ES7800226

INIS-mf--4474

N E A SEMINAR ON THE STORAGE OF SPENT FUEL ELEMENTS

Madrid, 20th - 23th June 1978

EXPANSION OF CAPACITY OF SPENT FUEL POOLS AND ASSOCIATED PROBLEMS

J.L. de Francisco, J. López-Cotarelo, J.Mª Ramos

S E N E R, Técnica Industrial y Naval, S.A. Bilbao (Spain)

SENER

EXPANSION OF CAPACITY OF SPENT FUEL POOLS AND ASSOCIATED PROBLEMS

J.L. de Francisco
J. López-Cotarelo
J.M. Ramos
SENER, Técnica Industrial y Naval, S.A.
Bilbao (Spain)

Expanding the spent fuel storage pool capacity is a good solution for utilities facing the current shortage in fuel reprocessing capacity. This paper reviews the problems more likely to be found when expanding a spent fuel storage facility by using high density storage racks. Basically three types of problems arise:

1. Problems related with the characteristics of the new facility

2. Problems related with the works of expansion, and

3. Problems related with the long term storage of large quantities of spent fuel.

SENER

INDEX

SENER

1. Introduction

The current situation at the back end of the nuclear fuel cycle is dominated by two unfavourable conditions: (1) the delay of the reprocessing industry to develop and put in operation the adequate reprocessing capacity, and (2) the concern recently arisen about reprocessing with regard to the non proliferation question.

For the utilities operating or building nuclear power plants, this means that in a future that ranges about ten years from now, they will not have the possibility of sending their spent fuel for reprocessing and consequently will have to keep it while a solution is worked out.

The immediate course taken by a great number of utilities operating nuclear power plants, has been to expand their spent fuel storage facilities, installing high density racks that allow an average increase by a factor of 2.4 in the spent fuel storage capacity.

This paper outlines the different problems that arise when such expansions are implemented, specially when the spent fuel storage facility is already operating and there are fuel elements stored in the pool.

The main purpose of the paper is therefore to show the way in which the expansion of a spent fuel storage facility leads to a wide series of technical problems whose solution depends on a careful engineering work.

The paper also outlines the actual trends and criteria to be considered when solving the above problems in order to implement a spent fuel storage facility expansion under the appropriate safety and operational requirements.

2. Analysis of the technical characteristics of the new facility

2.1 Analysis of existing buildings and structures to verify compliance with new design criteria

The expansion of the capacity of a spent fuel pool means an increase in the weight the pool floor must support, as the number of spent fuel elements stored per unit area increases, as well as the amount of structural material (racks).

To get a better feeling some figures are given: (1) weight of water in a typical spent fuel pool, 1200 t; (2) total weight per storage position, (PWR, typical) buoyancy excluded, 620 kg; and (3) total weight per storage position (BWR, typical) buoyancy excluded, 240 kg.

For a typical PWR plant it was customary to have a pool capacity for 1 1/3 cores; that amounts for a 1000 MWe plant to 120 t. For a typical BWR plant the usual practice was to have a pool with capacity for 1 1/4 cores; that amounts to 240 t, for a plant of the same output.

It is generally accepted that pool capacities can be increased by a factor of 2.4. Thus, the increases in weight become: (1) for a PWR plant 300 t, and (2) for a BWR plant 600 t, with an increase of 13.5% and 25% respectively.

These increases are quite significant and their effects must be considered from all points of view.

SENER

From the point of view of static loads, it must be considered that the effect on the floor is usually calculated considering that the maximum load per unit area applies to the whole floor slab. This gives a large margin which allows an increase in the total weight, enlarging the loaded surface.

However, there is an increase in the load per unit area of the order of 5-10%, which can be accomodated by using more refined calculational methods which may show an extra loading capability on the existing structures or allow a reduction in the uncertainty margins.

The spent fuel pools are seismic category structures, which must be subjected to a dynamic analysis under safe shutdown earthquake (SSE) conditions. The increase of the weight stored causes a worsening of the dynamic situation, but this is significant only for pools situated at upper levels, as it is the case in BWR plants with MARK-I type containment buildings. Fortunately these pools were designed some time ago, and the refinements done in dynamic analysis current calculational methods, allow for load increases.

However, in these cases advantage can be taken of new analysis methods which allow racks to be simply resting on the pool floor. In this situation, coupling between pool floor and racks is of a sliding type, and a significant reduction in dynamic stresses is obtained.

The coupling between the pool (floor and walls) and the new racks presents some special problems, due to the incidence on the pool liner integrity.

