTIONS

Référence des débits de dose: VP7 TR3 1994

Protection biologique — Point chaud — Débit de dose à 1 m — Débit de dose au contact

Appendix 2

Example of a Time and Dose Saving Coffee Break Arrangement
Loviisa Power Plant (Finland)

IMATRAN VOIMA OY
Loviisa Power Plant

A time and dose saving coffee break arrangement

Loviisa 1 and 2 are two PWRs of 465 MWe each. Loviisa 1 was started in 1977 and Loviisa 2 in 1980. The average annual collective radiation dose to workers for these almost 30 reactor years of operation is 1 man Sv per reactor. Less than 5 % of the annual collective dose is received during operation, so there is a strong correlation between the duration of the annual refuelling outage and the radiation dose. A normal refuelling outage in Loviisa takes 3-4 weeks.

The short duration of our outages is one of the reasons for the low doses, and *one of the reasons* for short outages is a special coffee break arrangement.

In Finland every worker is by law granted *a coffee break of 12 minutes after two hours of work.* So, besides a longer break for eating during an 8-hours' shift, there must be two coffee breaks. The normal procedure for workers in the controlled zone to have a coffee is laborious. So, the time spent away from the work spot is typically 45 to 50 minutes per coffee break in other plants. In Loviisa the time necessary for this procedure has been cut down to less than 20 minutes:

The fast Loviisa way	**The normal laborious way**
1. Wash your hand	1. Wash your hand
2. Monitor yourself	2. Monitor yourself
	3. Go to shoe boundary
	4. Undress shoe covers
	5. Undress overall
	6. Move into dressing room
	7. Unlock your locker
	8. Put on your street clothes
	9. Walk to the restaurant
3. Have your coffee and your cigarette	**10. Have your coffee and your cigarette**
	11. Go to dressing room
	12. Undress your street clothes
	13. Put clothes into locker
	14. Move to the shoe boundary
	15. Put on your overall
	16. Put on your shoe covers
4. Return to your work spot.	17. Return to your work spot.

In most other plants the worker needs to go through all steps 1 to 17 on each coffee break. The Loviisa worker ca have his coffee and cigarette with his *protective overall and his shoe covers on*, and then return straight to his job.

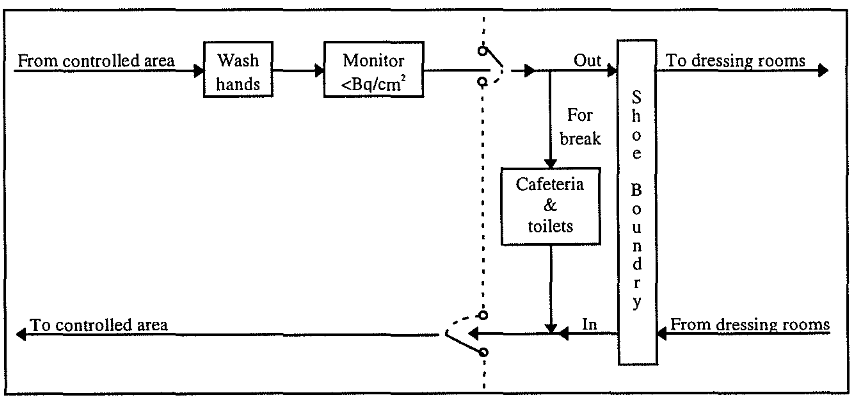
We have changed *one hour of break time* into *one hour of working time* for each man per shift, and we believe this has some effect of the outage duration. A reduction of the revision length saves hundreds of thousands of dollars a day.

Of course, nobody is irradiated during his coffee break. However, we argue that cutting down revision time by this break arrangement *saves radiation doses*, too. This is because the doses to workers of many professions depend directly on the *length* of the outage. For instance, this is the case with radiation protection staff, house keeping staff, work supervisors, guard men, laundry personnel, rounding operators, etc.

This Loviisa philosophy was used since the very commission of the plant in 1977. It has later been adopted in some other plants, either in the same or in a modified way. A prerequisite to make it possible is, that the plant has *no major contamination problems*. Contaminated areas must be cleaned immediately, local shoe boundaries must be used when working on contaminated components and washed protective clothes must be monitored using the *contamination limit for street clothes* recommended by ICRP, i.e., 4 Bq/cm^2.

After having passed the gate monitor the worker can have his coffee or his tea and/or a cigarette. This will be served free of charge, as the workers don't carry their wallets in this area. There are also toilets in connection to the coffee shop area. There are no chairs in the break rooms and the rooms are quite small. They will soon become crowded unless people are circulating. As the line comes in it forces the "over-flow" of people out, back to their job.

This arrangement is not in conflict with international recommendations nor with radiation legislation or rules given by the radiation safety authorities. From the radiation protection point of view a worker who passes a gate monitor with the alarm level set at 4 Bq/cm^2 is "a free man", *even with his protective clothes on*. The coffee shop is situated *between the final monitors and the dressing rooms for street clothes*. From the dressing room the workers are free to go home. See flow scheme below and picture on next page.

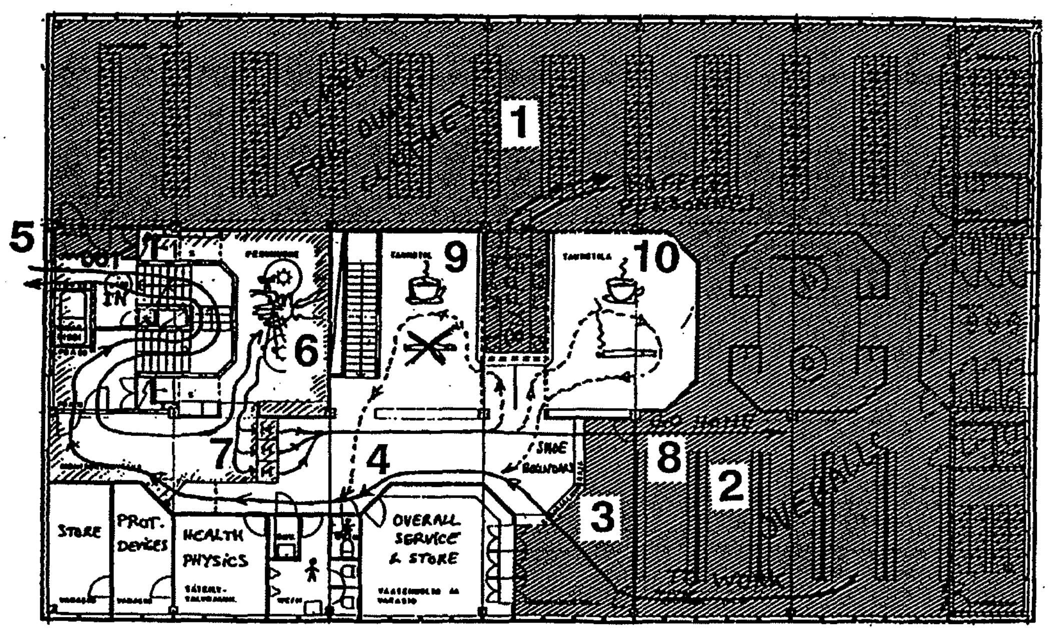


White areas = Controlled area
Grey areas = Uncontrolled, "clean" zone

Workers arriving to the work leave their street clothes in room 1. They then take their overalls from room 2 and shoe covers from room 3. Thereafter they go to work along the arrow 4.

People leaving the controlled area arrive at point 5. They wash their hands in room 6 and pass through the gate monitors at point 7. If they are free of contamination they may either go home or go for lunch, arrow 8, or they may have a coffee break and smoke a cigarette in either of the rooms 9 or 10. In case of a contamination alarm, the overall or the shoe covers must be changed in room 6. Each monitor has a gate which will not open unless it gets a "safe" - signal from the contamination measurement.

The coffee shop personnel serve the workers from the "clean" area between the rooms 9 and 10. The coffee, doughnuts and cigarettes are brought from the clean area, and they never pass the controlled zone. The coffee shop personnel working in the buffet, behind the U-formed bar-desk, do not use overalls.



Appendix 3

Example of Data Collection System
France

The Information System FRADOSE
(used by the French contractor FRAMATOME)

FRAMATOME has developed a computerised data base system for the collection and analysis of radiation protection data concerning specialised maintenance operations performed in nuclear power plants.

After each operation, a "radiation protection job form" is filed by the RP technician who has followed the job. The form consists of eight pages of generic information, plus two pages specific to the type of operation and containing detailed dosimetric data. All these data are entered into the data base so that statistical calculations and syntheses of operations can be performed.

The following maintenance operations are included in the data base:

- Mechanical steam generator tube plugging (manual and automatic remote controlled)
- Mechanical steam generator tube plug extraction
- Steam generator tube extraction (manual and automatic remote-controlled)
- Shot peening of steam generator tubes
- Heat treatment of steam generator tube U-bend
- Reparation of pressuriser liquid phase instrumentation nozzles
- Replacement of control rod guide tube support pins
- Reparation of the steam generator nozzle dam sealing surface
- Insertion of secondary steam generator tube plugs in previously plugged tubes

1. GENERIC DATA

The following data are common for all type of operations:

First page: Identification of operation

- Identification number
- Object of job
- Name of writer
- Start date of job (day-month-year)
- Name of units
- "State" of unit (Cold shutdown, Hot shutdown, Power at XX% of nominal power, Other)
- Type of outage: (Short outage, Long outage, Ten-yearly outage, Five-yearly outage, Unplanned outage, Pre-service inspection, Other)

- Cycle number
- Number of days since the beginning of the outage
- Duration of job
- Type of job:
- (Modification, Normal maintenance, Specialised maintenance)

Second page: Equipment system and work location

- Equipment system ID number, name of system, element of system
- Location of the job
- Other systems and locations

Third page: Implemented protection

- Individual protection (type of protective suits)
- Collective protection (negative pressure containment, ventilated anti-contamination tenting, decontamination,...)
- Shieldings (lead sheet, lead bricks, lead blanket, specific shielding...)

Fourth page: Contamination

- Surface contamination (yes or no)
- Air contamination (yes or no)
- Measuring instruments used

Fifth page: Individual exposure

- List of workers with name—section or enterprise, function, individual dose
- Total number of workers
- Total collective dose
- Mean individual dose per worker

Sixth and seventh page: description of job performed and observations

Eighth page: dose rate map

2. SPECIFIC DATA RELATED TO THE TYPE OF JOB

First page: Table of dose rates in the main areas before and after RP actions

The name of areas and the measurement points are pre-defined on the form.

Second page: Collective dose and time of exposure per job phase and area- Mishap doses and times per job phase

The name of areas and phases are pre-defined on the form.

Appendix 4

ALARA Job Review Forms
Clinton Power Station (USA)

Illinois Power

ALARA Post-Job Review Form

Authorizing Doc:	RWP:	AJR	
Location			
Job Description			

Est Man-hours	Act Man-hours	% Difference	Est Man-rem	Act Man-rem	% Difference	Act Effective Dosc Rate (mu/nr)

Check one or more of the appropriate items listed below which may have contributed to higher than expected man-hour/man-rem accumulation.

	1) Job scope changed or was extended.
	2) Job site radiological conditions changed.
	3) Encountered scheduling /work co-ordination difficulties.
	4) Work extended due to tool/equipment failure.
	5) Work extended due to wrong or unavailable parts/tools/equipment.
	6) Work extended due to unplanned job-site prep requirements.
	7) Work extended due to interruption/interference caused by other work activities.
	8) Inadequate compliance with radiological controls.
	9) Inadequate consideration of good ALARA practices.
	10) Radiation Work Permit inadequacies.
	11) Inadequate shielding.

