COMPARISON OF REGULATIONS AND LICENSING PROCEDURES FOR FUEL CYCLE FACILITIES PARTICULARLY WITH REGARD TO EXTERNAL HAZARDS

Proceedings of a Specialists' Meeting
Salamanca, (Spain)

9th – 11th December 1986

COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS
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STEERING COMMITTEE FOR NUCLEAR ENERGY

COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS

Working Group on the Safety of the Nuclear Fuel Cycle

Comparison of Regulations and Licensing Procedures for Fuel Cycle Facilities, particularly with regard to External Hazards

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NEA

The OECD Nuclear Energy Agency (NEA) was established on 20th April 1972, replacing OECD's European Nuclear Energy Agency (ENEA, established on 20th December 1957) on the adhesion of Japan as a full member.

NEA now groups all European Member countries of OECD and Australia, Canada, Japan and the United States. The Commission of the European Communities takes part in the work of the Agency.

The primary objectives of NEA are to promote co-operation between its Member governments on the safety and regulatory aspects of nuclear development, and on assessing the future role of nuclear energy as a contributor to economic progress.

This is achieved by:

- encouraging harmonization of governments' regulatory policies and practices in the nuclear field, with particular reference to the safety of nuclear installations, protection of man against ionizing radiation and preservation of the environment, radioactive waste management, and nuclear third party liability and insurance;

- keeping under review the technical and economic characteristics of nuclear power growth and of the nuclear fuel cycle, and assessing demand and supply for the different phases of the nuclear fuel cycle and the potential future contribution of nuclear power to overall energy demand;

- developing exchanges of scientific and technical information on nuclear energy, particularly through participation in common services;

- setting up international research and developmental programmes and undertakings jointly organised and operated by OECD countries.

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-operative Agreement, as well as with other international organisations in the nuclear field.
The NEA Committee on the Safety of Nuclear Installations (CSNI) is an international committee made up of scientists and engineers who have responsibilities for nuclear safety research and nuclear licensing. The Committee was set up in 1973 to develop and co-ordinate the Nuclear Energy Agency's work in nuclear safety matters, replacing the former Committee on Reactor Safety Technology (CREST) with its more limited scope.

The Committee's purpose is to foster international co-operation in nuclear safety amongst the OECD Member countries. This is done in a number of ways. Full use is made of the traditional methods of co-operation, such as information exchanges, establishment of working groups, and organisation of conferences. Some of these arrangements are of immediate benefit to Member countries, for example by improving the data base available to national regulatory authorities and to the scientific community at large. Other questions may be taken up by the Committee itself with the aim of achieving an international consensus wherever possible. The traditional approach to co-operation is reinforced by the creating of co-operative (international) research projects, such as PISC and LOFT, and by a novel form of collaboration known as the international standard problem exercise, for testing the performance of computer codes, test methods, etc. used in safety assessments. These exercises are now being conducted in most sectors of the nuclear safety programme.

The greater part of the CSNI co-operative programme is concerned with safety technology for-water reactors. The principal areas covered are operating experience and the human factor, reactor system response during abnormal transients, various aspects of primary circuit integrity, the phenomenology of radioactive releases in reactor accidents, containment performance, risk assessment, and severe accidents. The Committee also studies the safety of the fuel cycle, conducts periodic surveys of reactor safety research programmes and operates an international mechanism for exchanging reports on nuclear power plant incidents.

The Sub-Committee on Licensing, consisting of the CSNI Delegates who have responsibilities for the licensing of nuclear installations, examines a variety of nuclear regulatory problems and provides a forum for the review of regulatory questions, the aim being to develop consensus positions in specific areas.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Background</td>
<td>5</td>
</tr>
<tr>
<td>I. OPENING OF THE MEETING</td>
<td>5</td>
</tr>
<tr>
<td>II. THE INTERCONNECTION BETWEEN SPECIFIC LEGISLATION REGARDING EXTERNAL HAZARDS AND THE TECHNICAL BASIS BEHIND IT (Country Presentations)</td>
<td>5</td>
</tr>
<tr>
<td>United States</td>
<td>5</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>6</td>
</tr>
<tr>
<td>Spain</td>
<td>7</td>
</tr>
<tr>
<td>Japan</td>
<td>8</td>
</tr>
<tr>
<td>France</td>
<td>9</td>
</tr>
<tr>
<td>Federal Republic of Germany</td>
<td>9</td>
</tr>
<tr>
<td>Belgium</td>
<td>11</td>
</tr>
<tr>
<td>III. DISCUSSION OF THE DIFFERENCES AND ANALYSIS OF THE TECHNICAL ISSUES</td>
<td>11</td>
</tr>
<tr>
<td>Extreme Environmental Conditions (wind, tornado, snow, flood, high and low temperatures, rainfall)</td>
<td>11</td>
</tr>
<tr>
<td>Earthquakes</td>
<td>12</td>
</tr>
<tr>
<td>Fire Hazard and Explosions</td>
<td>14</td>
</tr>
<tr>
<td>Missile Impact (aircraft crash, tornado-borne missiles, internally generated missiles)</td>
<td>15</td>
</tr>
<tr>
<td>IV. SUMMARY SESSION</td>
<td>17</td>
</tr>
<tr>
<td>Extreme environmental conditions</td>
<td>17</td>
</tr>
<tr>
<td>Earthquakes</td>
<td>18</td>
</tr>
<tr>
<td>Fire Hazards</td>
<td>19</td>
</tr>
<tr>
<td>Missile Impact</td>
<td>20</td>
</tr>
<tr>
<td>V. CLOSURE OF THE MEETING</td>
<td>22</td>
</tr>
<tr>
<td>Annex 1 List of Participants</td>
<td>23</td>
</tr>
<tr>
<td>Annex 2 Agenda for the Meeting</td>
<td>27</td>
</tr>
<tr>
<td>Bibliography</td>
<td>28</td>
</tr>
</tbody>
</table>
Background

At the plenary meeting of the Committee on the Safety of Nuclear Installations in November 1985, the delegates agreed that regular meetings of the Working Group on the Safety of the Fuel Cycle would, in future, take place every two years; in the years between such meetings, a Specialists Meeting would be organised by the working group on a subject of topical interest. This Report concerns the proceedings of the first of these Specialists' Meetings, held in Salamanca, Spain, at the kind invitation of the Consejo de Seguridad Nuclear of Spain and the Empresa Nacional del Urania S.A.