The general practice is to make only fixed attachments on those pool areas where embedded roll bars already exist and to apply on the liner compressive stresses only and as low as can be obtained. This is achieved by increasing the number of legs; but there is a limit to the number of legs as, if too many are used, it might become difficult their adjustment to obtain an even load distribution.

The option is open to support the rack upper part against the pool side walls, but this would bring as a consequence that the walls would support dynamic loads, which, in some cases, they were not designed for. Nevertheless some designers have taken this option.

The ideas stated before can be condensed in the following points: (1) pool structure calculations must be reviewed to take into account load increases; (2) this constitutes no problem for structures at the ground level, unless old racks were attached to the pool floor only and the new racks are supported to the side walls; (3) on pools located at a certain elevation above the ground level, it could be interesting to use sliding type supports, with the purpose to improve working conditions, under seismic loads; and (4) the main concern, regarding rack-pool interaction, is to maintain liner integrity.

2.2 New rack structural studies

Racks are structural elements that must be designed to seismic category I and to other conservative requirements including: (1) due consideration to fuel element movements within their storage channels, simultaneously striking the rack under seismic conditions; (2) due consideration when analyzing horizontal stresses to trapped water within the rack and the associated water in the outside; and (3) due consideration to the maximum pull that could be exerted by the fuel element handling crane hook.

Typically a rack is formed by several square channels, where the elements are placed, which are solidly attached to a support structure. This support structure could be simplified if each channel and the corresponding fuel element were supported on the pool floor. But this solution requires it to be dry and clear so all feet adjustments can be checked. This situation is not the usual one; frequently the new racks must be installed while irradiated fuel elements are in the pool. In this case racks are built with a reduced number of legs (four or five) that can be adjusted from the fuel handling platform.

In the case of racks fixed to the pool floor, the structural design is enhanced by employing lateral supports between racks and to the pool side walls.

In the case of racks simply supported on the pool floor and thus with sliding capability, the structural design is simplified. But the dynamic analysis must include a displacement calculation under design bases earthquake, to establish separation requirements between racks and between racks and side walls, in order to avoid striking in case an earthquake occurs.

The basic design requirements for racks is to assure that under the most unfavourable solicitations no distortions will occur which alter neither the multiplication constant or the cooling conditions of the fuel elements.

2.3 Fuel elements cooling studies

The irradiated fuel elements generate heat as a consequence of fission products decay. This heat generation rate can be calculated according to various formulae as a function of burn-up and decay time.

Although at the beginning heat rate decays rapidly, by the time spent fuel elements are placed in the storage pool they generate still enough heat so that their cooling creates a problem that must be analyzed carefully. Once the elements are stored in the pool, they are being cooled by natural convection; the use of high density racks may hinder this process, thus becoming necessary to analyze it in detail.

Two design criteria can be established: (1) a limiting cladding temperature, and (2) film boiling not reached.

In any case the riser flow path cross sections are to be studied, specially around the fuel element to avoid a local boiling that could blow the water from a large area. Adequate flow path cross sections must be provided for the down-coming water and the circulation of cold water, from the pool inlet to the lower part of the worst located element, must be carefully studied.

It is advisable not only to make a simple convection analysis of the "worst" fuel element, both from the point of view of location and heat generation, but to study the pool overall convection pattern. This study must be done with the cooling system in operation and out of service.

2.4 Spent fuel pool cooling capacity review

The Standard Review Plan (1), establishes that the pool temperature will not exceed 60°C and the water level will remain constant for the maximum heat

(1) Standard Review Plan, Section 9.1.3, 11.24.75, "Spent Fuel Pool Cooling and Clean-up System".

SENER load and with the normal pool cooling system in operation. More restrictive requirements could be imposed, both in normal and abnormal conditions, to avoid too high humidity in the spent fuel building atmosphere and roiling of the pool water.

Usually spent fuel pool cooling systems are designed with some extra capacity or for operating conditions whose severity can be reduced without jeopardizing safety and, in many cases, those cooling systems can be supported by other plant cooling systems.

Another point to be taken into account is that after one year storage the heat generated by an irradiated fuel element is about 20 times less than the heat generated a few hours after full power operation (when it is transferred to the pool). This leads to the conclusion that no problems would be met with cooling systems capacity, except in the subsequent period after refuelling.

Nevertheless, the pool cooling system capacity must be reevaluated under normal operating conditions, abnormal operating conditions, accident conditions, etc.