Comments:

Suggestions for Future Improvements - Lessons Learned

ALARA Engineer: Date:

Section 3 - Job Exposure Estimate Section

List the job breakdowns by expected tasks to be performed in the RCA (RWP man-hours)

Tasks	Brief Task Description	Est Man/hrs	Est mR/hr	Est Man/rem
Totals				

Section 4 - ALARA Section

<table>
<tr><th></th><th colspan="2">ALARA Planning</th><th></th></tr>
<tr><td colspan="4">Will special training or mock-up training be required?</td></tr>
<tr><td colspan="4">Will a pre-job meeting be established?</td></tr>
<tr><td colspan="4">Will the use of photos or videos be helpful?</td></tr>
<tr><td colspan="4">Review and/or creation of radiological history?</td></tr>
<tr><td colspan="4">Will a post-job meeting be established?</td></tr>
<tr><td colspan="4">Have job interference and time wasters been identified?</td></tr>
<tr><td colspan="4">Is the job a high risk job or first time evolution?</td></tr>
<tr><td colspan="4">Will the use of a Radiological Work Plan be established?</td></tr>
<tr><td></td><td colspan="2">Exposure Reduction/Engineering Controls</td><td></td></tr>
<tr><td colspan="4">Will stay times and dose limits be established?</td></tr>
<tr><td colspan="4">Will shielding the components or work area be beneficial?</td></tr>
<tr><td colspan="4">Will a glove box or some type of containment be used?</td></tr>
<tr><td colspan="4">Will component or are decom be performed?</td></tr>
<tr><td colspan="4">Will remote handling devices or observations be established?</td></tr>
<tr><td colspan="4">Will shielded casks or pigs be needed?</td></tr>
<tr><td colspan="4">Will the use of portable ventilation be used? (HEPA)</td></tr>
<tr><td colspan="4">Establish the type & frequency of special surveys.</td></tr>
<tr><td colspan="4">Is decay of the source reasonably beneficial?</td></tr>
<tr><td colspan="4">Can the source be removed? e.g. flushing, etc.</td></tr>
<tr><td colspan="4">Will low dose areas be established?</td></tr>
<tr><td>Actual Man-rem from previous performance</td><td></td><td colspan="2">Actual Man-ours from previous performance</td></tr>
<tr><td colspan="4">Comments:</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td colspan="2">ALARA Engineer:</td><td>Date</td><td>Ext.</td></tr>
<tr><td colspan="2">ALARA Committee Review</td><td colspan="2">Date</td></tr>
</table>

ALARA Post-Job Review Form	**Illinois Power**

Section 1- Job Information

Authorizing Doc:	RWP:	AJRR
Location		
Job Description		

Section 2 - Job Planning

	Yes	No	N/A	(Mark Applicable bares)	
1) Will the job require a system breach?	❑	❑	❑	Services	
2) Can components be moved to a lower dose area?	❑	❑	❑	Services requires for the job	
3) Is the job procedure or work package prepared?	❑	❑	❑	Lighting	❑
4) Are the applicable parts verified, staged?	❑	❑	❑	Electrical	❑
5) Radiological Hold points identified?	❑	❑	❑	Breathing Air	❑
6) Has a tool list been developed?	❑	❑	❑	Instrument Air	❑
7) Will special tools be required?	❑	❑	❑	Welding/Burning	❑
8) Are the special tools staged?	❑	❑	❑	Ventilation	❑
9) Has prefabrication been considered?	❑	❑	❑	Remote Video	❑
10) Has the job history been reviewed?	❑	❑	❑	Comm-Headsets	❑
11) Will the job generate rad-waste?	❑	❑	❑	Area Decon	❑
12) Has the Radwaste disposition been established?	❑	❑	❑	Component decon	❑
13)Has the access/exist from the work area been established?	❑	❑	❑	Temp Shielding	❑
14) Communications Provided?	❑	❑	❑	Relamping	❑
15) Experienced worker selected?	❑	❑	❑	System drain	❑
16) Has cross training been considered?	❑	❑	❑	System flush	❑
17) Staging/set-up in an accessible area?	❑	❑	❑	Cutting/Grinding	❑

What specific ALARA Actions are incorporated into this job?

Supervisor/Planner: Date:

Appendix 5

"Mishaps Analysis Grid"
France

MISHAPS ANALYSIS GRID – 1st page

Identification of the job :
Area : Material :

---

1. MISHAPS ANALYSIS

MISHAPS DESCRIPTION:
....
....
....

Are there any radiation protection consequences? immediate ❑
probably in the future ❑

Are there modifications of working conditions (contamination...)? yes ❑ no ❑

If yes :
Impact on individual protection ....
....
Impact on working time : ....
....
Work phases concerned by the previous modifications : ....
....
Modification of one or more dose rates :
....

Dose rate	Area	Dose rate	Area
....	....	....	....
....	....	....	....
....	....	....	....

Work phases concerned by these dose rates: ....
....

Estimated impact of the mishaps on the level of exposure : ....

Actual impact of the mishaps on the level of exposure : ....

MISHAPS ANALYSIS GRID – 2nd Page

Identification of the job :
Area : Material :

---

2. ANALYSIS OF MISHAP CAUSES FOR POST-JOB REVIEW AND OF FEED-BACK

1. INADEQUATE PROCEDURES

- General process ❑
- Procedure to bring tools in the area ❑
- Conditioning procedures ❑
- Procedures for removal of tools ❑
- Procedures for wastes removal ❑
- Protection procedures : ❑
- Individual protection ❑
- Collective protection ❑
- RP procedure for intervention ❑
- Installation of service air/water ❑
- Others .... ❑

....

2. INFORMATION, COMMUNICATION, TRAINING

- Bad or insufficient training of workers ❑
  - Inadequate or ill-adapted training programs:
    - technical program ❑
    - ALARA program ❑
- Mock-up training : - not planned ❑
  - inadequate ❑
- Defective communication ❑
- Wrong verbal information or oversight ❑
- Defective or partial technical information ❑
- Defective maps ❑
- Others .... ❑

....

3. WORK MANAGEMENT

- Defective pre-job analysis ❑
- Bad distribution of tasks between workers ❑
- Bad pre-job planning ❑
- No follow up of job planning ❑
- Bad co-ordination
  - between workers ❑
  - between teams ❑
  - between firms ❑
- Insufficient availability of
  - workers ❑
  - tools ❑
  - machine ❑
- Unsuitable tools ❑
- Others .... ❑

....

....

4. WORK AREA PREPARATION AND WORKING CONDITIONS

- Bad arrangement of working area ❑
- Inadequate cleanliness and bad arrangement of working area ❑
- Bad visibility/hearing ❑
- Deficient or unsuitable scaffoldings ❑
- Work constraints
  - working position ❑
  - light ❑
  - heat ❑
- Others:.. ❑

....

....

5. INCIDENT DUE TO TOOLS

- Tool failure ❑
- Lack of service air/water ❑
- Inspection of tools failure ❑
- Communication equipment failure ❑
- Others .... ❑

....
....
....

6. INCIDENT DUE TO HUMAN FACTORS

- Error due to a non application of rules or procedures ❑
- Diagnostic error ❑
- Not adapted reaction ❑
- Reaction time too slow ❑
- Physical failure ❑
- Others .... ❑

....

DISCUSSION WITH THE TEAM OF CAUSES OF MISHAPS, IN ORDER TO IDENTIFY AND RANK THOSE AT THE ORIGIN OF THE MISHAP

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Appendix 6

Post Job Briefing Forms
France

To be discussed with the team leader of the job

Identification of the job:
Area : Material:
Description of the job:

1.	Were tools and material availale at the right time?	❑	❑
2.	Was the area ready for your task at your arrival?	❑	❑
3.	Was the protection suitable for your job in this area?	❑	❑
4.	How much time did you have to prepare the task? Was it enough?	❑	❑
5.	Have other jobs interfered with your tasks?	❑	❑
6.	Has the working area been kept clean and in order to facilitate the work?	❑	❑
7.	Did your team members know their level of exposure	❑	❑
8.	Have you told them to limit this exposure each time it was possible?	❑	❑
9.	Was your team conscious of the dosimetric objective of the work?	❑	❑
	Was it motivated	❑	❑
10.	Did you have co-ordination problems with other teams, other departments?	❑	❑
	Which type of problems have you encountered which have increase the level of exposure?		
11.	Did you have difficulties in implementing the solutions to your problems?	❑	❑
12.	Did you have administrative problems?	❑	❑
13.	Was there a specific event which allowed you to reduce exposure?	❑	❑
14.	Will you perform your task in the same way the next time?	❑	❑
15.	Do you think that the process must be changed?	❑	❑

DEVELOP HERE THE POSITIVE ANSWERS :

....

....

....

....

....

8. WORK ASSESSMENT AND FEEDBACK

The final stage of work is that of assessment and feedback. However, when applying the Work Management philosophy to jobs, this is also the first stage because, in essence, the process is continuous. In a generic approach, two levels of information may be necessary to provide complete feedback: the "internal" level, which consists of an analysis of in-plant performances, and the "external" level, which will provide national and/or international data favouring the exchange of new ideas and allowing the plant to assess its position with regard to other plants of the same type.

8.1 Experience Data Bases

One important tool to ensure efficient feedback is a complete information system allowing the collection, the analysis and the storage of data. For this last point, the use of computer data bases is essential. With regard to the two levels mentioned above, both types of data are useful, and both include data as to the time, manpower, equipment, dose, etc., associated with a particular task or class of tasks. At the internal level, this data can be collected directly before, during and after jobs. Computer-based collection systems, most easily associated with the operational dosimetry system, can be very efficient at collecting this type of information.

> In the US, for example, detailed information as to workers controlled zone entry and exit time, and worker dose is collected using the electronic dosimetry system. At Illinois Power Company, the PREMS, Personnel Radiation Exposure Monitoring System, collects worker area access and dosimetry information. This includes each entry and exit to the radiologically controlled area (over one million entries and exits per month during outage periods), as well as to specific work sites which are equipped with satellite radiation control points, such as the drywell, the refuelling floor, etc. This system provides valuable data concerning the time and dose that workers actually spend at their work areas.

In France, a similar system, called MICADO, is being installed in some plants to collect this same type of detailed information. Each time a worker "badges in or out" of the controlled zone, the entry duration and dose are recorded, and are tracked according to a set of "Job Codes". Job Codes are assigned by the outage management (with the participation of radiation protection) to track specific tasks (charging pump replacement), or specific classes of tasks (scaffolding).

It should be noted, however, that time in the controlled zone and time at the work site are not the same, such that for very detailed studies for dose-saving purposes may require more detailed information than is available from simple "badge in and out" systems. This problem can be overcome by having the multiple badging points within the controlled zone, and at the entrance to each work area under study.

In terms of external data, some detailed information such as that described above is available at the international level. Organisations such as the NEA's ISOE Programme (see § 5.4 for further details), and other studies performed by such organisations as INPO in the United States, and WANO, can provide detailed dose, manpower, and duration information for some jobs or classes of jobs.

In terms of work assessment, the indicators used to assess work, and the bench marks against which these indicators are judged, must be multifaceted. For example, collective dose and individual dose distribution must be joined by other indicators such as person-hours, number of workers, work duration, rework required, delays and problems, etc. For such bench marks and indicators, data from pre- and post-job ALARA analysis, historical data and data from other sites is essential. (see also § 7.4 on the collection of feedback data during work implementation).

8.2 Post-Job Review

The extent and nature of a post-job review will vary depending upon the job being reviewed. That is, larger jobs will require more in-depth review than smaller jobs. Some flexible criteria for helping to decide which jobs should be reviewed (such as total collective dose involved, the total number of person-hours involved, a percentage of over or under estimation of the total collective dose and/or the total number of person-hours, etc.) should be established to guide job reviewers. In general, the review should be conducted by a multi-disciplinary team, and the objective of the review should be to establish what portions of the job were performed well or badly, and which could be performed better, and how, in the future.

The workers having performed the work should directly provide their suggestions as to how the work could have been improved, or how the problems encountered could have been better addressed. We have seen in §7.4 that this information can be collected by way of post-job briefings. But it is also possible to organise specific meetings with contractors at the end of the outage. This may involve paying the contractor to remain at the site after the completion of the work.