I. OPENING OF THE MEETING

1. The meeting was opened by Professor J. Jodra, Commissioner of the Nuclear Safety Commission (CSN) of Spain. In his welcome to the delegates, Professor Jodra recalled that the Working Group on the Safety of the Nuclear Fuel Cycle provided a useful forum for discussing the safety aspects of fuel cycle facilities. In particular, the 1981 NEA/OECD Report (Bibliography Ref. 36) on the Safety of the Nuclear Fuel Cycle, which had been produced under the guidance of the Group, had been well received and was used in several countries. Since the ICRP Criteria for Radiation Protection had to be applied to nuclear fuel cycle facilities, both the CSN and the Empresa Nacional del Urania S.A. (ENUSA) fuel fabrication company had thought it appropriate to host the Specialist Meeting at Salamanca, which is close to the ENUSA fuel fabrication plant at Juzbado and also to the main Spanish uranium field. Professor Jodra closed his introduction by wishing the delegates a successful meeting.

2. On behalf of the participants and the CSNI, the Chairman of the meeting, Dr. Baetslé, thanked the CSN and the ENUSA company for their offer to host the meeting and thanked Mr. J. Gonzalez, Director of ENUSA, for making the detailed practical arrangements for the meeting.

3. The Secretary reported that apologies for absence had been received from Mr. Chitwood (USDOE), Mr. Spoonley (United Kingdom NII) - represented by Mr. Smith, Mr. Ospino (Belgium, Belgoprocess), Mr. Guidotti (Italy, ENEA), and Mr. Hebel (CEC, Brussels).

4. The Agenda (SEN/SIN(86)54) for the meeting was adopted. (This is reproduced as Annex 2).

II. THE INTERCONNECTION BETWEEN SPECIFIC LEGISLATION REGARDING EXTERNAL HAZARDS AND THE TECHNICAL BASIS BEHIND IT (COUNTRY PRESENTATIONS)

In this part of the meeting, the delegates briefly outlined relevant issues concerning licensing procedures for fuel cycle facilities, particularly highlighting the diverse responsibilities of the various organisations concerned with licensing and regulation. The actual technical issues, although briefly touched upon in this section, were discussed more fully in part III of the meeting.

United States

5. Mr. Roberts briefly commented on the distinction between materials licences and facility licences. Materials licences were covered by the Title 10 (Energy) Code of Federal Regulations (CFR) - Parts 30 (by-product
material); 40 (source material (uranium)); 70 (special nuclear material (U233, U235; Pu)); and 72 (spent fuel storage). Facility licences for enrichment and reprocessing were covered by 10 CFR part 50 (Production and utilization facilities). Regarding 10 CFR Parts 30, 40 and 70, no specific requirements for protection against external hazards were stipulated, except where plutonium was being handled. Mr. Roberts also noted that the large and diverse land area of the United States was in many cases subdivided into geographical regions when considering licensing issues for fuel cycle plants. For example, high winds (except tornadic winds) of greater than 160 km/h were generally assumed to occur only in the region around the Gulf Coast; also, reference earthquakes of less than 0.2g horizontal ground acceleration were normally assumed, except on the West Coast.

6. Regarding non-10 CFR Part 50 facilities, several computer codes relevant to external hazards and the fuel cycle had been developed or were in the process of development:

FIRAC - this was an extension of FIRIN and was used for the calculation of through-facility fires. (Copies of the code were in use in Germany, Italy and the United Kingdom);

EXPAC - this calculated the effect of explosions within facilities. The code had still to be validated experimentally and no manual was yet available;

TORAC - this code calculated the effect of the passage of a tornado through the facility. Again, the code had still to be validated and no manual was available yet.

7. On 10 CFR Part 50 facilities, Mr. Roberts commented that no commercial fuel reprocessing was performed in the United States, and all uranium enrichment was under the control of the Department of Energy. Mr. Roberts also noted that URENCO were seeking to enrich commercially in the United States.

United Kingdom

8. Mr. Smith noted that regulatory responsibility for commercial fuel cycle facilities was with the Nuclear Installations Inspectorate (NII) of the Health and Safety Executive. Neither Government departments nor the U.K. Atomic Energy Authority (UKAEA) needed licences, although they were required to conduct their nuclear affairs to the same standards as commercial licensees. The basic philosophy was twofold: all that was reasonably practical must be done to ensure safety; and the responsibility for safety rests with the licensee. It was not a requirement that probabilistic safety assessments should be used in safety assessment, but many occasions arose where engineering judgement had to be used - such as quantifying rare external events. In the assessment of seismic issues, the return period used was 10,000 years and consequently some extrapolation of real data was needed. The NII expected some sort of sensitivity study to be performed by licensees to see if any "cliff edge" effects existed just beyond the design base where a rare event had serious consequences. This approach could be extended to other hazards (for example coastal flooding) where historical data was poor. Regarding man-made external hazards, a combination of statistical and probabilistic methods was required.
9. Mr. Sheppard commented that the seismic event was often regarded as the "umbrella" event in the United Kingdom. Licensees proposed and defended their safety cases against a "lack of objection" response from the regulatory body. For external hazards, the deterministic approach was that most frequently used and this started by an estimate of a (site specific) 10-4 probability earthquake, from which the anti-seismic design of the plant evolved. In the case of high winds, floods, etc., a different approach was taken, the facilities being designed against a "once in 50 years" rate of occurrence and the structural response to a 10-4 situation was evaluated. Replying to Dr. Baetslé, Mr. Sheppard noted that the THORP complex was designed against a 0.25g horizontal ground acceleration which equates to a 10,000 year return period event. The performance was also evaluated against 0.35g to give a measure of confidence against cliff-edge effects.

10. Dr. Brown noted that, within the UKAEA, the Safety & Reliability Directorate was responsible for central safety advice and oversight. UKAEA existing plant (some of which was old) was surveyed and judged against standards on a case-by-case basis.

11. The most recent new plant to be suggested is the proposed European Demonstration Reprocessing Plant (EDRP). This would be part of the European fast reactor collaboration, and would service about four commercial sized reactors. For this plant, overall risk related design targets had been adopted of 10-7/a for an individual risk of death (immediate or delayed) in an accident, and 10-6/a for an individual risk of death in routine operation. These are for the public. Worker targets were also adopted.

12. Aircraft crash probabilities had been assessed at about 6 x 10-5/a for a light aircraft and 6 x 10-6/a for a cargo aircraft, crashing on the Dounreay site. Both these probabilities required consideration of anti-crash designs, but current opinion is that the buildings around areas of high radioactivity inventory are adequate by design for other reasons, largely shielding in the more active areas. The frequency of high speed military aircraft crash was felt to be sufficiently low not to require specific protective measures.