The worst case must be analyzed, that is, that the pool water reaches the boiling point and the emergency make-up water system must be placed in operation. If, as a consequence of this analysis, an unacceptable condition is found, a decision must be taken; either to increase the capacity of the spent fuel pool cooling system or to increase fuel element cooldown time within the reactor vessel. Needless to say that both solutions have a heavy penalty money-wise.

2.5 Spent fuel pool purification systems capacity review

The capacity of this system will be affected during the construction phase as well as during the subsequent storage. It is expected that no changes are required in the system design and that the design requirements regarding water clarity, chemical purity, activity, etc., will be met. However, system operating time would be affected, as well as frequency of filter cartridge changes, frequency of resin changes and/or accumulated activity in those components. These parameters must be evaluated.

The main contamination sources of the pool water are: (1) reactor coolant, which has gone through a purification process during the cooldown period, and (2) deposits on fuel element cladding (crud).

During the pool modification operations another contamination source will be present: deposits on the various pool structures that will be affected by the different operations done on the pool.

For the above reasons it is necessary to perform adequate theoretical and experimental analyses and to forecast contaminant increases and the new operating times of the system during the modification works and subsequent operation. From these analyses the conclusion would be drawn on wether changes are needed or not and on the new operating times.

Other aspects to be taken into consideration, when analyzing the new purification needs, is the fact that long term storage of fuel elements increases the radioactive product leaks from fuel rods. Fuel pellets leaching seems a negligible possibility.

2.6 HVAC systems capacity review

The fuel building HVAC systems are affected basically for the following reasons: (1) an increase in the amount of evaporated water, as a consequence of somewhat higher water temperature; (2) an increase in the amount of radioactive gases that could be released from the fuel elements, as a consequence of a larger number of elements stored in the pool; and (3) the higher amount of evaporated water leads to a higher amount of iodine released to atmosphere.

These three facts lead to the need to review the HVAC system design and to evaluate its capacity to cope with the new working conditions, both during the modification work as well as during subsequent operation.

The relation between the overload that the HVAC system and its components are being subjected to and the higher evaporation and removal of heat generated must be forecast and studied. System operating procedures must be reviewed.

2.7 Radwaste systems impact studies

As a consequence of storing a higher number of fuel elements the spent fuel pool purification systems and the HVAC systems would operate during longer periods of time and, as indicated before, filters, resins, etc., would be changed more frequently. These operations would lead to a higher consumption of water for resin regeneration, resin changes, etc; altogether it would cause an increase in the amount of radioactive waste produced. Although the problem created by this increase is not important with regard to the total amount, it is convenient to establish an upper bound so as to know its incidence upon the operating conditions and radwaste transportation and storage requirements.

It is estimated that the amount of solid radioactive waste generated during the expansion work can be between 0.5% and 3% of the total amount of waste generated annually by the plant, when averaged over the plant lifetime.

In addition, it is also estimated that the increase in solid radwaste due to the operation of the expanded facility will be about 1% of the waste production before expansion (2).

2.8 Radiological analysis of the new facility

With the purpose of knowing the radiological conditions of systems or installations which process radioactive materials, a radiological analysis should be made. The objectives of this analysis would be to know in detail the radioactive material inventories and their isotopic spectra for normal operating conditions, for postulated abnormal conditions and for the maximum expected conditions. This would give the basic information to determine the required shielding, to know the ambient conditions and to know radioactive product releases in normal operating conditions or in accident conditions.

The radiological analysis starts with the radioactive materials primary source within the fuel elements, their transfer mechanism to the pool water, their diffussion through the water, their retention by the purification

(2) "Environmental Impact Appraisal by the Office of Nuclear Reactor Regulation Relating to a Modification to the Spent Fuel Pool for Facility Operating License No. DPR-28" Vermont Yankee Nuclear Power Corporation. Vermont Yankee Nuclear Power Station. Docket No. 50-271.

components, their deposition on pipe walls, etc.

Once the data on the isotopic spectra and concentrations of the various radioactive materials are known at the different location and components, the radioactive sources, the required shielding, and the access and operating conditions would be calculated.

This would allow to (1) decide the suitability of old shieldings or the need to enlarge or modify them; (2) know radiation levels at the pool surface during the different phases of fuel handling, including pool expansion operations and subsequent storage; (3) know the new radioactive levels in the cooling and purification systems; and (4) to know radioactive material accumulation on the process systems, their required shielding , etc.