The use of "Suggestion Forms", available during the outage, where workers can propose various actions to reduce the exposures, is also a good way of collecting relevant data. In order to incite workers to complete such forms, it is necessary to provide them an "answer", telling them that their suggestions have been analysed and eventually taken into account. The centralisation of these forms must be well organised, and it is essential to designate one person (or a group of people) to be in charge of collecting and analysing the suggestions. (see example of such form in Appendix 1).

When analysing operations, a structured method should be applied. In order to identify the most important areas requiring action, a classification of the causes of reworks (or mishaps) can be used (see examples in Appendix 2 and 3). For specific operations, "Time and Motion" studies allow the evaluation of the techniques used in performing the procedure, and target areas which will improve the overall efficiency of the process. These studies may also cover other areas, such as: work station design, development of improved work method, establishment of time standards (see example in Appendix 4).

For the analysis of the dose trends for an operation which has been performed several times, perhaps in different ambient dose rates, it is necessary to "normalise" the dose in relation to a reference ambient dose rate. This normalisation allows the identification of the real exposed time spent for each job. It can be noted here that this type of analysis has shown that when the operation is performed in a low ambient dose rate after having been done in higher dose rates by the same team, workers tend to spend more time than necessary in the area because they are used to a certain level of exposure, and pay less attention when the dose rate is not as significant. This fact points out the need to provide workers with an estimated dose before each intervention, taking account of actual dose rates (see example in Appendix 5).

The preparation of outage reports, which include technical and radiation protection data, is essential. Such reports must include analyses of the causes of deviation from outage goals (in a positive or negative way), recommendations for improvement, as well as identification of the "good practices". These reports should be widely distributed within the outage structure.

Also, in the United States, some plants develop "ALARA Reports" describing the performance of the station for the year, and as compared to any dosimetric goals established for the year. Such reports discuss not only the outage period(s) for the station, but also the non-outage periods for the entire year. Both job-by-job and "roll-up" (summary) information for multiple jobs can be provided to describe actual performance versus expected performance. Opportunities for improvement are generally outlined, and responsibilities for follow-up actions are defined.

Several American stations have established "visionary" goals for their performance. For example, a station with a current annual collective dose of 2.5 person-Sv per unit may establish a goal of 1.5 person-Sv per unit within the next five year period. Exposure reduction plans to meet that goal are then developed and tracked, using a form such as that provided in Appendix 6.

8.3 Job Review Follow-up

To "close the Work Management loop", a mechanism for assuring the implementation of the job feedback is necessary. In order to ensure that the recommendations are implemented, it can be useful to organise, after the outage, one or more multi-disciplinary meetings devoted to the analysis of the outage, to identifying these follow-up actions to be implemented, and to assigning responsibilities for the completion of those actions. These decisions may be taken by the ALARA Committee, when it exists, or by a more general "Outage Analysis" group. In either case, such a follow-up group should exist on a "year-round" basis, changing roles from outage follow-up to outage planning as the next outage arrives. This will help assure the appropriate continuity of experience from outage to outage. It should be noted that such year-round coverage philosophy generally exists in most countries.

In order to assure the completion of appropriate suggestions, such formalised systems as tracking lists, or more informal systems such as simply maintaining the post-job review team in tact for the preparation and planning of subsequent work, have been utilised. In either case, input from the post-job review team is essential to the appropriate follow-up of work. For example, in Japan, at the Fugen plant, during outage periods weekly meetings between radiation protection staff and contractors are held to discuss the ongoing status of jobs, and to evaluate the effectiveness of dose reduction initiatives. In Sweden, at the Ringhals 2 plant, the incorporation of previous experience has led to a reduction in collective dose for reactor vessel head removal and replacement. From 1977 to 1995, this exposure has been reduced from around 200 person mSv to less than 50 person mSv.

To complement the information available at the plants, it is necessary that the plant remain in contact with other plants from the same utility and from others, at a national and international level. The participation at radiation protection meetings favours the exchange of information and allows workers to be aware of the new techniques.

In Germany, an organisation gathering all the major German electricity utilities (nuclear or not) and also some other European countries has been created (named VGB). There is a VGB-group of health physics managers and all German nuclear power plants are represented. This group meets twice a year at the site of one of the plants. Usual items for discussion include:

- exchange of information, experience
- report of special radiation protection actions
- regulatory developments
- discussion of such specific radiological items as: beta-dosimetry, internal dosimetry, ALARA-subjects, ISOE.

In the United States, the PWR and BWR Owners Groups organise each year one or more meetings. The Nuclear Energy Institute (NEI) also supports a Health Physics Information Forum, providing a means for utility radiation protection managers to gather annually. Items for discussion include those described above for the meeting of German radiation protection personnel. Similar meetings are also sponsored about once every two years by the Institute of Nuclear Power Operations (INPO).

In Sweden, for example, there are several groups of managers (from Ringhals, Forsmark, Oskarshamn, and Barebeck) sometimes including managers from Finnish plants, which meet routinely. Examples of such groups include site managers, operations managers, maintenance managers, etc., but also groups of people below the management level. There are also annual radiation protection meetings between the Radiation Protection Managers of Swedish and Finnish plants, the ABB Atom Fuel factory and in recent years people from the Studsvik Research Centre in Sweden, the Halden reactor in Norway and the Risö research centre in Denmark.

In France, where all plants belong to the same utility, several inter-plant meetings are organised with the objective of sharing "good practices" for the reduction of exposure. These practices are regularly grouped together in a file which is send to all plants and used by the technical and radiation protection staff. When generic problems are encountered in several plants (like hot spots or vessel head cracks), specific files presenting how to deal with the problem are elaborated and send to all plants (see examples of good practice information sheet and the list of specific ALARA documents in Appendix 7).

At an international level, the information network created by the ISOE System allows participating plants to ask specific questions to the other plants by the intermediate of the Technical Centres. The "Level 3" of the ISOE data base (NEA3) contains good practices, and descriptions of technical or radiation protection problems. This data base is available for all plants participating in ISOE (see examples in Chapter 6, Appendixes 1 to 3). Also associated with ISOE, annual Topical Session meetings bring radiation protection managers together to discuss specific issues of current interest, including such topics as steam generator replacements, fuel failure, chemical decontamination, and electronic dosimetry.

In addition, for the past ten years the Commission of the European Communities (CEC) has held annual meetings of radiation protection experts from its member countries to discuss a variety of issues. Participants generally present the current status of their programmes and any interesting work which has been performed during the past year.

8.4 Programme Audits

Finally, the entire system of Work Management implementation should be audited periodically to assure that it is functioning properly. Again, many systems, from very formal to very informal, have been tried.

8.5 Summary

The post-job assessment of work, and the appropriate follow-up of those actions seen as necessary, are among the most important parts of any task evolution. To properly perform such assessments, some sort of benchmark is most helpful. With the growing experience in the nuclear power industry, such data bases can now be constructed including international experience and can be of great use to plants in all countries. In terms of post-job review, it is essential to have a multi-disciplinary team to conduct the review, and to include as much direct input from the workers, including contractors, as possible. The follow-up of recommendations and lessons learned should then, ideally, be performed by the same multi-disciplinary team which conducted the post-job review. Normally, follow-up will lead directly into the next implementation of the operation under consideration, such that a certain closure (job conception, scheduling, planning, implementation, assessment, and follow-up, job modification as per lessons learned, scheduling, planning, etc.) occurs and the job becomes progressively optimised, and modified appropriately to keep up with current technological developments.

8.6 Work Assessment and Feedback Case Study

In the case of the implementation of Work Management practices to the assessment of work and to work feedback, again, several approaches are possible to justify new programmes. For example, in terms of work assessment and feedback, a programme to form the review groups necessary for various jobs would include the costs of setting up and maintaining such a group, and the cost for interviewing contractors after their jobs were completed. These are mostly person-hour costs. In addition, the costs of implementing appropriate modifications should be considered. Again, an example of a job performed before and after the implementation of such a review-team approach would be the best to illustrate the analysis of benefits.

As an example, much experience was gained, and put to use, by the Neckarwestheim plant in Germany, in the area of core barrel screw replacement. During the 1986 outage, it was noted that 90 core barrel screws needed replacing due to cracking. This "emergent work" task, identified during the outage, was planned as best possible, but still resulted in 920 mSv of collective dose. Re-evaluation of the work performed indicated that some improvements could be made in working techniques, and these improvements were implemented for screw replacements during the 1987 and 1988 outages. The following table summarises the results of this work:

Year	Number of screws changed	Collective dose for direct work on screws (mSv)	Average collective dose to replace one screw (mSv)	Total collective dose for screw replacement (mSv)
1986	90	920	10.2	3720
1987	471	730	1.5	2840
1988	375	480	1.3	2750

The dosimetric conditions encountered when changing and handling the screws were as follows:

Location of Measurement	Condition of Measurement	Dose rate (mSv/h)
Core Barrel	Under water, 23 cm from surface	33500 - 15300
Container with defective screws	In air, surface measurement	100000 - 70000
Defective screw	Surface measurement	600 - 700

The dosimetric performance achieved in the second and third years shows that evaluation and planning of high dose-rate jobs is very necessary to effectively save dose.

Appendix 1

Example of radiological suggestion form
U.S.A.

Radiological Suggestion Form	**ILLINOIS POWER**

Section 1 - Originator	RS				-	
Name: Dept. Ext. Mail: Date						
Area or procedure affected by this Suggestion						
Description of Suggestion						
Reason for Suggestion:						

Section 2 - Suggestion Evaluation

Radiological Improvement ❑ ALARA Improvement ❑ (check one) If the suggestion is an ALARA Improvement attach a cost benefit analysis.	
What is the estimated cost of the suggested improvement? Will the suggestion improve exposure reduction?	
What are the estimated benefits of the suggested improvement? (Attach additional information if necessary)	
The suggestion is not cost justifiable but should be implemented ❑ The suggestion should not be implemented ❑	
Attachment ❑ Yes ❑ No	The suggestion is cost justifiable and should be implemented ❑
Recommend assignment to:	
Comments	
S-RE	Date:

Section 3 - Final Review/Approval

The suggestion IS approved ❑ The suggestion is NOT approved ❑ CCT ❑	
Director of implementing department:	Date:
Individual assigned to for implementation:	
D-PRP:	Date:

Appendix 2

Classification of the Causes of Rework
France

This case study presents some analysis performed in some French NPP between 1991 and 1993, in order to identify more precisely the main factors influencing the level of exposures.

Two types of operations have been chosen for this analysis. The first one concerns routine maintenance operations on primary circuit valves. The second type deals with post-incident operations. For all these operations, a specific follow up of doses and exposure time has been performed in order to be able to identify exactly the part of dose due to mishaps.

1. Routine maintenance operations

Table 1 provides the percentage of mishaps according to their origin for a total of 14 maintenance operations performed on primary circuit valves during two outages on two different units. On an average, 23 % of the total collective dose was due to mishaps, but for some specific operations, the mishaps dose was reaching up to 40% of the associated collective dose.

Table 1.
Analysis of mishap causes for eleven maintenance operations performed on primary circuit valves

Type of mishaps	Percentage / Total
Tools	26 %
Preparation of working area	25 %
Training	24 %
Procedure	6 %
Environment	6 %
Waiting time	5 %
General organisation	4 %
Shieldings	4 %
TOTAL	**100 %**

This type of analysis allows to identify the main causes of "non-productive" exposed time and the first priorities in work management actions which must be undertaken in order to lower the needless exposures. In the case of routine maintenance operations, it seems important to improve the suitability of tools to the environment and their reliability especially when they have to be used for several successive operations. The preparation of working area and the training of workers also take a non negligible part in the possible causes of mishaps.

2. Post-incidental operations

After the discovery of cracks on some reactor vessel head penetrations in 1991, it was decided to inspect and, if necessary, repair part of the 900 MW and 1300 MW units' vessel heads in France. Because of the urgency of the situation and in the absence of feed back experience in this domain, the first operations didn't benefit of a good preparation. This situation leads to an "abnormal" rise of mishaps' frequency. An analysis these mishaps for 22 operations performed on 13 French units for inspections or repairs between March and October 1992 revealed that the mishap rate was on an average twice the expected one for routine maintenance operations. Table 2 presents an analysis of the mishap causes.