13. Effects caused by the occurrence of extreme temperatures, high winds, rainfall and snow were likely to be encompassable within the normal design base, which was reviewed against the 10-4 return period event. There was a difficulty for the coastal site as there is an extremely poor data base for high wave heights, and hence great uncertainty in the specification of a 10-4/a event. Using some statistical extrapolations gave values in excess of 30 m height. Seismicity at Dounreay was assessed to be lower than the average for the United Kingdom, but at the present the same building design standards, as noted by Mr. Sheppard, were being used. This was recognised as giving an increased margin of safety.

Spain

14. Mr. de Carlos described the design criteria applied to the licensing of the Juzbado Uranium Oxide Fuel Facility (Bibliography Ref. 32). On the analysis of external risks, hazards satisfactorily taken into account included maximum flood level (a dam in the Tormes river was located upstream of the plant); hurricanes; snow and ice; and a combination of accidental conditions and natural phenomena. The most serious postulated accidents at the plant
were a large fire or a criticality accident. The Juzbado plant shop was not designed against external missiles (there was no commercial airport in the area and the site was far from highways). Special consideration of seismic qualification for the fire protection system at Juzbado had not been required although where seismic design was included a design basis event of 0.15g phga was used; combustible materials had been avoided in the construction and the existing walls were fire resistant for at least 150 minutes. Although two different fire protection systems had been specified for the plant, an additional fixed CO2 extinguishing system was installed in those areas where a fire would produce a breakdown in the safety systems.

15. On the use of fire hazard analysis to calculate risk from fires, Dr. Sütterlin commented that it was sometimes simpler to use passive procedures. Mr. Rodrigo replied that the use of combustible materials had been avoided and materials such as petrol were kept in auxiliary buildings. Professor Jodra commented on methods for reduction of risks from the use of hydrogen - oxygen bottles were installed outside the building walls. On the use of probabilistic safety assessments, Mr. Rodrigo commented that level 1 PSAs were to be performed on all Spanish nuclear power plants soon, and the approach would probably be extended in time to nuclear fuel cycle facilities. Mr. Roberts commented that the Spanish regulations regarding anti-seismic design appeared more conservative than the norm. Professor Jodra replied that, according to Spanish legislation (of 1964) the facility had to be regarded as a nuclear facility, not a radioactive facility.

16. Regarding safety criteria for site selection for radioactive waste disposal in Spain (see Bibliography Ref. 33), Dr. Brown asked if acceptance criteria would be probabilistically or deterministically based. Mrs. Rulz-Lopez replied that as radiological criteria, i.e. doses or levels of radiation, were being considered then probabilistic methods could be employed. Professor Jodra added that the criteria were not yet embodied in Spanish law. Replying to Dr. Baetslé, Professor Jodra also said that two low-level repositories were planned for 1990 and one high-level repository for 2015, and that all suitable geological structures in Spain were to be investigated before firm decisions on quantification of criteria could be made.

Japan

17. Mr. Iwanaga noted that regulatory guides for the licensing of reprocessing facilities had been issued in February 1986. These guidelines stipulated basic requirements and included: estimation of doses from releases during normal operation; safety assessment of abnormal transients; and requirements concerning seismic design. External hazards were categorised as either man-made (fires, explosions, missiles, etc.), or natural (geological meteorological, geo-hydraulic, etc.). Regulatory Guide 13 (Considerations on Earthquakes) classified the facilities according to the potential effects of radiological releases to the environment after earthquake-induced damage. Of these classifications, Class A facilities (those having the greatest potential effect on the environment) included facilities whose failure or functional loss could cause a criticality accident, spent fuel storage facilities and facilities containing plutonium in solution. Guide 14 (Considerations on Natural Phenomena other than Earthquakes), specified requirements against, for example, tsunamis, ground slides, typhoons and heavy snowfalls. The design bases considered in this guide were more severe than those which were known to have occurred in the past. Guide 15 (Considerations on Fire and Explosion), specified that the plant should be so designed that the confining function should be properly maintained even if fire and explosion should occur.
18. Evaluation methods following the above guides were currently under examination by the regulatory body, and in terms of aseismic design evaluation similar methods were used for reprocessing plants as for nuclear power plants. In the safety evaluations, a "design basis event" was selected to confirm a defence-in-depth principle for the design of the facility and a "site evaluation accident" was assumed for the evaluation of isolation distances.

France

19. Dr. Grall commented that regulations concerning nuclear power plant had been adapted to the specific situation concerning nuclear fuel cycle facilities. Both deterministic and statistical methods were applied in the quantification of external hazards. A deterministic approach was used for earthquake consideration and a statistical approach for aircraft crash. In the case of fire assessment a dual approach was followed, in that deterministic methods were used for assessing the causes and statistical methods were used for assessing the consequences. Regarding earthquakes, a deterministic approach was used on two fronts: for the geological knowledge of the site; and for a historical categorisation of earthquakes. For this latter aspect, seismic "provinces" (regions of seismic homogeneity) had been defined and the maximum possible (probable) earthquake within each of these provinces assessed - then a one level higher earthquake was assumed to be possible. An additional factor was considered in the case of old facilities in that "local" rather than "regional" reference earthquakes were used in the assessments.

20. On assessment of aircraft crash on fuel cycle facilities, Dr. Grall noted that the whole potential area of the facility was calculated – taking into account relevant approach angles. Contrary to the general distribution of military aircraft crashes noted in the United Kingdom, military aircraft crashes in France were found to be concentrated within 20 km of military airfields.

21. On fire assessment, Dr. Grall commented that use of statistically based methods for the assessment of the likelihood of fires was difficult, if not impossible, although it was possible to derive the probability of fires having certain consequences. Filters (capable of operating up to 200°C) were used and great importance was placed on fire prevention, in that the minimum flammable inventory, and the smallest possible entities, were used in compartments to stop fires spreading.

22. Mr. Berger said that for the new reprocessing plant at La Hague, regulations specified that the plant should either withstand a magnitude 8 (M.S.) earthquake or it should be demonstrated that the consequences were acceptable. Design of the reprocessing facilities at Cadarache took account of the risk from aircrash involving the firefighting aircraft in the area. Regulations concerning the storage of uranium hexafluoride took into account the risks arising from propane transport in the near vicinity of the plant, and measures were taken to prevent flooding of burning propane into the installation.