2.9 Fuel handling procedures review

It is not expected that the extension of capacity of a spent fuel pool would bring important changes to the fuel handling procedures. This is a matter that depends strongly on the particular pool being considered. Nevertheless a careful review of fuel handling procedures must be done and, if deemed appropriate, changes in procedures would be implemented and described in the safety analysis report. As a general view, the following points should be kept in mind: (1) some handling problems could arise in those pools where the cask storage pit is not physically separated from the spent fuel pools; (2) a logical storing sequence must be established so that individual element cooling is enhanced and fuel drop risk is minimized; and (3) establishing interlocks and/or administrative controls to avoid a fuel element passing between racks and walls or between racks should be considered.

In the case that radioactive contaminated pieces are stored in the pool their handling procedures should be evaluated and reviewed.

2.10 Criticality studies

The design of a facility to store fuel elements must assure its safety and its subcriticality during normal operating conditions as well as under postulated accidents.

To assure the above conditions, criticality studies are performed based on the following hypothesis: (1) the fuel has the highest enrichement that could be possibly employed in the plant; (2) an infinite storage lattice is to be analyzed; (3) if absorbent materials are used, their absorbent properties will be considered in a conservative manner; (4) no credit is to be taken for movable poison curtains or control rods; (5) no credit is to be taken for poison disolved in the pool water, such as boric acid; (6) allowances should be made for uncertainties in manufacturing and in calculations; (7) effects of an optimum moderating condition should be considered; (8) abnormal positioning of fuel elements should be considered, such as a fuel element being moved on the space between the racks and the walls, or a fuel element lying flat on top of the racks; and (9) the maximum calculated k_{eff} must be less than 0.95.

Diffusion codes, specially developed for this purpose, have been shown to be adequate for criticality calculations. These codes could be complemented and checked with codes based on Montecarlo calculation techniques.

Another interesting aspect is to install in the facility radiation monitors to measure or to detect fission neutrons, thermal neutrons, gamma radiation, surface contamination, etc.

2.11 Accident analysis

In practice this analysis does not require any kind of special treatment, as the most important accident analyses have previously been done for the original facility. For example, the radiological consequences of the fuel handling accident will be practically the same. Nevertheless, it will be necessary to analyze with certain detail some specific aspects related to possible accidents during pool capacity expansion works, as well as during the subsequent operation.

As regards this point it should be analyzed: (1) fuel element drop and its effects on the new racks, consider that a fuel element drop (a) should not cause unacceptable distortions on the new racks neither to the fuel elements; (b) should not cause a k_{eff} above 0.95; (2) the consequences of a failure in the spent fuel pool cooling system, considering the new geometric and thermal conditions, created by the extension of capacity; (3) the consequences of dropping objects on the pool that might lead to the plugging of a fuel element cooling channel or to distort the water flow in specific areas; and (4) expansion work procedures to foresee and to avoid accidents, as well as to evaluate and minimize its consequences.

2.12 Safety analysis report

It is an usual practice in the project of a nuclear facility to make a safety analysis report, which includes information regarding the nature, characteristics and purpose of the facility. This information allows the licensing body to review and to evaluate the facility, so it can be constructed, erected and operated without an undue risk for the safety and health of the public.

The safety analysis report to be prepared for an expanded spent fuel pool facility must cover two different parts: (1) work related to the expansion of the pool capacity; (2) facility operation.

A typical break-down of such a safety analysis report should be as follows: (1) old facility description; (2) description of changes to be made; (3) description of expanded facility as finished; (4) radiological studies; (5) radioactive waste generation; (6) installation, erection, and commissioning procedures; (7) technical specifications; (8) accident analysis; and (9) quality assurance program.

2.13 Technical specifications

Regarding technical specifications a point should be kept in mind. The bases for k_{eff} calculation actually place an upper limit on the fuel enrichment that must be reflected in the technical specifications; this limit might bring, later on plant life, a limitation on plant operation, as is the case when it is decided to go to an 18 month cycle. This point should not be overlooked and should be properly evaluated.

3. Tasks related with the expansion of facility

Section 2 deals with questions regarding the expanded spent fuel storage facility. The following paragraphs will deal with the proper expansion activities and outline the procedures to be followed for such activities.

3.1 Existing fuel rack removal procedures

When expanding the capacity of spent fuel storage pools in operating plants, two basic options are available: (1) fill the free spaces between the existing racks with new high density ones, or (2) substitute high density racks for all or part of the existing racks, in addition to better filling the available pool area.

Normally the second option is followed in order to get substantial capacity increases; in this case the existing racks must be removed with the pool full of water and with spent fuel stored in the vicinity of the working area.