Table 2. **Analysis of mishap causes for 22 operations performed on 13 French units for inspections or repairs of reactor vessel head**

Type of mishaps	Percentage / Total
General organisation	38 %
Tools	29 %
Training	18 %
Shieldings	11 %
Procedure	2 %
Waiting time	1 %
Environment	1 %
TOTAL	**100 %**

The urgency of operations was translated into organisation problems, mainly due to the disturbance of outage plannings, and to the lack of feed back structures between the various concerned sites. The tool mishaps came partly from the non integration of radiation protection or environmental aspects from the very beginning of their development.

These results underline the need to be able to create rapidly specific incident structures allowing to speed up circulation of information and to favour the co-operation of the various actors.

3. The "benefits" of ALARA programs

The application of a specific ALARA program for these post-incidental operations started by the beginning of 1992. Given the number of involved units, and the great haste of operations, the degree of integration of ALARA procedures differed largely from one operation to another. The analysis of the average percentage of mishap dose for the same operations as a function of the degree of integration of ALARA at the different stages of the preparation, follow up, and feed back experience analysis, shows a direct link between these two factors (see Table 3).

Table 3.
Average percentage of mishaps for 22 operations on reactor vessel heads

Degree of integration of ALARA programs	Average percentage of dose due to mishaps (min-max)
No application of a structured ALARA procedure.	70 % (50 - 80)
No specific ALARA preparation, but application of the ALARA procedure during the operation.	40 % (30 - 50)
ALARA preparation and follow up, but no full technical control of the operation.	30 % (15 - 40)
ALARA preparation and follow up, and use of feed back data from previous operations.	10 % (0 - 30)

At the beginning of 1993, EDF estimated that 5 man-Sv had been saved on the vessel head operations by implementation of ALARA programs.

Appendix 3

A Rework Analysis Made at Ontario Hydro
Canada

1. Definition of Rework

Work repeated in whole or in part
Worsens the original problem
Did not meet planned expectations
Did not resolve the original problem

2. The Rework Control Program

Implemented:
to define, identify and trend rework
to improve plant design, maintenance, modification, implementation and work processes
to minimise radiation exposure and costs

3. Rework potential

Reworks may be due to deficiency in :

- Design
- Procurement
- Implementation
- Operation
- Maintenance

The deficiency may causes an increase in:

- Dose
- Time
- Manpower requirement
- The planned work

4. The specific forms used to collect data :

Rework Identification form:

•Nature of the Rework (be as specific as possible): ________________________________

____

____

•Location (Unit, Building, Elevation, Component): ______________________________

____

____

•Probable Cause of rework: ____

____

____

•How was Rework Identified: ____

____

____

•Identified by: Company _____________ Unit ___________ Name (optional)

____

• Identified on: Year: _____ Month: _______
Day: ______Time: ___________

Notes, Drawings, etc…

Rework Investigation Form:

Deficiency Noted in:

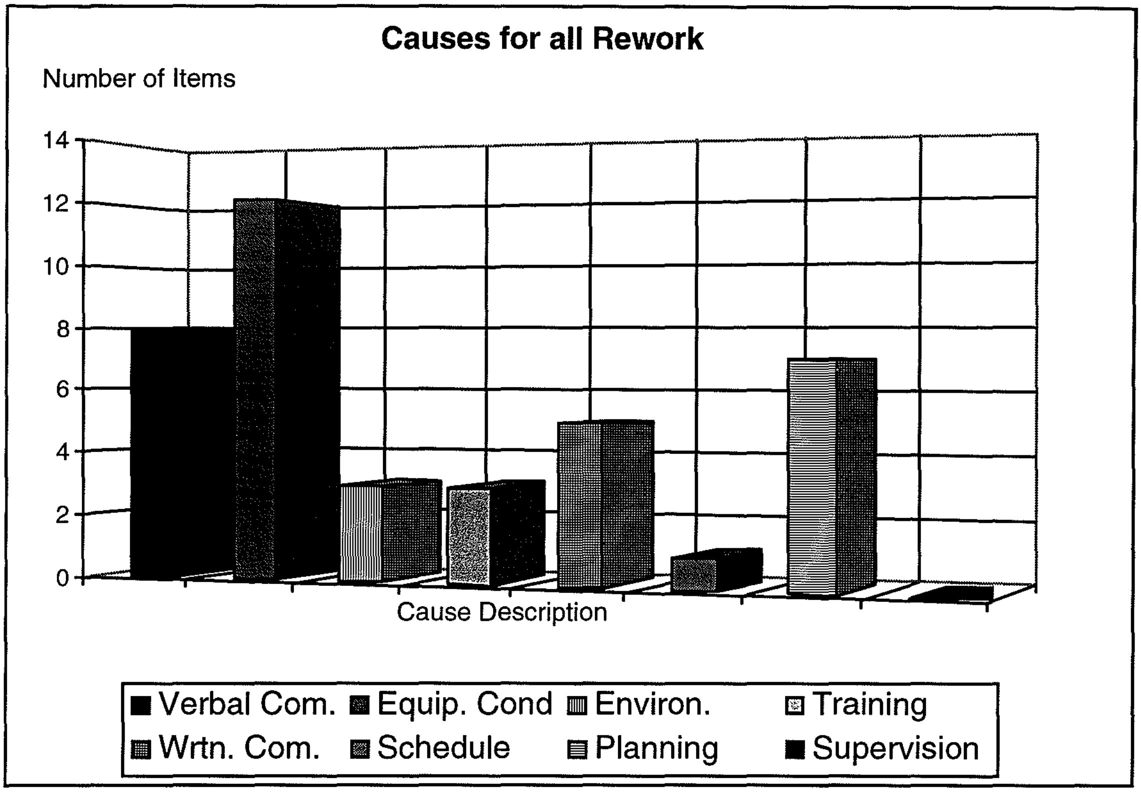
- ❑ Design
- ❑ Implementation
- ❑ Maintenance
- ❑ Procurement
- ❑ Operation
- ❑ Other_________________

Cause of Rework

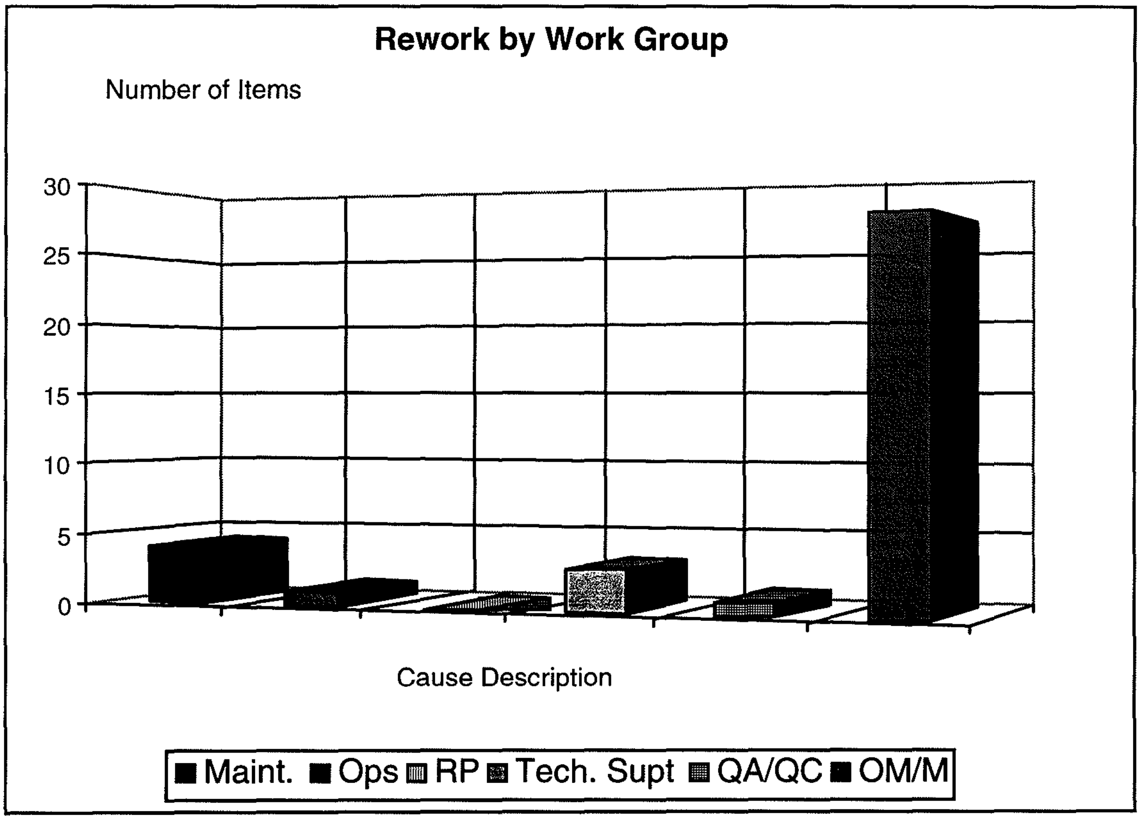
- ❑ Verbal Communication
- ❑ Equipment Condition
- ❑ Environmental Condition
- ❑ Training
- ❑ Written Communication
- ❑ Work Schedule
- ❑ Job Planning
- ❑ Supervisory Methods

Radiation Dose for Original Task: ___________Person-mSv
Radiation Dose for Rework: ___________Person-mSv
Corrective Actions:_________________________________