Federal Republic of Germany

23. Dr. Mathlak briefly summarised the legal basis of the various Atomic Energy Acts, the various Ordinances & Regulations, and Safety Guides, in force and in use in Germany. The Atomic Energy Act was in place to protect life,
health and property against hazards from nuclear energy, ionising radiation, etc. Concerning Ordinances & Regulations, the Radiological Protection Ordinance was the most important (in the context of this meeting), in that it specified dose limits. Regarding Safety Guides, Dr. Mathiak noted that conventional guides were not adequate for the assessment of earthquakes, explosions, aircraft crash, flood, fire etc., on nuclear facilities. He commented that in any discussion on licensing regulations an understanding of the relevant political structure was necessary. In Germany the eleven Länder (States) were subject to Federal Supervision regarding implementation of the Atomic Energy Act, and the Minister for the Environment, Preservation of Nature and Reactor Safety (BMU) prepared the Ordinances and issued the Safety Guides. Asked if radiation dose limits were applied to each individual installation, Dr. Mathiak said that if buildings had a functional connection then they were assessed as a single installation, but if there was no interdependency then the buildings were assessed separately. Regarding the release in normal operation however, the preload of the site has to be taken into account. Regarding Safety Guides, Dr. Mathiak noted that conventional guides were not adequate for the assessment of earthquakes, explosions, aircraft crash, flood, fire, etc. on nuclear facilities. Cost benefit analysis was used to some extent, although safety aspects were paramount.

24. Dr. Sütterlin continued that the necessity to protect a nuclear facility against external impacts depends on the risk being attached. Due to the risk, the external impacts can be divided into Common Events, Accidents, and Hypothetical Events. Common Events are connected with practical experience such as snow, wind, etc., and the design loads have frequencies of 10^{-2} to 10^{-3} per year; the goal of protection is to prevent any harm on the nuclear facility and releases of radioactivity that exceed the limits of normal operation. The codes and standards to be met by the design against Common Events were the same for any industrial plant and installation, nuclear facilities included (general design). These were the Federal Codes e.g. DIN-Codes and the codes of the individual Länder (States), e.g. LBO, a civil engineering code that gives the special standards and regulations in the States and which is of particular importance in the context of this meeting. For accidents such as earthquakes, internal fires and explosions the goal of countermeasures is to keep the release of radioactivity within the limits of permitted accidental release as laid down in the radiation protection ordinance. It is common experience that accidents have frequencies up to 10^{-4} per year. Regarding safety Dr. Sütterlin noted that the conventional guides were not adequate for the design against accidents and he explained the application of the KTA-rules for the design against earthquakes which originally had been set for nuclear power facilities only, but they were helpful to grade the accident countermeasures for other nuclear facilities too. Hypothetical events have frequencies beyond 10^{-4} per year; countermeasures to reduce risk were met by technical as well as organisational means. Especially for aircraft crash and external explosions, the necessity of additional design depends on the anticipated hazard that may result when an aircraft hits the nuclear installation (nuclear risk); this risk is compared with the existing risk of an aircraft crash in the environment of the nuclear facility (conventional risk). If the nuclear risk exceeds the conventional risk the facility will be designed against aircraft crash and external explosion respectively; the design itself is then based on deterministic load assumptions. Some sort of cost benefit analysis is used, although safety aspects are paramount. Dr. Sütterlin pointed out that the major external impacts, especially aircraft crash, were regarded as the umbrella events.
Belgium

25. Dr. Baetslé commented that the Royal Decree of 28th February 1963 was still valid in Belgium, and defined the rules which must be observed to protect the population and the workers against risks from ionising radiation. The Decree was currently being adapted and updated to include present knowledge. Regarding new or refurbished nuclear facilities, the licensee prepared a preliminary file which was discussed at local, provincial and national levels in turn. The construction phase of facilities was subject to a construction permit, which could be granted after a PSA had been performed and a Safety Analysis File prepared. This PSA considered the impact of the plant on the environment and also took into account the effect of external hazards. The procedure for exploitation required a complete detailed description of the facility and a satisfactory commissioning test, as well as the completion of a personnel distribution sheet. An exploitation permit was granted by Royal Decree, and followed a review of the safety record of the plant and also inspection of the facility by suitably qualified organisations.

26. Dr. Baetslé then illustrated this procedure by describing the design approach defined during the study of the possible re-opening of the former Eurochemic reprocessing plant, shut down in 1974 for non-technical reasons. During this review, internal and external hazards considered were: extreme environmental conditions (using statistics gathered since 1830); fires and explosions (typical features peculiar to the site included a nearby canal along which hazardous materials were transported, and also a pressurised natural gas pipeline running underground along part of the site fence and crossing the nearby canal); earthquakes (a safety evaluation was performed according to the United States' 10 CFR 100 App.A (Bibliography, Ref. 1)); and missile impact (the site is situated on the landing approach path of a military airfield around 30 km away. Dr. Baetslé noted the Eurochemic aircraft design basis (150 ms⁻¹ + 5 te of fuel having three minute burn time) provided an umbrella for other accidents also. Fuller details concerning this review were given in the paper prepared for the meeting (Bibliography, ref. 29).

III. DISCUSSION OF THE DIFFERENCES AND ANALYSIS OF THE TECHNICAL ISSUES

In this part of the meeting, the delegates expanded their presentations on technical issues on an item-by-item basis.

Extreme Environmental Conditions (Wind, tornado, snow, flood, high and low temperatures, rainfall)

Wind, tornado

27. On the magnitude of the highest wind speed classification (360 mph) in the United States, Mr. Roberts commented that this had been selected on a deterministic basis. The Japanese delegates commented that historical data were used in Japan and the maximum wind speed used for design purposes was 60 m/s (135 mph). However, in most cases, design against earthquakes provided a more than adequate protection against high wind speeds. Dr. Sütterlin commented that in the United States, buildings needed to be protected not only against the pressure exerted by high winds but also against wind-borne missiles.
Extreme temperatures

28. Dr. Brown noted that the duration of extreme temperatures had to be taken into account as well as the actual temperatures reached.

Floods

29. Dr. Grall commented that in France, the maximum height of a wave created by the sudden and total destruction of upstream dams was calculated for facilities located on rivers. This wave height, when added to the maximum river height, gave an indication of the height of dykes required -- hence the approach used was deterministic. For the Federal Republic of Germany, Dr. Sütterlin commented that the degree of canalisation affected the maximum flooding depth; for example, calculations had been performed for the maximum high water levels expected on a 100 year return frequency (on the river Elbe). However, three successive floods of a higher level had been caused by water being brought in on the canal system from up to 70 km away. Mr. Roberts commented that 100 year flood levels were often meaningless when recent urbanisation had occurred; increased surface run-off could cause the 100 year flood levels to be considerably exceeded.