The difficulty of this task depends on how the existing racks are installed. In some cases the task can be performed by a careful work from the platform above the pool and the proper use of special tools. In other cases, divers are required to cut the anchoring elements without damaging the pool liner. In a certain pool the divers had to cut a tunnel through the racks to get up to the anchoring points that were otherwise out of reach.

The success in this task depends greatly on its careful planning and on the preparation of very detailed working procedures. Working procedures must consider all the apects of the task in order to get the following objectives: (1) avoid accidents in the stored fuel; (2) minimize personnel doses; (3) avoid the possibility of troubles leading to the utilization of special and emergency procedures; and (4) speed up work execution.

If any task is considered specially difficult, it could be advisable to train the personnel involved by means of models and the use of the special tools under simulated conditions.

3.2 Facility inspection and preparation before installing the new racks

This job has two different aspects: (1) final inspection of the state and conditions of the spent fuel pool bottom to discover any relevant detail hidden by the installed racks before its removal; and (2) evaluation of the spent fuel building facilities, such as cranes, aisles, openings, hatches, platforms, etc., with regard to the work of removal and disposal of the existing racks as well as the installation of the new racks. Regarding this, it may be pointed out that sometimes the new racks are partially assembled inside the fuel building before installation in the pool.

The installation of temporary shieldings must also be considered in order to provide adequate protection for the workers in case the existing racks were strongly contaminated after removal.

3.3 High density rack supply and preparation at the site

High density racks delivery by the manufacturer must be preceded by a thorough inspection at the shop by the purchaser.

Detailed reception procedures should be prepared, including checking the spent fuel assembly storage channels verticality and centering.

Among the reception tests must be included the insertion and removal of a dummy fuel assembly into and from each storage channel, measuring the friction forces in both directions and verifying that they do not fall outside the specified range.

Transport of the racks can be troublesome if they are too large; therefore a modular design should be preferred and the rack modules could be pre-assembled inside the fuel building where they have to be installed.

Sometimes, however, the pool bottom conditions are such that they exclude the use of standard modules and force the design of "tailor made" racks that can be difficult to transport and handle.

3.4 High density rack installation procedures

In every pool expansion job, detailed installation procedures for the new racks must be prepared in order to perform correctly this most important activity. These procedures should include an appropriate treatment of the following aspects: (1) location accuracy; (2) adjustment of the supporting legs so as to get a good contact with the floor without producing undue tensions; (3) coupling between racks; (4) rack anchoring in case it is required; (5) side stops between racks and with the pool walls; (6) personnel protection against radioactivity during installation work; (7) speed up installation work; and (8) falling objects accident prevention.

3.5 Decontamination and disposal of existing racks

Before removal of the existing racks their surface contamination and radioactivity must be evaluated and checked in order to adequately plan the tasks of disassembling, transporting and final disposing of the racks, and decision on the disposal alternatives.

Rack contamination can be of three kinds: (1) dry deposits or insoluble materials stuck to the rack surface; (2) radioactive materials occluded in the passivation layer that covers the rack surface; and (3) activation products.

It is foreseen that activation products will contribute a negligible amount to the racks activity, due to their service conditions under practically no neutron flux. However, activation effects must be evaluated with regard to handling and disposal activities, because these activation products cannot be removed.

Current experience does not suggest that occluded products have much importance regarding their radiological effects. Nevertheless rack pickling should be considered as a possible alternative, and the case for a thorough decontamination should be evaluated against the alternative of handling and final disposal of low activity radwaste, with the problems it brings with itself.

Most of the radioactive contamination of the racks is due to the cruds laid down on them, which can be removed by washing This washing operation should be carefully studied to decide whether it has to be performed in the spent fuel pool or outside it and its impact on waste production and treatment.

Eventually the racks should be considered as low activity solid radwaste, and disposed of as such after cutting them down into pieces in order to allow storage in a small volume.

3.6 Personnel dose evaluation and radiological operating procedures

Many of the spent fuel pool expansions when there are stored spent fuel assemblies, are performed under high radiation levels that require the installation of special shieldings, the removal or relocation of the radiation sources and by all means, the utilisation of special procedures during the work

In addition, due to the different tasks related to this work, a relatively high amount of people becomes involved and must remain in a limited area, thus meaning a dose accumulation in man-rem.