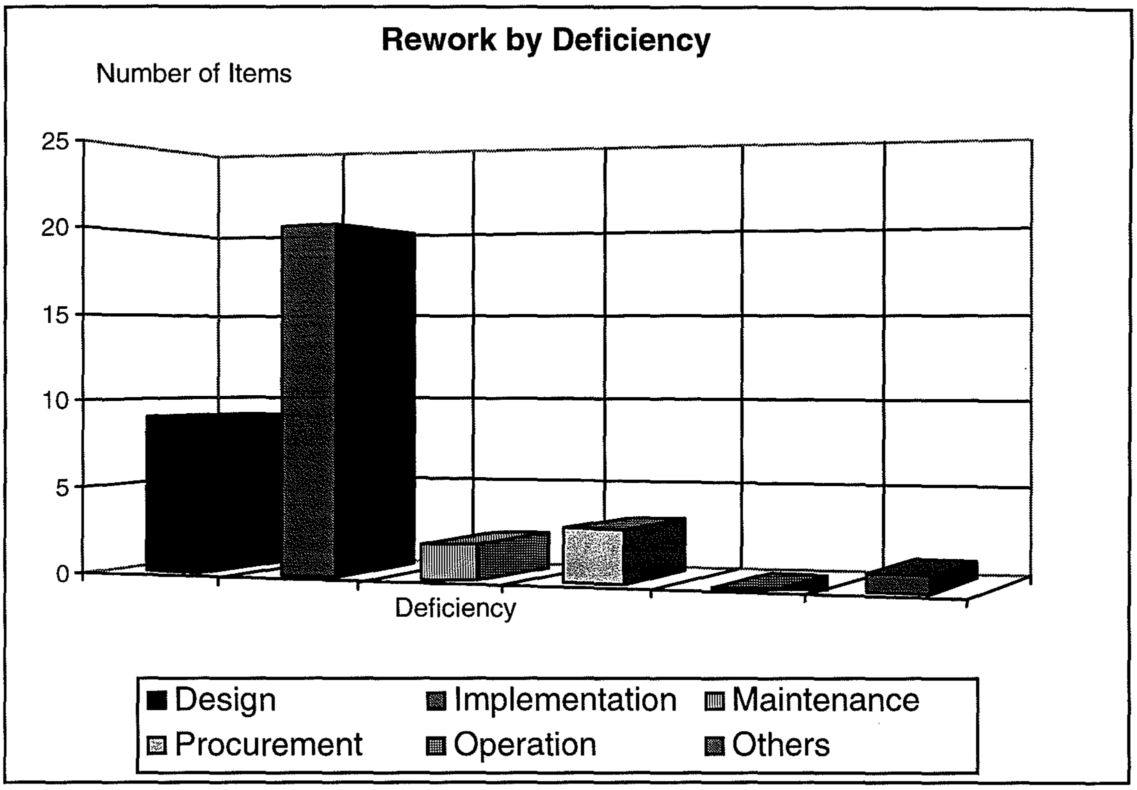
5. Results

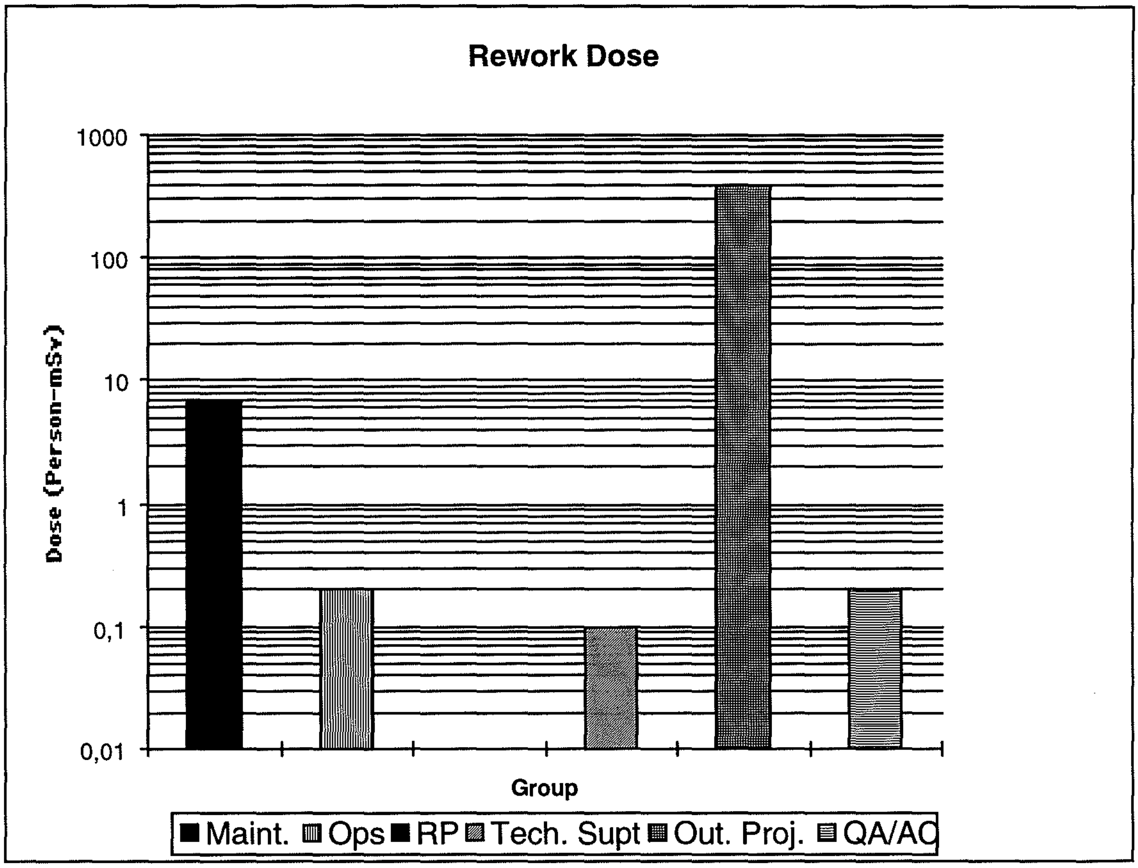


Causes for all Rework
Number of Items
14
12
10
8
6
4
2
0
Cause Description
Verbal Com.
Equip. Cond
Environ.
Training
Wrtn. Com.
Schedule
Planning
Supervision



Rework by Work Group
Number of Items
30
25
20
15
10
5
0
Cause Description
Maint.
Ops
RP
Tech. Supt
QA/QC
OM/M


Rework by Deficiency
Number of Items
25
20
15
10
5
0
Deficiency
Design
Implementation
Maintenance
Procurement
Operation
Others


Rework Dose
1000
100
10
1
0,1
0,01
Dose (Person-mSv)
Group
Maint.
Ops
RP
Tech. Supt
Out. Proj.
QA/AC

Appendix 4

Example of Time and Motion Study
LaSalle Power Plant (USA)

Commonwealth Edison Company
ISOE #2 - Time & Motion Study

GENERAL:

USA
LaSalle - 1&2 - BWR/5 - Cycle 4
Contact: Shane Marik through Paul Nottingham
Phone: 815-357-6761 x-2234 Fax: 815-357-6761 x-2268
Address: LaSalle Station
Chemistry
2601 N 21st RD
Marseilles, Il 6134-9757

DESCRIPTION OF THE WORK:

Date of work: 1992

The disassembly of a highly radioactive control rod drive (CRD), recently removed from the reactor, in preparation for overhaul and reassembly. The CRD disassembly procedure is a radiologically significant, complex and time consuming process. CRD disassembly typically employs two people.

WORK MANAGEMENT PRACTICE DESCRIPTION:

Motion and time study of the control rod drive disassembly process. The purpose of the study is to evaluate the techniques used in performing the procedure and target areas which will improve the overall efficiency of the process.

The study may also cover other areas, such as: work station design, development of improved work methods, establishment of time standards, estimation of labor costs, development of effective tooling, selection of proper equipment, training of workers and the training of managers to be method conscious.

DOSOMETRIC INFORMATION:

	Without Management Work Practice	With Management Work Practice
Collective dose:		
15 minutes into task:	0.78 mSV (78 mrem)	0.40 mSV (40 mrem)

Procedure duration seconds:

man one:	1779	1136
man two:	1779	778

Percent of time working:

man one:	47%	70%
man two:	32%	63%

COMMENTS ON EXPOSURES AND RADIATION PROTECTION ACTIONS:

Attachment A: Time and Motion Study CRD 92-001

ADDITIONAL COMMENTS:

None

SUMMARY

This motion and time study has identified five areas of concern with the technique in which we disassemble the CRD unit. After completing this motion and time study, we estimate that the disassembly procedure should be 45 percent more efficient than seen on the video tape. The study of motion and time is the study of technique, by improving technique we improve the motions performed and the time it takes to perform them. The first area of concern was the work area and its organisation. Secondly, the design of the CRD rebuild tank needs to be improved. Third, communication is very critical in this operation, we need to improve it. Fourth, it is noted from the video study that an improvement in the handling of the CRD is essential. Fifth, the procedure used to standardise the disassembly method needs revision.

The layout of the work area needs to be changed to become more efficient. First, we recommend placing the tool rack across the tank so the tools hang at eye level from a recoil apparatus. This will form a work habit so the workers will know instinctively where tools are located. Second, air lines should be plumbed onto this tool rack to accommodate breathing air lines and air powered tools.

The CRD rebuild tank itself was found to be a source of inefficiency. We recommend a recovery system be developed for parts and tools that are dropped into the tank.

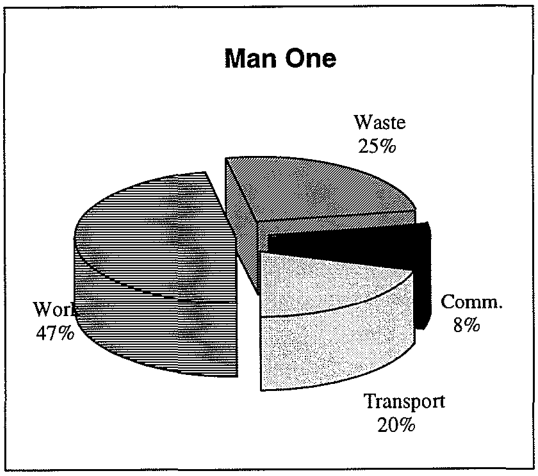
It was noted during the video study that communication is needed, an improved communication device should be utilised.

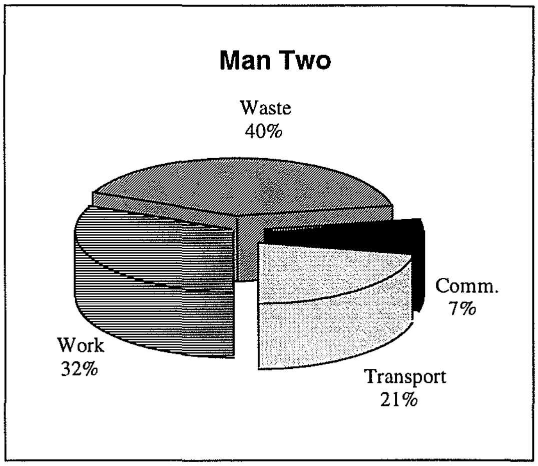
In the rebuild tank, movement of the CRD is manual, creating two serious concerns. First, the workers handle the CRD when they are lifting or rotating it increasing their exposure. Second, is the serious safety concern of an individual straining to lift or rotate the CRD. A redesigned tank including a mechanical lifting and rotating device will reduce exposure and the risk of injury during lifting and rotating the CRD. The procedure, is now written as a one person job. We utilise two people in an attempt to speed up the disassembly process. This then creates confusion about who will perform the next task, since the procedure is written in a step-by-step format. Rewriting the procedure to using two people to complete the disassembly task is required.

In conclusion, by reorganising the room, redesigning the rebuild tank, satisfying the communication needs, accommodating the workers with a lift and rotating device and rewriting the procedure, Commonwealth Edison will benefit in several areas. First, the labour cost will be reduced by the quicker process time. Second, by eliminating the safety concern we can reduce the risk of injury. Third, the new faster process will reduce the exposure received by our workers. Overall, the CRD disassembly process will improve by a projected 45 percent.

These recommendations are documented by the motion and time study #CRD92-001.

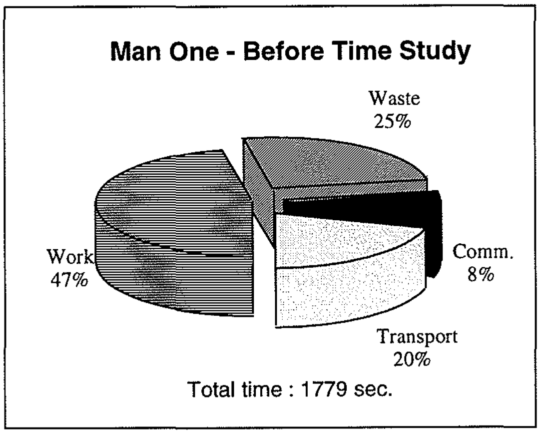
Time and activity

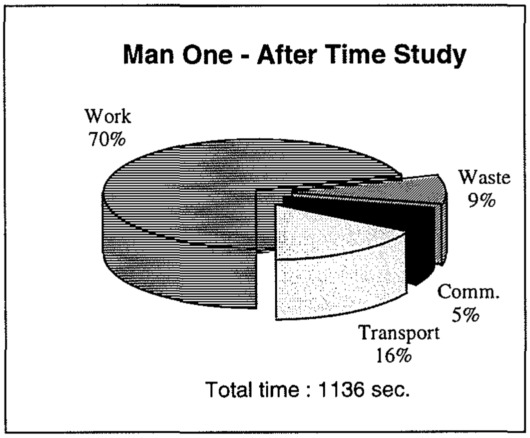




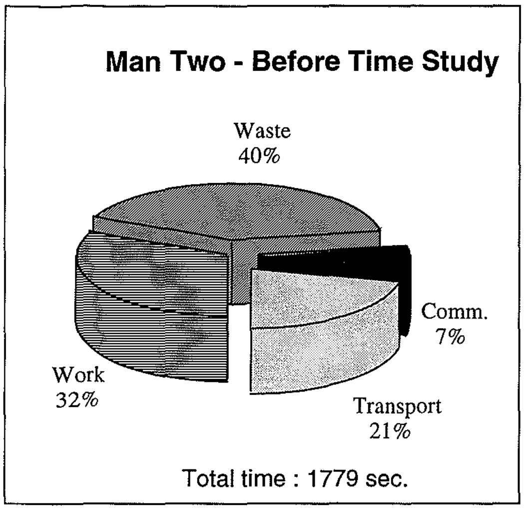
Total time : 1779 seconds
CRD Disassembly