Snow

30. Dr. Brown commented that the occurrence and effects of snow were difficult to assess; for example, should one consider historical snowfall records or local effects. One effect of snow which should be considered was its capability to disrupt supplies and services. Mr. Sheppard also commented that because snow took some time to build up, remedial (clearance) work was normally possible. Dr. Sütterlin added that the time factor could have a significant influence on the provision of services and supplies -- such as nitrogen supplies for inert gas systems -- this could lead to a hazardous situation developing.

Earthquakes

31. On the nature of earthquakes, Dr. Grall reported that in France there was good general agreement on historical frequencies and distribution, and within "homogeneous regions" one could define a level that the plant had to sustain. Mr. Sheppard said that in the United Kingdom there was a requirement to demonstrate the existence of an effective barrier -- an engineered provision to prevent or terminate a fault occurring at a frequency of occurrence of 10-4/year and also to demonstrate that no "cliff edge" effects were present. The results of historical searches were used to produce a seismic hazard curve for the Sellafield site. This consists of a plot of horizontal ground acceleration (hga) v probability of occurrence. The design basis earthquake is identified from this seismic hazard curve. For example, the facilities at Sellafield were designed against a 10-4/year earthquake producing 0.25g hga and cliff-edge effects were checked to ensure that there would be no catastrophic collapse at 0.35g hga for a 10-5/year earthquake. For the THORP reprocessing facility which contained 2,500 "wet chemistry" vessels and 750,000 pipe welds, there was no possibility of performing dynamic seismic calculations. It was thus the licensee's duty to define effective barriers and seek approval for them from the Health and Safety Executive. It was vital to ensure that plant safety features remained operational after a seismic event. It was the plant designers job to take the plant "design intent document" and analyse the structure and the plant to see that the
design intent was followed. This was performed from the deterministic viewpoint, i.e. working forward from the specific earthquake. Regarding the simultaneous occurrence of an earthquake and a criticality incident or a fire, Mr. Sheppard noted that the facilities had to be defended against the simultaneous occurrence of an earthquake and a criticality incident; on the simultaneous occurrence of a fire and an earthquake, it had to be demonstrated that there was a certain period of time (30 minutes) before there could be any risk to the public. In this regard bulk shielding integrity was important as it may be necessary to approach the facility closely in order to be able to recover.

32. Some discussion took place on seismic qualification of "old" facilities. It was noted that at Sellafield in the United Kingdom, the licensee was undertaking a review of the old plants' capability to withstand seismic events -- it being recognised that some of the older equipment, being so massive, may already have adequate seismic resistance. On older French plants, Dr. Grall commented that whereas the La Hague complex was designed against level 7 earthquakes, this needed to be raised to level 8 earthquakes in the case of older pre-existing buildings. Where existing buildings were included in extensions, they needed re-inforcing in some instances. For the Federal Republic of Germany, Dr. Sütterlin commented that the design of cranes had to be such that they would not fail during an earthquake, and it was common to re-inforce concrete base structures routinely to prevent this happening.

33. On the design of fire protection systems against earthquakes, Mr. Sheppard, for the United Kingdom, commented that regarding in-cell fires various types of fire fighting equipment are being considered. The seismically qualified foam injection system is proposed in all cells containing flammable solvents. For the Federal Republic of Germany, Dr. Sütterlin reported that a considerable quantity of nitrogen was required for inertisation and there was a need to design the nitrogen supplies against earthquakes -- this involved for example, the presumed failure of bridges etc. in the locality, so everything needed to be available on site.

34. On soil profiles, Mr. Roberts, for the United States, reported that the soil/structure interface was subject to extensive investigations. These included: the composition of the soil and how far it was from the bedrock; the composition of the soil over geological time; and the liquefaction problem. Professor Jodra, for Spain, described the effects resulting from expanding clays, on which one Spanish unit had been built. Here the buildings were moving in different directions.

35. Dr. Brown raised the question of requalification of facilities after they had been subjected to small (significant, but not necessarily over the design basis) earthquakes -- the United Kingdom's view was that facilities need requalification after such events. Dr. Sütterlin said that seismic monitoring instrumentation was installed in some fuel cycle facilities in the Federal Republic of Germany and it was possible to recalculate the effect of the earthquake on the building. Mr. Iwanaga reported that seismics design methods in Japan had been established based on the experience of various earthquake hazards, vibration experiments, and comparison study between simulated and monitored acceleration values in response to seismic waves. So, the simulation analysis technique has enough reliability to assure safety after the earthquake. Dr. Grall, for France, reported that the plastic properties of concrete were calculated in static and dynamic conditions; this made it possible to show that the plant was safe in the worst conditions and also to demonstrate that the plant was still operational after a seismic event.
Fire Hazard and Explosions

36. It was noted that there was a much higher non-availability of fire-fighting equipment, in particular CO₂ systems, in the Federal Republic of Germany than in the United States, the German concept being to go towards passive fire prevention techniques such as dividing walls etc., whereas the United States has favoured an active fire-fighting concept. However, there were no significant different probabilities for fires in the two countries: for the Federal Republic of Germany, a frequency of 0.12 fires per year per nuclear power facility against a frequency of 0.17 fires per year per facility in the United States. (Mr. Roberts commented here that since the United States required a "quick" fire-fighting system, then every fire was reported and this accounted for some of the difference noted.) Some significant differences were also noted between criteria for notifying fires in the different Member countries. Dr. Sütterlin reported that in the Federal Republic of Germany the fire frequency reported was that, for the overall facility (NPP), whereas in the United Kingdom for instance, the approach was to record the frequency of initiating events -- such as the number of times the fire brigade were called at Sellafield. The high quality of the fire prevention procedures in the nuclear industry was demonstrated by comparison with non-nuclear industry where a fire frequency of 0.26 fires per year per facility was reported in the United States.

37. On the passive fire fighting philosophy practised in the Federal Republic of Germany, Dr. Sütterlin commented that compartmentalisation meant that one compartment could burn out completely, but its contents still retained intact because the containments were highly fire resistant. However, this compartmentalisation gave problems with connecting ducts for ventilation and services. Mr. Roberts reported on experiments at Pacific North West Laboratories which indicated that, for some contaminated materials, radioactive releases were predominant prior to actual ignition. With other contaminated material, such as contaminated paper, the releases were linear. On thermal shock from carbon dioxide fire extinguishers, Dr. Sütterlin thought that the negative aspects of CO₂ were not a particular problem, but perhaps justified some investigative work in the future.