The different radiation sources to be considered in the area are: (1) the stored spent fuel assemblies; (2) the existing racks to be removed; (3) the rack decontamination products; (4) the pool water; (5) the building atmosphere, through which radioactive products can be inhalated; and (6) the radioactive background of the spent fuel pool facilities (in many cases the containment building, etc.).

Therefore the operations radiological risk, to which the personnel will be exposed to during the work, must be evaluated; such risk must be reduced as much as possible, as well as the accumulated dose. Therefore a detailed schedule and procedures for each task should be prepared in advance, based on the following points: evaluation of the potential radioactive sources, radiological classification of the different working areas, radiological classification of the different work steps, permanent (personnel and area) and temporary radiological monitoring and personnel decontamination procedures.

This planning and procedures will allow to make a suitable radiological evaluation of the tasks to be performed.

3.7 Industrial security

The special characteristics of the spent fuel pool expansions, when the pool is already operating and partially filled with spent fuel, require a detailed consideration of the security features. This work always involves a large amount of people, in addition to the plant staff, that will have access to a facility where considerable amounts of radioactive materials are stored and handled.

The security plan for the work is a part of the general security of the plant and should give attention to the following points: (1) control of personnel having access to the working area; (2) detection and location of intruders; (3) remote area watching; (4) parcel and box inspection; and (5) special security devices.

An emergency plan for the works, in relation with the Main Plant Emergency Plan, should also be foreseen from both the radiological and security points of view.

4. Special questions affecting the operation of expanded spent fuel storage facilities

Up to now in plant spent fuel storage facilities were designed for the storage of a fraction of the core during the period between two refuelings, plus a spare space for an emergency core discharge.

The foreseen storage time was short and the amount of fuel stored never was expected to be above two cores in the worst case. But the new developments in the spent fuel disposal problem have reversed the situation, originating a new set of problems whose final answer is still to be given.

The following paragraphs are an introduction to two of the most immediate problems to be faced by the operators of the expanded spent fuel storage facilities.

4.1 Problems associated with the material behaviour during long term storage in water pools

Current designs of spent fuel storage pools provide for about ten year storage and the existing pool expansions will follow this trend, so as not to be in disadvantage with regard to the new facilities.

In addition, independent storage facilities are being envisaged as an interim solution while a final decision is taken and put into practice as regards reprocessing.

In the latter case dry storage is considered as a possibility, but in the immediate future the more familiar underwater storage is most likely to be used as a solution.

Therefore, the behaviour of the different materials involved after long term immersion in demineralized water or boric acid solution, as is the case for the PWR, is a subject of utmost importance for the operators of the spent fuel storage facilities.

The fuel assembly materials are stainless steel and zircaloy, the last being used in most cases as cladding material. The spent fuel storage racks are usually of stainless steel or aluminium alloy; the second being preferred for the BWR pools where no boric acid is mixed with the pool water.

The fuel assembly materials have been exposed to severe radiation of all kinds before storage, and all the material will get high gamma ray doses during their service life. In addition, these materials are in contact between them, as well as with the pool liner (usually stainless steel), forming galvanic pairs whose long term effects are not well known.

In addition, many designs of high density storage racks include the use of neutron absorbers mainly based on boron compounds, which must remain in place and keep their absorbing properties during the whole service life of the facility. Current designs use encapsulated neutron absorber in aluminium or stainless steel cladding, but this solution may pose new manufacturing difficulties.

As a whole, the present picture shows a lack of data on long therm corrosion effects under the several situations to be considered and consecuently extensive research should be carried in experimental as well as in industrial facilities.

Last september the Battelle Pacific Northwest Laboratories prepared a survey on "Behaviour of spent nuclear fuel in water pool storage" (BNWL-2256/UC-70) for ERDA, whose conclusions are optimistic but cautious and recommend the exploratory examination of selected pool stored fuel, particularly for storage periods over twenty years.

4.2 Problems associated with industrial security for large amounts of stored spent fuel

The probability of spent fuel elements being stolen with the purpose of using their plutonium, should be considered very small, as these elements are highly radioactive and consequently of a very difficult and hazardous handling as well as reprocessing. Nevertheless, it is evident that a possible sabotage against a spent fuel storage pool, containing millions of curies, may have very serious consequences. For this reason, in the USA, the Federal Regulation 10 CFR 73 is also applicable to the spent fuel storage pools, with special reference to acts leading to spent fuel rupture and dispersal.

Therefore, after each spent fuel storage pool expansion, the Security Plan and Procedures should be reviewed and the protective measures around the storage pool reinforced in order to achieve a sound protection against intentional spent fuel rupture and dispersal.