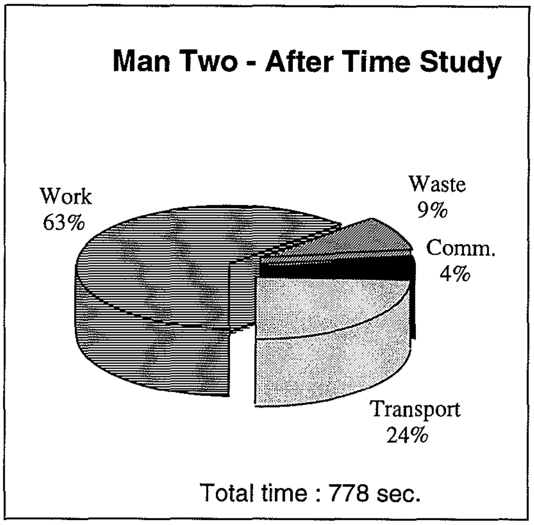
Man One

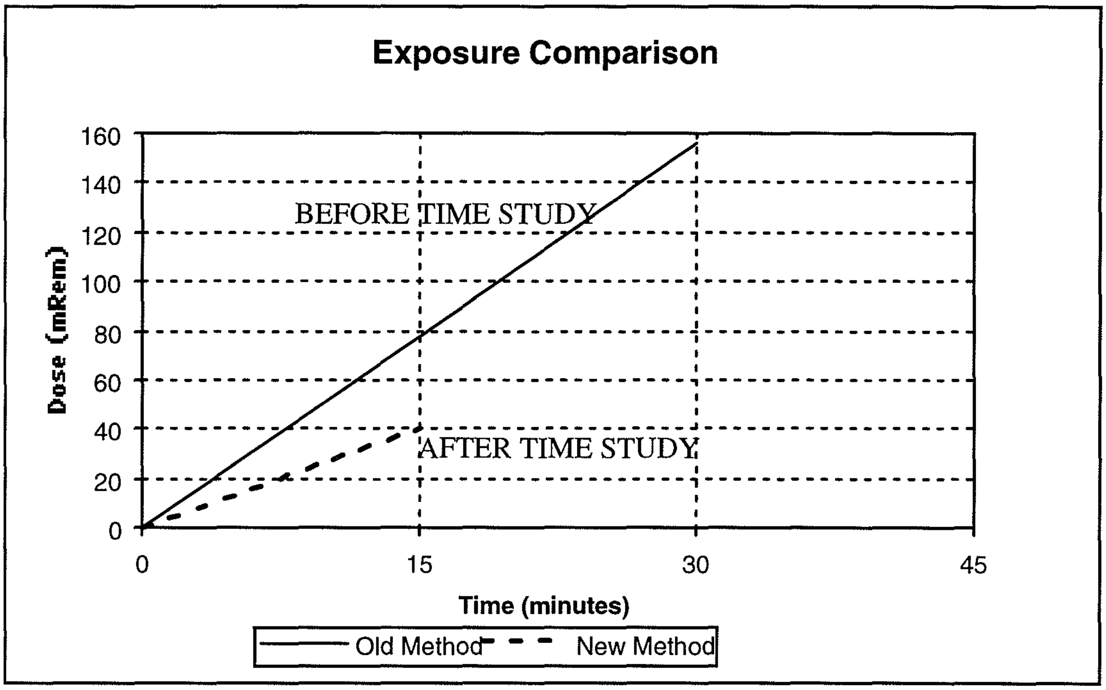




Man Two


Man Two - Before Time Study
Waste
40%
Comm.
7%
Work
32%
Transport
21%
Total time : 1779 sec.


Man Two - After Time Study
Work
63%
Waste
9%
Comm.
4%
Transport
24%
Total time : 778 sec.


Exposure Comparison
160
140
120
100
80
60
40
20
0
Dose (mRem)
BEFORE TIME STUDY
AFTER TIME STUDY
0
15
30
45
Time (minutes)
Old Method
New Method

Appendix 5

Example of Analysis of Normalised Doses
France

Usually, the impact of dose rates is taken into account when workers have to perform a job in high ambiences. In this case, it is well known that the stress resulting from the dose rates can influence the productivity of workers. For such operations, the workers should perform a specific training to lower the potential effect of dose rates on the technical performance of the operation. The analysis of feed back data concerning some specialised maintenance operation has pointed out another effect of dose rates which could be called the "lax" effect: when the same operation is performed in various radiological conditions, the lower is the ambient dose rate, the longer is the time spent to perform the job.

For example, the analysis of the collective exposure associated with the machining of Residual Heat Removal System heat exchangers performed on 17 French units between 1984 and 1988 by nearly the same team, revealed clearly this type of behaviour. The trend of the collective dose without any reference to the associated dose rate, shows that an asymptote is reached starting from the eighth operation and the collective dose is nearly equal to 50 man-mSv for the last seven operations. However, the various operations have been performed in different ambient dose rates. In order to make a true comparison of the exposure associated with the operations, the collective dose has to be related to the same value of ambient dose rate. It can then be noticed that the "normalised" total doses of the last seven operations vary widely (See Figure 1).

The comparison between the "normalised" total collective dose (which in fact represents the level of exposed time) with the level of ambient dose rate reveals an inverse relationship between the level of dose rate and the exposed working time. This is shown on Figure 2, especially for the last operations when the workers are "used" to receive a collective dose of 50 man-mSv. As long as they have not reached the 50 man-mSv level, they are not really concerned by the level of exposure, considering they still have some "dose credit".

This type of result demonstrates the need for adequate estimates of collective doses before each job taking into account the actual ambient dose rate, and for a proper information of workers and health physicists before starting the work.

Appendix 6

Exposure Reduction Plant

(United States)

The Pennsylvania Power and Light Susquehanna nuclear power plant develops an annual list of projects to reduce occupational dose for the coming years. An example of such a table is presented here. In addition to the project estimated person Sv savings, projects costs, schedules and responsible groups are listed.

Item number	Description	Estimated Person-rem Savings per year	Costs	Schedule
94-002	Investigate use of cameras across the organisation for exposure reduction		Manpower	4095
94-009	Upgrade hp survey maps/pictures for work packages	0.2-0.3	100K	3094
94-016	Evaluate reducing requirements for building work support scaffolding to seismic requirements	1-2 potential	Manpower	
94-010	Develop specifications to s?? qualify shadow shielding to eliminate the time and dose for safety impact barriers		Manpower	3095
94-022	Implement damin vessels heel modification - U2	3	612K for project	3095
94-024	Develop man-rem commitment per gram of Co-59 released into the reactor vessel	N/A	Manpower	???
94-025	Develop list of valves that are potentially significant cobalt contributors	N/A	Manpower	4095
95-002	Perform flush on Jet Pump Instrument (N8) nozzles	5-10	10-15 K	U18R10 U27R10
95-003	Develop a generic modification for MDV quick disconnect	4-5		On-going
95-004	Evaluate alternatives (e.g. cameras, use of HP rover) for firewatch in the drywell	0.5-0.6		4095
95-005	Change Demin beds to "Magic" resin U-1		140K	4095
95-006	Evaluate in-situ cleaning of LRW filters	3.5	>100 K	

Sponsor	Resp. Group	Reference	Implementing Mechanism	Comments/Status
HP (Team lead)	HP MT	Benchmark, Report EAC # 93-003, 92 030 92 010		Survey results analysed, forming a CPIP team
MT HP		INPO/MGMT/Training		Closed. To be incorporated into the NIMS Rad Protection Module
MT		SAC Mtg 9/16/93		EWR or 40829
HP MT		Post-Job	TSR	U1/U2 DW and RHR complete. Remainder will be evaluated on case-by-case basis.
CHEM		5 year plan	DCP 93-3083	Complete
HP		Source term reduction plan		Closed. Action will be tracked under 94-026 per Cobalt Reduction Plan
MT		Source term reduction plan		
MT (ISI)			RPV 94-014, initial study not feasible.	Closed-determined not feasible.
MT		E&S Comment	DCP # 94-9901	Closed
MT (E&S)		Benchmark report	NDAP-0A-0441 PCAP	Complete
CHEM		Chemistry Plan	Resin Specs PPR & Ops	Closed - will not be done due to impact on surfaces
CHEM		EAC 94-005		On hold for decision on Condensate Filtration.

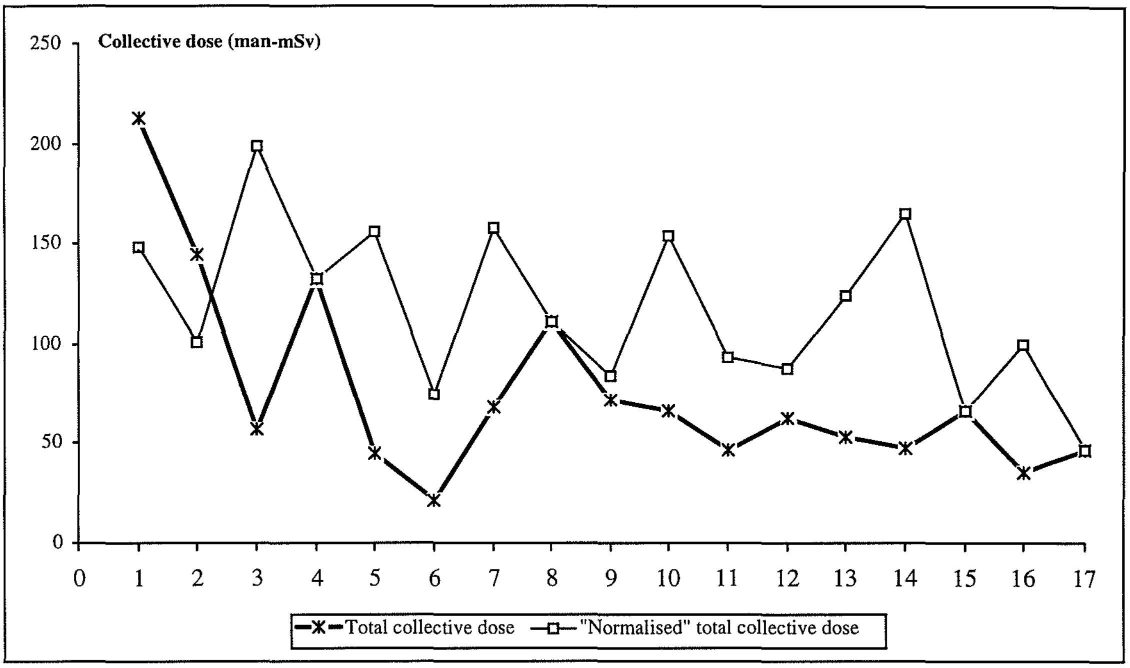
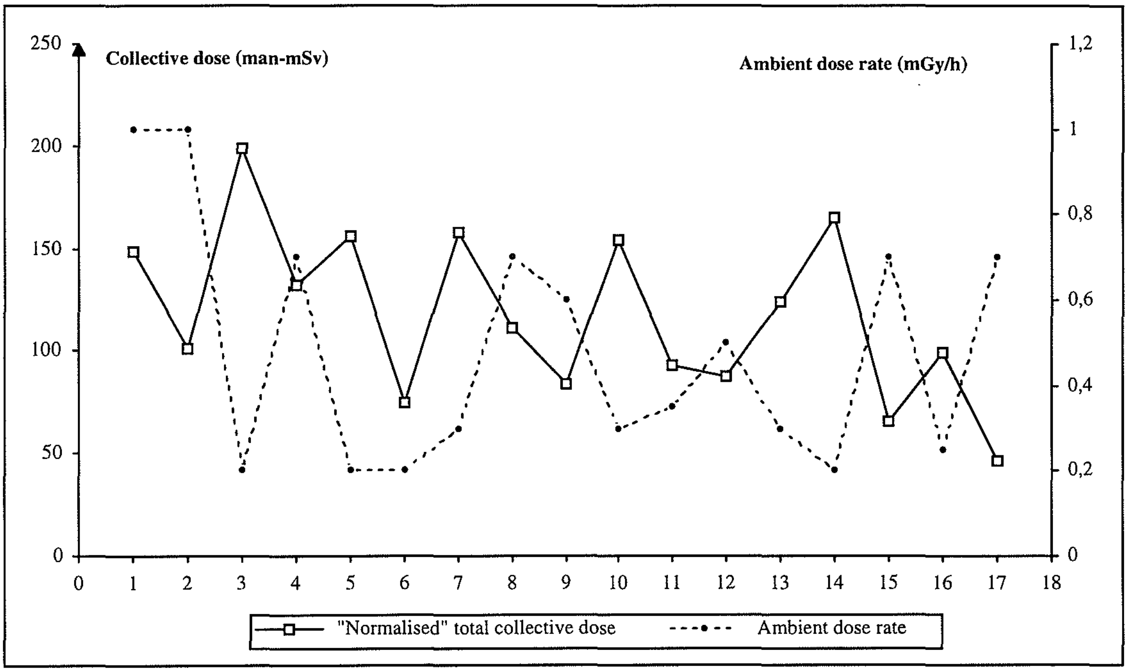