38. In a general comment, Mr. Sheppard said that there appeared to be a good agreement on quantifying fire risks. In the design of the THORP facility at Sellafield, the estimate of likely consequences had been made early in the design process and identified the risk that solvent fires represent.

39. Some discussion took place on the problems associated with transport of contaminated combustible materials, where a high probability of fire had been reported. Mr. Roberts said that only a few low-level waste burial sites existed in the United States; many regional compacts were being set up and the sites were being rotated between States, so transport of waste was an important issue. Dr. Brown noted the particular problems associated with hot fires of long duration, where releases of semi-volatiles such as ruthenium and strontium could cause a significant public hazard. Dr. Sütterlin agreed, saying that contamination by such semi-volatiles would cause big problems when repairing the plant; this was particularly significant with medium-active waste. Hence, fires should be "ranked" when performing risk assessments. Also fire was a significant common cause for disabling safety systems and the aim (in the United Kingdom) was to have a two-hour safety barrier between systems of safety significance.
40. Considerable discussion took place on the problems and benefits associated with ventilation systems in fuel cycle facilities and no consensus view was evident. Dr. Baetslè gave details of a hydrogen explosion which had occurred in Belgium in a unit designed to separate tritium from water. This unit had comprised essentially an electrolyser and a separation column and had since been made safe by "compartmentisation". The earlier explosion had resulted from human error because an emergency ventilator had not been switched on. Dr. Grall noted that in the event of an external fire, it was generally advantageous to stop the ventilation in normal industrial facilities, but ventilation was particularly important in fuel cycle facilities as the pressure gradients and steps between compartments etc. was present to contain the material and hence protect the workers and public, so it was essential to maintain the pressure gradients whilst dealing with the fire. Destruction of material was not an important issue compared with the need to avoid contamination. On filters, Dr. Grall highlighted the importance of double filtration to get dilution effects and hence avoid too sharp an increase in filter temperatures. Dr. Baetslè commented that in Belgium, new regulations stated that in plutonium handling facilities the ventilation should always be "on".

41. On explosions in fuel cycle facilities, Mr. Roberts drew attention to NUREG CR 4593 (Bibliography, Ref. 9) on non-nuclear explosions in fuel cycle facilities. Follow-on information may become available as the work was being brought together in an accident analysis handbook towards the end of 1987.

**Missile Impact** (aircraft crash, tornado-borne missiles, internally generated missiles)

42. Dr. Brown commented that in the United Kingdom, aircraft impact represented the largest external missile; concerns were answered on two grounds: the hazardous inventory; and the probability of impact. Light civil aircraft of up to two tonnes weight were assessed as having a probability of impact of between 10^-5 and 10^-6 per year; and heavy civil aircraft and military aircraft at between 10^-6 and 10^-7 per year for crashes in areas away from military airfields (the engines of large civil aircraft being regarded as equivalent to military aircraft). The threat from aircraft came not only from the actual impact damage, but also from fires caused as a result of the impact as 90 per cent of aircrafts have fire associated. Different missiles gave different effects: hard missiles giving a "punching" mode of damage possibly with a scabbing effect on far surfaces; soft impacts giving bending and deformation leading to a cone failure. It was possible to model such effects reliably as scaling factors appeared valid up to 8X. Internally generated missiles were not thought to be much of a problem and could be guarded against fairly easily as few sources existed: for example, centrifuges should be protected by an anti-missile barrier. In the United Kingdom, missile impact damage had been modelled successfully up to around 20 per cent strain by the EURODYN 02 code for two dimensional problems and by DYNA 3D code for three dimensional cases. Mr. Roberts commented that the DYNA code had been used successfully in the United States to model flask impact effects and the effects of tornado-borne missile impacts. Mr. Roberts also commented that the aircraft impact frequencies were lower in the United States than in the United Kingdom and the threat from light aircraft crash was normally enveloped by design against tornado-borne missiles. All agreed that "missiles" caused by dropped crane loads were a serious threat which must be taken into consideration.
43. Some discussion took place on the effects of aircrash onto UF₆ storage facilities, Dr. Sütterlin noting that this was not considered as a nuclear hazard in the Federal Republic of Germany because there was no significant radiological hazard. Some delegates reported that hazards from UF₆ storage were being reduced by converting the UF₆ into U₃O₈. On the relative merits of pond and dry storage wastes, Dr. Sütterlin commented that cast iron casks were used in Germany. They were invulnerable to external impacts, even from an aircraft crash, they were insensitive to water loss, and were more economic than pool storage. Dr. Grall commented that problems arising from water loss from ponds were tolerable because times of the order of one day were available before problems arose and plenty of water sources were normally available. Problems would arise however in the case of impacted fuel elements. Dr. Sütterlin commented that pool storage had been taken into account for a previously planned waste management centre at Gorleben. In spite of the low probability of aircrash on the site it had been found necessary with respect to the available storage capacity to plan for buildings to be erected over pools. Therefore and also from the economic viewpoint, dry storage had been specified for the Wackersdorf reprocessing facility.

Mr. Roberts commented that dry storage was the approach favoured in the United States for the planned Monitored Retrievable Storage Facility (MRSF).
IV. SUMMARY SESSION

44. During this session the rapporteurs, appointed at the start of the meeting, summarised the technical issues discussed under the various headings under agenda item 3. These summary reports were discussed at the meeting in draft form and subsequently submitted to the Secretariat by the rapporteurs in revised form, taking into account comments made at the meeting. These revised reports follow under the headings:

1. Extreme Environmental Conditions
2. Earthquakes
3. Fire Hazards
4. Missile Impact

1. EXTREME ENVIRONMENTAL CONDITIONS

Rapporteur: Dr. L.H. Baetslé, SCK/CEN, Mol

45. In the discussion concerning tornadoes, large snowfall, floods, high and low temperatures, and extreme rainfall it became apparent that the buildings and facilities are generally erected with such a degree of conservatism that these natural elements, except for floods and tornadoes, can be considered as conventional problems.

Floods

46. Among these hazards only floods were considered by all countries as a threat which has to be taken into account when designing a facility.