Figure 1
Evolution of the collective dose for the machining of RHR exchangers



Appendix 7

Example of Good Practice Information Sheet
France

DSRE

ALARA

good practice information sheet

Maintenance Engineering

OPTIMISATION OF THE INSTALLATION AND REMOVAL OF THERMOCOUPLE COLUMNS TIGHTENING AND LOOSENING TOOLING FOR CONOSEAL JOINT

DOSIMETRIC SAVING : 2.5 mSv per shutdown

COST OF INVESTMENT : Screwdriving machinery + control panel: 149,000 F 1992 / plant

UPDATED AVERAGE COST PER INTERVENTION : 13,600 F 1992 (over 5 years)

DESCRIPTION OF PROCEDURE

TOOLS TO ENABLE:

- pre-tightening of the 6 CONOSEAL joint compression screws
- loosening of the 6 screws during removal

NB: a part can be added during screw loosening to facilitate screw braking

ADVANTAGES :

- simplicity of use
- substantial time-saving, in particular when the screw-braking device is used (2h30 per shutdown in a high dosimetric atmosphere)
- simultaneous tightening of the 6 screws (uniform pressure on the joint ensures that the column remains vertical)
- reduction in number of personnel (1 rather than the previous 2)

DSRE

ALARA

good practice information sheet

Maintenance Engineering

OPTIMISATION OF OPENING/CLOSING OF INSPECTION COVERS ON CONTROL ROD ASSEMBLY MECHANISM VENTILATION DUCTS

DOSIMETRIC SAVING : 9.2 mSv per inspection (4 covers)

COST OF INVESTMENT : 40,000 F 1992 / unit

UPDATED AVERAGE COST PER INTERVENTION : 4,100 F 1992 (over 20 years)

DESCRIPTION OF PROCEDURE

The time for assembly/disassembly of the ventilation duct inspection covers involves the unscrewing of 16 screws per cover.

The modification involves drilling a hole in the existing covers, plugged by an autoclave system enabling rapid opening and closing of the covers.

ADVANTAGES :

- notable time-saving (approximately 3 hours per inspection)
- reduction in number of personnel

ANNEX I

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ANNEX II

EXTENDED READING LIST

ALARA bei Planung und Betrieb von Kernkraftwerken/ atw 40.Jg. 1995 Heft 1 Januar by D. Mertin/RWE, M Holl/Muhlheim Kerlich, P. Jung/Phillipsburg,W. Beutele/Neckarwestheim, L. Bergemann/Gundremmingen, HP Kapteinat/VGB

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ANNEX III

Work Management in the Offshore Oil and Gas Industry
From The
NEA Workshop on Work Management and Good Practices for Reducing Outage Costs, Duration and Exposure
Paris, October 1995

The preparation of this report on Good Practice in Work Management was aided by the input from an NEA-sponsored workshop of the same title, which took place at the OECD Headquarters, in Paris, in November 1995. Attendance at that workshop is included in Annex IV. In order to help participants put their work in context with the implementation of Work Management in other industries, one of the Workshop papers, prepared and presented by Mr. G. A. Blackmore of the Offshore Safety Division (OSD) of the Health and Safety Executive (HSE), discussed good practice in the off-shore oil industry. This paper is presented here in its entirety.

1. Introduction

The Offshore Safety Division (OSD) of the Health and Safety Executive (HSE) was asked to provide a speaker for the conference to comment on working arrangements in offshore oil and gas industry. This paper forms a basis for that presentation. The author considered several options whilst planning the presentation. The option chosen was to review the draft ISOE Expert Group report against the template used by OSD to assess the offshore management arrangements and to comment on relevant similarities and differences. The author fully accepts that some of the comments made may not reflect the reality in the nuclear industry and asks the reader to simply dismiss them. The author believes the possible advantage gained in taking this approach is that the reader may note practices, or gain knowledge or ideas from the offshore industry that they may develop and use. This approach was agreed with the conference organiser.

2. Background

In 1986 the Piper Alpha tragedy, in which 167 people lost their lives in the complete destruction of an offshore installation, was an incident the industry did not think could happen. The public inquiry into the incident led to the Cullen report with 106 recommendations and ultimately to a new regulatory approach. This approach required people in charge of an installation to submit a safety case in which a demonstration of the adequacy of the Safety Management System formed a significant part.

Over 200 safety cases have been submitted covering fixed and mobile installations. The larger installations comprise a helicopter base, a marine supply base, a hotel, and equipment to extract, process and pump hydrocarbons ashore.

The companies who submit safety cases range from multinationals such as Shell and Elf to small British companies owning a single installation. These companies however only employ around 20% of the workforce on United Kingdom Continental Shelf (UKCS), the remainder being employed by contractor organisations.

3. The OSD review method

OSD reviews the Safety Management Systems (SMS) content of offshore safety cases against an 18 element template that aligns with the model in the HSE document Successful Health and Safety Management. To simplify this paper the author has only commented on the relevant elements. In addition, the author has provided information about management and work practice found in the offshore industry.

4. Review results

4.1 Policy and Objectives for working arrangements

Companies engaged in work on the UKCS have a safety policy signed by top management in recognition of their commitment. Additional policy statements describe the intent of other activities, *e.g.* policy statements for operational and maintenance management. Management in the offshore industry consider policy statements to be important communications tool. It is only by effective communication of these lower tier policies that an empowered workforce can play its part in setting operational direction as opposed to simply complying with procedures.

The overall health and safety policy statement will often refer to the need to involve major contractors in developing these additional policies and objectives. In recent years the major offshore companies have developed much greater working relationships with contractors and purchasers. A UK initiative called CRINE - Cost Reduction In the New Era has been set up to reduce costs by 30%. CRINE aims to maximise UK recoverable reserves, increase competitiveness of UK suppliers and sustain UK employment at a higher level than otherwise possible. This initiative has supported the development of 'Gainsharing alliances' in which major contractors, suppliers and clients form alliances for a particular project to share the benefits and financial risks. If one of the contractors in the alliance can reduce the cost of their part of the project then the alliance as a whole shares out the savings made. Conversely if the project overruns on time or cost then the alliance partners share the loss. This approach has led to greater teamwork.

One similarity between the two industries is the higher cost of onsite work. Work undertaken offshore is significantly more expensive than onshore work just as work in active areas is more expensive than in non active work areas. The offshore industry has successfully reduced expensive offshore work by building and commissioning progressively larger modules onshore. Modular weights presently extend up to 10,000 tonnes.

The policy section of the ISOE report has a clear statement that management should show commitment to ALARA. Furthermore the report stated that one of its key objectives for the nuclear industry is radiation dose reduction. In the offshore industry, we do not have anything equivalent to dose to measure nor can we directly measure risk and so we look for indirect performance indicators that may give better management control of activities. Obvious performance indicators are measurement of maintenance backlog for safety critical equipment, other less obvious performance indicators are measurement of numbers of workplace inspections, numbers and quality of toolbox talks, numbers of visits by senior managers to installations. One offshore company has applied the following indicators to its contractors:

- Onshore contractor management must present their safety appraisals twice a year to offshore installation manager

- Onshore contractor management must visit the installation monthly for major contracts & quarterly for smaller contracts

- A contractor representative must feedback to offshore installation manager an analysis and action points arising from incidents

The industry management accept that improvement in indicator performance will not necessarily reduce risk but there is an belief that better control will result. To use an example from the ISOE report, section 7.4_describes how communication may be improved at Clinton due to providing phone numbers of people responsible for major outages. In an offshore context some companies would monitor the number and content of such calls to use as an indicator of whether the system was effective.

The ISOE working group may wish to consider if similar indirect indicators could be useful to the nuclear industry in improving performance e.g. numbers of times top management attend ALARA committee meetings; response times for incident investigations.

4.2 Organisation, structure and accountability

The larger offshore companies have undergone significant organisational change in recent years. Managed units have become smaller, there is more accountability for performance, more emphasis on business processes rather than functions and a closer integration of technical support functions with operations. In some companies the transfer of technical staff away from functional groups to operational groups has resulted in some dilution of technical expertise and more divergence of operational standards. The positive side has been the increased ownership of the problems.

In the report it is noteworthy that Chapter 7 on work implementation deals first with the role of radiation protection then goes on to talk about the role of supervisors. There are other examples were control appears to be placed out of the line. Chapter 7, section 2 refers to 'radiation protection worker' who will follow a particular job, or radiation protection workers who may be asked for a signature before the work can commence. A further example in Chapter 5, section 3 refers to integrated planning and states that it has been a primary goal to make maintenance planners rather than radiation protection personnel, responsible for radiation protection planning down to job level.

The above statements make interesting comparisons with the offshore industry. In the past many companies employed safety technicians who would monitor tasks, provide advice and progress the job. Nowadays many companies have eliminated this role thus leaving line management wholly responsible for decision making. There are some indications that the pendulum has moved too far and line management are not calling on the knowledge of the safety professional.

Section 3 of Chapter 5 also refers to the geographical location of job planners but many people would argue that organisational location was equally important. The offshore industry has recognised the importance of good communications between support and line functions. For example, companies will take people from the design office and use them during the construction stage and later during the commissioning phase of an operation, even where these people have different employers. The objective is to collocate people at the worksite. As a second example, companies assign so called 'area responsible personnel' who oversee activities in their particular area during operations and shutdown. Using their knowledge of the area and the activities underway they can minimise overlap and prevent conflict. They are also held personally accountable for deficiencies in their area.

The ISOE report recognises the importance of good communications in an organisation. Recently there has been recognition of the need for top management to be involved in activities at all levels in the organisation by, for example, periodically attending design reviews and tool box talks, and by participating in safety meetings and audits.

The ISOE report does not mention control of change probably because QA forms a major part in the management of a nuclear installation. In all offshore safety cases control of technical change was mentioned but it was noticeable that control and review of organisational change, other than replacement of individuals, was not considered and yet has major risk implications.

4.3 Workforce involvement

The ISOE report has greater detail and emphasis on workforce involvement than the offshore industry safety cases. It clearly recognises the need to educate workers beyond the basic and technical skills to understanding ALARA concepts. Management in the offshore industry has, in many areas, a pessimistic view on the value they have gained so far from engaging the workforce in producing the safety case. Some companies have developed the attitude with regard to involvement of their workforce 'you can take a horse to water but you cannot make it drink'. This attitude may exist because the companies have failed to motivate the workforce adequately. Historically some companies, perhaps this applies more to the construction contractors, were not open with their employees and this resulted in the perception that they could lose their job if they voiced criticism too strongly. This practice has largely died away but may still reside in the minds of contract workers and this may inhibit motivation for involvement.