Two approaches to cope with this type of hazard have been put forward:

- some countries take into account the highest flood levels historically recorded and erect the nuclear facilities on specific locations or at sufficient altitude to avoid major damage. An additional elevation with respect to the highest flood level is to be considered as a safety measure;

- some other countries, where dams are widespread and built upstream of potential or existing nuclear sites, take into consideration this hazard by designing the buildings in such a manner that they withstand the waterwave released from the collapsing dam.

Tornadoes

47. Only the United States has special regulations with regard to tornadoes which are considered as an additional hazard to the nuclear facilities. The country was subdivided into three distinct sections with maximum wind speeds of 240, 300 and 360 mph. These extreme wind speeds have only a locally devasting effect but require special construction designs. Experimental evidence has been provided that steep pressure changes may damage the integrity of ventilation systems which have to be designed especially to
withstand such conditions. The Federal Code 10 CFR 50 prescribes the design
criteria to which nuclear facilities must comply. Although hurricanes with
wind speeds of 100 mph have great climatic influence, they do not provide an
additional threat to conventionally well designed buildings.

48. However, failure of communication and the disturbing influence of the
external hazards on plant control equipment were identified as problem areas
(e.g. lightning, power failure due to weather conditions, etc.).

2. EARTHQUAKES

Rapporteurs: Dr. L. Grall, CEN, Fontenay-aux-Roses, France
Dr. L.H. Baetslé, SCK/CEN, MOL, Belgium

49. There was fairly good agreement between the various countries
participating in the meeting on the general considerations and the basis for
anti-seismic design of facilities.

50. The first basis is the knowledge of historical situations all over the
considered country. With the addition of geological and tectonic data,
seismotectonic regions can be derived where a given level of earthquake has to
be taken into consideration. Ground acceleration levels are defined and
consequently the basis for the definition of seismic resistance of the
buildings and the equipment are decided upon.

51. The methodology can be defined by various classes of equipment and
facilities. In every case the goal is to avoid any unacceptable effect on the
population.

52. The main technical contribution to this area came from Japan where
earthquakes constitute a daily life problem. The chart of earthquakes showed
an homogeneous distribution of earthquakes throughout the country except in
the upper north of Hokkaido. In order to cope with the earthquake threat very
special measures are taken in the design of nuclear facilities. They include:

- a historical and seismotectonic survey of site specific earthquakes
  in order to determine the Basic Design Earthquake Ground Motion;

- a very sophisticated series of measures as prescribed by their
  Essentially, in the measures, static and dynamic seismic forces are
  properly defined respectively for each classification.

53. European countries are less threatened by earthquakes and take into
account the most heavy earthquake known in historical times or derived from
tectonic observations in rocks. For fuel cycle facilities one degree more is
then taken into consideration and the buildings should be resistant to this
acceleration. In the United Kingdom 0.25g is considered, in the Federal
Republic of Germany and France 0.15g, and in Belgium 0.025g.

54. During a revision of older installations, e.g. EUROIDIF, no additional
measures or reinforcement needed to be made.

55. The United Kingdom's approach to existing installations is very
pragmatic and involves primarily securing pipes and equipment which will be
regarded as lost in the case of major earthquakes.
56. A question was raised which has no evident answer: after a low-level earthquake, is it necessary to requalify the facility, and if so, what are the requirements? [The Japanese delegation have subsequently commented on this as regards the situation at their Tokai Reprocessing Plant: "There is an earthquake intensity meter installed in the central control room. During and after earthquakes, except minor ones, operators check the plant operation status, equipment function, etc., according to the specified check procedures. In this way, we have had no experience of abnormalities found up to now."]

3. FIRE HAZARDS

Rapporteur Dr. L. Süßterlin, GRS Köln

57. Discussions on fire hazards were divided into two parts:

- external fires
- internal fires.

External Fires

58. All Member countries agreed that external fires are not regarded as very hazardous external events as protection can be achieved by simple measures.

There are two different approaches to protection.

a) In most Member countries a hazard assessment is carried out and individual fire protection measures, siting (distance to fire loads) and air-intake filters are considered. In these countries there are no general requirements for the fire resistance of the buildings of a nuclear facility.

b) In two Member countries (Spain, Federal Republic of Germany), a deterministic analysis of protection against external fires is carried out. According to the codes all buildings have to withstand external fires for a definite time (Spain 150 minutes, Federal Republic of Germany 90 minutes). This time is regarded as sufficient for the fire fighting teams to arrive at the scene and control the fire. To prevent intake of explosive gases from the exterior (environmental hazards), detectors are installed which actuate valves to close the air intakes.

Internal Fires

59. All Member countries agreed that:

a) Fire protection is very important for nuclear fuel cycle installations. The phenomena to be dealt with are temperature, pressure and smoke.

b) The goal of fire protection is to maintain the function of the barriers that enclose nuclear material, as well as safety-relevant systems. No release of radioactivity into the environment may occur that exceeds permitted limits.
c) The special goal of protection in nuclear facilities and the need for high quality in the reliability of fire fighting systems is not normally met by the experience gained in the fire protection of normal industrial facilities.

d) Similar approaches for fire prevention and fire fighting are followed in the different Member countries. The concepts include an implicit risk assessment, but the measures taken into account are based on deterministic evaluations to some extent.

In some countries (e.g. United States) an active fire fighting system is preferred; in other countries (e.g. FRG) fire protection is preferably achieved by passive means.

e) The frequencies of fires seemed to be similar in the different countries, as also were the specific frequencies for fires in special situations (e.g. cable ducts, oil reservoirs). However, detailed information was not yet available.

f) Some differences seemed to exist in the field of ventilation. In some countries there are requirements that the ventilation must be kept functioning in case of fire, in other countries the ventilation should be stopped.

There was agreement that the pressure graduation within a nuclear facility is safety relevant and that it is necessary to keep the escape routes free of smoke.

60. As these discussions would have exceeded the scope of the Specialist Meeting there was a proposal to discuss them in more detail in a Specialist Meeting on fire protection and fire fighting in nuclear fuel cycle facilities.

4. MISSILE IMPACT

Rapporteur Dr. M.L. Brown, UKAEA (SRD), Culcheth

61. The meeting felt that there were few, if any, significant sources of internal missiles in fuel cycle plants. Of external missiles, aircraft were felt to be the most important. For sites having large turbine equipment nearby, a turbine breakup could also be a significant source of potential missiles at a similarly low level of probability.

62. There seems to be no prospect of performing a detailed probabilistic risk analysis on aircraft impact because of the complexities of impact dynamics and response. However, some form of risk approach is used by all countries to draw aircraft crash into consideration in plant safety. The way in which this is done varies from country to country, but it involves consideration of both hazardous material inventory and probability of impact. For example, a plant having a low inventory of material may not be assessed because the risk would be low even in the event of a crash, or the probability of a crash may be so low that no assessment is felt necessary whatever the quantity of material involved.
63. When considering the adequacy of protection against aircrash it is necessary to consider realistic source terms. The meeting noted that recent work at Battelle Pacific Northwest Laboratories in the United States would draw together studies on possible release fractions in a variety of accident scenarios that might be useful in this. It is also necessary to consider realistic crash scenarios. As examples, the angle of impact is normally taken into consideration in France, and in Germany when considering the effect of crash on transport flasks not qualified to resist it, the management practice of storing such flasks in the middle of an array of qualified flasks is taken into consideration in assessing the probabilities. It was noted that fire could not in general be ruled out following an aircraft crash (most crashes are followed by fire) and that this sometimes leads to a specific fire protection requirement. For example, in a Belgian assessment five tons of aircraft fuel burning for three minutes was taken as a typical case.

64. When considering the probabilities of air crash there are clearly problems in translating data from one country to another. For example, French military aircraft crashes occur in general close to air bases whereas in the United Kingdom such crashes are more widely distributed across the country, not necessarily only in training areas. It is also important to take site-specific circumstances into account. As examples: at Cadarache in France flights of forest firefighting aircraft are considered; at the Belgian fuel plant the proximity of a NATO air base is taken into consideration; and in the United Kingdom at Dounreay the local airstrip on the site must be considered.

65. When it comes to translating an aircraft impact into a given loading on the structure, the Federal Republic of Germany is the only country to have developed a specific loading function. This approximates the loading curve believed to result from a Phantom military aircraft flying at approximately 250 metres per second.

66. Given a defined aircraft threat either in terms of a specified aeroplane or loading, the meeting felt that at least approximate methods were available to assess the effects on a structure. The Federal Republic of Germany, the United States and the United Kingdom all mentioned specific calculational codes or formulae. Whilst not being exact, these methods were felt to be adequate given the uncertainties in the specification of the original impact. The United Kingdom (SRD) are producing a handbook on impact assessment.

67. It was noted that in the particular case of uranium hexafluoride storage, the non-nuclear risk dominates. This would result not from impact alone, but from any associated fire. It was noted that France was converting depleted UF6 to U3O8 for storage - as a hazard reducing measure.

68. It was noted in passing that as far as aircraft crash is concerned, cask storage may have safety advantages over pond storage. This is, however, only one aspect of storage safety and is not likely to be a dominant one.

69. Following safety assessments that consider the factors noted above, only one country (the Federal Republic of Germany) has found it necessary to introduce specific aircrash protection measures. It is felt that these measures, when taken, provide not only aircrash protection but a form of "umbrella" protection against a variety of other hazards such as terrorist attack.
70. In other countries it is considered that measures introduced for other reasons, for example shielding or security, give sufficient protection against aircrash. Introduction of protective measures on a case-by-case basis is not ruled out, however.

71. Finally, recent German work comparing the conventional effects of aircrash with the additional effects due to nuclear hazard was noted. The conventional effects dominate, with the possible exception of very low probability severe events. This work is not used in any formal safety or licensing submissions but it puts a useful perspective on the problem.

CLOSURE OF THE MEETING

72. In closing the meeting, Dr. Baetslé thanked all the participants for their presentations and written contributions. Dr. Baetslé also thanked the Spanish Government, through the Nuclear Safety Commission represented by Professor Jodra, for offering to host the meeting in Spain, and the ENUSA Company, through Mr. Gonzalez, for the detailed local arrangements, which had also included a most informative technical visit to the ENUSA plant at Juzbado. Finally, Dr. Brown, speaking for the other participants, thanked Dr. Baetslé for his effective chairmanship of the meeting.
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ANNEX 2

Agenda for the Meeting
[SEN/SIN(86)54]

1. Adoption of the Agenda [SEN/SIN(86)54]

2. The interconnection between specific legislation regarding external hazards and the technical basis behind it (Country Presentations)

3. Discussion of the differences and analysis of the technical issues in the following areas:

   3.1 Extreme environmental conditions:
       - wind, tornado
       - snow
       - flood
       - high and low temperature
       - rainfall

   3.2 Fire hazard and explosions
       - internal (e.g. solvent fires, radiolytic hydrogen explosions)
       - external (e.g. petroleum tank fires, LPG transport explosions)

   3.3 Earthquakes

   3.4 Missile impact
       - aircraft crash
       - tornado-borne missiles
       - internally generated missiles (e.g. from turbine explosions)

4. Summary session
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6. NUREG-1198 - Release of UF₆ from a Ruptured Model 4BY Cylinder at Sequoyah Fuels Corporation Facility: Lessons-Learned Report


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<table>
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<tr>
<th>No.</th>
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<tbody>
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<td>15</td>
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</tr>
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<td>23</td>
<td>SINDOC(86)213</td>
<td>Safety Assessment Principles for Nuclear Chemical Plant, UKNII</td>
</tr>
<tr>
<td>24</td>
<td>SINDOC(86)214</td>
<td>Impact Studies in the United Kingdom Atomic Energy Authority</td>
</tr>
<tr>
<td>25</td>
<td>SINDOC(86)223</td>
<td>1. General Status of Fuel Cycle Development and related Laws and Regulations in Japan</td>
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<td></td>
<td></td>
<td>2. Main frame of Licensing Procedure in Japan</td>
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<td></td>
<td>3. Guidelines relevant to External Hazards on Reprocessing in Japan.</td>
</tr>
<tr>
<td>26</td>
<td>SINDOC(86)224</td>
<td>Collection of Overhead Transparencies shown by the USA Delegation during the meeting</td>
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<tr>
<td>27</td>
<td>SINDOC(86)225</td>
<td>French Regulations on Nuclear Safety</td>
</tr>
<tr>
<td>28</td>
<td>SINDOC(86)226</td>
<td>Concepts and Design Criteria for the Protection of Nuclear Facilities against External Impacts in the Federal Republic of Germany</td>
</tr>
<tr>
<td>29</td>
<td>SINDOC(86)227</td>
<td>Design Approach defined during the study of a possible re-opening of the former Eurochemic Reprocessing Plant</td>
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<td>34.</td>
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<td>Safety Audit of BNFL Sellafield 1986, Volumes 1 and 2, Health and Safety Executive, HM Nuclear Installations Inspectorate.</td>
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