Whilst the more advanced UK offshore industry believe they have tried hard to involve the workforce, a study carried out to assess the effectiveness of the safety case legislation has indicated that in general the management has not been successful in raising the employee's awareness of safety case issues. One of the reasons given for this failure lay in the complexity of the safety case and the difficulty in linking actions of the workforce with the safety of the installation.

On this note the ISOE report does not state how management assure themselves that workers, particularly contractors, will feel free to speak up. In the offshore sector one company has used computer conferencing between managers and safety representatives to get non-attributable dialogue going. In another company the management has made extensive use of questionnaires to obtain the workforce perception of themselves and were particularly shocked by the pessimistic response.

Offshore regulations require installation safety committees to be set up and meet at specified intervals. The workforce are assigned to constituency groups of specified size and a committee representative is elected from each constituency. Everyone, including all contractors, working on an installation for any length of time will be assigned a constituency. Some companies go further and arrange meetings between safety representatives from different installations.

Appendix 4 of Chapter 7 refers to ALARA Job reviews with yes/no answers. Most people would recognise the danger that this approach may becomes mechanistic. One offshore company uses local hazard identification sheets in the form of charts showing hazards and risk and requires workers to assess qualitatively the expected consequences of activities if something goes wrong. This has proved quite successful in raising risk awareness and perhaps could have uses in the nuclear industry if applied to expected dose. This would provide a proactive approach to complement the 'mishaps analysis grid' in Appendix 5 of Chapter 7.

Finally one cannot leave the subject of workforce involvement without considering a significant difference between working arrangements in the offshore and nuclear industries. On most installations the workforce and management work 12 hour days on a two week tour of duty followed by two weeks ashore. This will clearly affect how people work, for example, during the tour of duty there is greater opportunity for mixing of personnel but a greater opportunity for increased stress from peer pressure and isolation from family. However it is clear that collocation alone does not guarantee integration. In an audit covering two installations owned by the same company, management style resulted in significant differences in co-operation between workforce and management for the two installations. Offshore companies consider management style to have a significant influence on safety but few audit this aspect.

4.4 Standards and procedures to control risk.

Prior to the Piper Alpha many offshore companies used a multitude of poorly structured procedures and standards that had grown primarily in reaction to events. The safety case regulations required companies to review their operations and put in place coherent systems for managing health and safety. In response companies carried out considerable work to identify hazards and assess risk using Quantified Risk Assessment (QRA) to support assessment of specific major hazard risks.

Whilst the present situation has certainly improved the coherency of the documentation, it has not improved its readability. It is still evident that the management and workforce are generally not aware of the contents of their suite of documentation and, because of its volume, cannot ever hope to become aware.

Companies are trying to address this difficulty in different ways. One company has extracted from the documentation all responsibilities relevant to jobs positions or functions. Another company uses tool box talks to emphasise what can go wrong and what actions can be taken to prevent or mitigate the consequences; results of Hazard and Operability Studies (HAZOPS) are sometimes used.

Section 4 of Chapter 7 refers to keeping records of doses linked to environment and activity. Offshore companies are planning to use personnel tagging systems, primarily to identify the location of personnel in the event of an emergency and secondly to attempt to assess risk exposure. The latter may only be an attempt to satisfy legislation and justify the safety case assumptions but will certainly be helpful in emergency situations.

Permit to work (PTW) schemes were highlighted in the Lord Cullen report into Piper Alpha disaster and hence have attracted considerable attention. The oil industry advisory committee (OIAC) has guidance for PTW systems and this includes a useful checklist for evaluating the adequacy of companies arrangements. Historically offshore companies have always used PTW schemes for a wide range of tasks ranging from the simple non hazardous like painting to the highly hazardous hot work. Different coloured forms are often used to indicate the nature of the hazard and all forms will be signed by the installation manager. In many companies the arrangements are cumbersome and form part of the work administration system. However, the PTW system can give a clear definition of scope of work and clarify interaction with other parties such as contractors. In addition there is a single point for co-ordinating work particularly at shift handover.

Release of hydrocarbons is the major concern on production plant. One particular safety case indicated that the installation was more vulnerable than most to explosion and pool fires. In response the company examined all hydrocarbon containing plant with the aim of trying to reduce the number of small bore connections such as instrument lines (a significant source of leaks). The company also sought to improve control of flange assembly by improving training, increasing inspection and switching to more reliable bolt tensioning methods.

4.5 Competence and training.

The ISOE report describes management commitment to a well educated and trained workforce; with knowledge of ALARA and acceptance of it for their own safety, i.e. being committed to ALARA. Team work is also emphasised. There is reference to the German system of highly trained workers with specific credentials.

In offshore industry when we speak of competence we mean education, qualifications, training and experience. The offshore industry is still grappling with the means to demonstrate competence in its specialist fields such as emergency command management. A number of companies, particularly contractors with a peripatetic workforce, use National Vocational Qualifications (NVQ) as a means of demonstrating competence. NVQs have elements of theory and training, and require a demonstration of competence through a structured range of exercises. Whilst NVQs are available in many disciplines from plant operator up to manager there is some scepticism of their value.

Some companies use simulators to train workers in the more hazardous processes but few would go as far as the description in Chapter 6, i.e. using mock-ups to train workers and then select those that are most efficient.

It was noticeable that the ISOE report mentioned 'periodic refresher training in work management and ALARA should be used to reinforce good habits'. Refresher training is not widely used on the UKCS except for specific activities, e.g. personal survival training, some aspects of fire-fighter training.

A growing area of interest for the offshore industry has been in emergency management training. It is true to say that in early years training was generally confined to musters and drills. Now much greater emphasis is given to selection, development and appraisal of managers to deal with credible emergency situations arising from safety case work. The more advanced companies develop and appraise offshore teams for both technical competence and managerial competence. Development and appraisal is carried out using onshore simulators and then through offshore exercises. There is however, a strong division of opinion between those who promote the value of training managers supported by a team of role players and those who wish to see the manager and team assessed together.

One or two companies believe that the lessons learned in assessment of people for emergency command situations can be used to assess how individuals behave in normal management situations.

Finally with the above comments on training and development in mind, the ISOE report deals extensively with motivational and other aspects of workforce involvement but perhaps it does not pay sufficient attention to selection of people.

4.6 Selection and control of contractors

Contractors have a major impact throughout the lifecycle of an offshore installation. They are widely used during design, commissioning, operation and abandonment. Indeed some companies operate installations using forty staff where only the manager belongs to the host company. In many cases the contract companies are responsible for assessment, training and development of their employees. The host company elects to monitor the systems.

The earlier comments in section 4.1 on the changing policy towards contractors is also affecting existing installations. Companies are improving working relations through setting common objectives, having common planning systems, taking part in common audits and jointly investigating accidents. The more advanced companies ensure that senior contractor managers are involved in developing and reviewing all aspects of the joint management system. It is perhaps too early to see the consequences of this policy change. On small platforms with a single dominant contractor it is difficult sometimes to separate contractor from company employee whilst on the larger platforms with numerous contractors there is some way to go to unite different contractor groups into an integrated workforce.

The incident rate for contractors is noticeably higher than for company employees but that may simply be due to their involvement in more hazardous activities.

The report recognises the importance of contractor involvement in planning in Section 3 of Chapter 5, but it is qualified by the term "somewhat limited because the contractors are not physically present on site much before the job is started". The contract employees may see this as weakening the demonstration of commitment by senior management in the nuclear industry.

4.7 Monitoring, Auditing and Review.

Monitoring is considered to be a line management responsibility and comprises active monitoring and reactive monitoring.

During active monitoring, supervision and management check compliance against operational standards, procedures and performance standards. There is much debate in the industry on monitoring and measuring performance as the industry delayers and removes levels of supervision. On the one hand, having supervisors check that operators have carried out tasks can lead to loss of responsibility for that task. This situation has certainly existed in the past. On the other hand some jobs are so important that a check is necessary. One company's solution has been to discuss critical tasks in the toolbox talks held prior to commencement of the task, and then require checking that the task has been completed either by a supervisor or by peer review.

Additionally there is an important balance between monitoring and self discipline. Some companies introduce the idea of line discipline whilst trying to ensure that a no blame culture exists. This topic has not however received a high profile in the safety cases.

It is noticeable that this report focuses on the importance of reducing occupational exposure but little is mentioned of control of activities that could lead to a major hazard. Presumably this is outside the intended scope of the report. There is a debate in the offshore industry on whether effort spent in achieving good control of occupational injuries such as slips, trips and falls will benefit control of major hazard risks. There is no correlation between the two but companies spend considerable effort to eliminate minor injuries.

Reactive monitoring occurs when companies are following up accidents, incidents or losses. The accident rate has been falling over the last few years although there are still significant gas releases. Companies use non-injury incidents as a source for continuous development. Many companies categorise the potential for incidents and will mobilise an investigation team with an authority level to reflect the potential of the incident.

It was noticeable in the report that post job briefing, the use of the mishaps analysis grid and in Appendix 3 of Chapter 8 rework analysis is used to achieve similar objectives.

The safety case regulations require auditing by parties independent of line management. Companies try to have people who do not have intimate knowledge the processes and activities in question to assess and challenge the line management norms. This is particularly difficult to achieve when auditing the higher levels of management and it is only achieved effectively when senior individuals are selected from outside the management unit. Some companies audit to excess, it is very repetitive and hence becomes mechanistic and not particularly challenging. In those companies where the culture is right, auditing is proving challenging and constructive.

There is little in the draft ISOE report about auditing.

Offshore companies have a range of approaches for reviewing the effectiveness of their SMS. At the most senior level a committee of senior management will periodically consider if the company is meeting performance targets and will also review the content and progress in closing out audit recommendations.

5. Concluding remarks

Following the Piper Alpha tragedy the offshore industry has made considerable progress in reducing incidents and accidents. Many within the industry believe this has been brought about by senior management paying greater attention to safety. To quote Lord Cullen from the public enquiry

"The top men in Occidental were not hard-nosed and uncaring people interested only in profit and unconcerned about safety. They said and believed all the right things but they did not get involved in the precise actions required, see that they were carried out and monitor progress."

In support of the intentions of the ISOE report, many safety professionals in the offshore industry believe that further progress will only be achieved if senior management begin to pay similar attention to the role that individuals play in applying the safety management system. Workforce diligence in implementing detail and their enthusiasm for improvement will only come about if senior management create the right conditions.

ANNEX IV

Participation List

NEA WORKSHOP ON WORK MANAGEMENT AND GOOD PRACTICES FOR REDUCING OUTAGE COSTS, DURATION AND EXPOSURE

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WORK MANAGEMENT IN THE NUCLEAR POWER INDUSTRY

As we near the beginning of the 21st century, the industrialised world continues to change. Economic pressures in all facets of modern industry have made productivity and cost competitiveness increasingly essential to the very survival of companies. Many of them have therefore adopted a very global approach to their work, stressing the importance of considering jobs from a multidisciplinary team perspective, and of following them through all stages of conception, design, planning, preparation, implementation and follow-up. This focus assures successful job completion – on schedule, within budget, with a sufficient level of quality, with minimum cost, and with a maximum chance of fulfilling the originally desired goal. This multidisciplinary, start-to-finish approach to jobs can be broadly termed Work Management.

This publication presents the concept of Work Management in very concrete terms: it presents details of how to implement Work Management in such areas as regulation, work management policy, worker involvement, work selection, planning and scheduling, work preparation, work implementation, and work assessment and feedback. Numerous case studies are presented of actual experience from the commercial nuclear power industry. This is a useful tool to help plant managers, maintenance engineers, outage planners, and radiation protection personnel to improve their implementation of work management, which can lead to reduced numbers of workers needed to perform a job, of person-hours spent in the radiologically controlled zone, and thus the overall cost of doing work. Moreover, this also leads to reduced occupational exposures in an ALARA fashion.

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