

IRSNINSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

Nuclear fuel cycle facilities, laboratories, irradiators, particle accelerators, under-decommissioning reactors and radioactive waste management facilities safety.

Lessons learned from events notified between 2005 and 2008

DSU Report n° 215



IRSN certified quality
management system

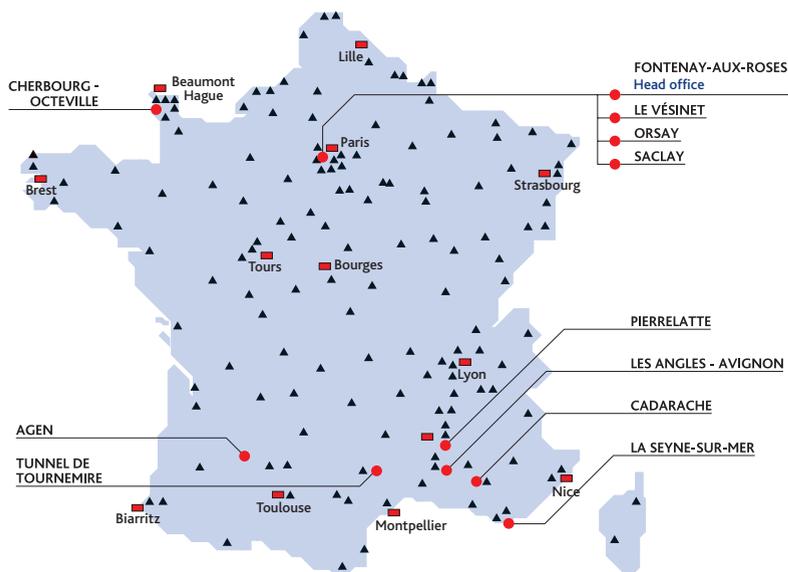
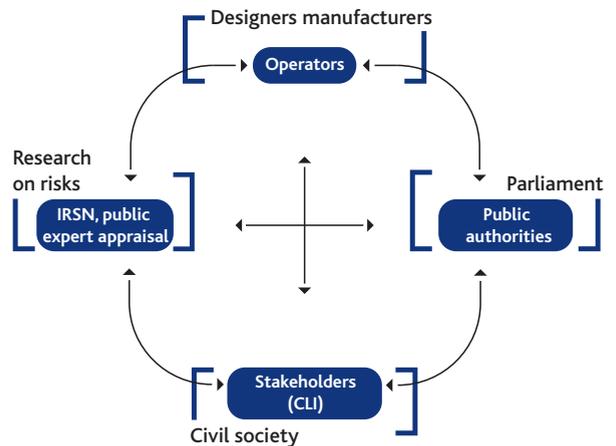
**PLANTS, LABORATORIES, TRANSPORTS AND WASTE
SAFETY DIVISION**

Enhancing Nuclear Safety, Security and Radiation Protection

The Institute for Radiological Protection and Nuclear Safety set up by law 2001-398 of 9 May 2001, is the French national public expert in nuclear and radiological risks. IRSN contributes to the implementation of public policies concerning nuclear safety and security, health and environmental protection against ionizing radiation. As a research and expert appraisal organisation, IRSN works together with all the parties concerned by these policies while preserving its independence of judgment.

THE FRENCH ORGANISATION FOR NUCLEAR SAFETY, SECURITY AND RADIATION PROTECTION

- **Operators** are responsible for safety of their facilities. They must demonstrate relevance of technical and organisational solutions applied for this purpose (safety files and release impact studies).
- **Public authorities** (Ministries, Nuclear Safety Authority – ASN, Defence Nuclear Safety Authority – DSND) define nuclear safety, security and radiation protection policies. They organise and implement checking in compliance with law 2006-686 of 13 June 2006 governing transparency and safety in nuclear matters.
- **IRSN** assesses the files submitted by operators to the different competent authorities. It permanently analyzes plant operating experience feedback. It assesses exposure of man and the environment to radiation and proposes measures to protect the population in the event of an accident. Nuclear safety being largely science based, IRSN's expertise capability is permanently enhanced through its research activities, usually developed in an international framework.
- **Local Information Committees (CLI) and the High Committee for Nuclear Transparency (HCTISN)** gather the stakeholders concerned by nuclear facilities, and constitute leading bodies for access to information and monitoring of safety and security, health and environmental protection issues.



Remote air radioactivity monitoring networks:
▲ Téléray Stations (gamma radiation monitoring) ■ SARA Stations (aerosol monitoring)
● IRSN sites



IRSN KEY FIELDS OF COMPETENCE – R&D AND OPERATIONAL EXPERTISE CAPABILITY

- Nuclear safety and security
 - Reactors
 - Fuel cycle
 - Waste management
 - Transport
 - Radioactive sources
- Radiological protection of people (including patients) and of the environment
- Nuclear & radiological emergency management and operational intervention capability
- Training and education
- Information management and interaction with stakeholders and the public

IRSN key numbers

1,786 persons
1,200 researchers and experts
M€321 (2010 budget)

TABLE OF CONTENTS

1	<u>INTRODUCTION</u>	3
2	<u>PRESENTATION OF "LUDD" FACILITIES AND THE SAFETY APPROACH</u>	4
3	<u>NOTIFYING EVENTS</u>	8
4	<u>THE IRSN APPROACH TO ANALYSING AND DEALING WITH EVENTS</u>	9
5	<u>GENERAL LESSONS FROM EVENTS NOTIFIED BETWEEN 2005 AND 2008</u>	10
5.1	CHANGES IN THE NUMBER OF EVENTS NOTIFIED TO ASN BETWEEN 2005 AND 2008	10
5.2	ASSESSMENT OF THE CONSEQUENCES OF EVENTS NOTIFIED TO ASN BETWEEN 2005 AND 2008	12
5.2.1	<i>Consequences of events notified to ASN for the environment and the population</i>	12
5.2.2	<i>Consequences of events notified to ASN for the workers</i>	14
5.2.3	<i>Consequences in the facilities</i>	15
5.3	GENERAL COMMENTS ON THE SIGNIFICANT EVENT REPORTS AND THE NOTIFICATION PRACTICES BY OPERATORS OF LUDD FACILITIES	15
6	<u>DESCRIPTION OF SIGNIFICANT EVENTS NOTIFIED BETWEEN 2005 AND 2008</u>	16
6.1	DESCRIPTION OF SIGNIFICANT FOREIGN EVENTS	16
6.1.1	<i>Event on 21 april 2005 in the THORP plant at the Sellafield site in the United Kingdom</i>	16
6.1.2	<i>Event of 11 march 2006 in the irradiation facility operated by STERIGENICS at the Fleurus industrial site in Belgium</i>	17
6.1.3	<i>Event of 26 august 2008 in the Radionuclide Institute (IRE) on the industrial site of Fleurus in Belgium</i>	18
6.2	DESCRIPTION OF SIGNIFICANT FRENCH EVENTS	20
6.2.1	<i>Events of 22 june 2006 and 13 december 2006 in the STAR and ATALANTE laboratories respectively located at the CEA Cadarache and Marcoule sites</i>	20
6.2.2	<i>Event of 20 october 2006 in the HAO/South facility of the UP2-400 plant at la Hague</i>	21
6.2.3	<i>Event of 6 november 2006 in the ATPu facility at the CEA Cadarache site</i>	22
6.2.4	<i>Event of 8 november 2006 in the high-level laboratories at the CEA Saclay site</i>	22
6.2.5	<i>Event of 10 september 2007 in the radioactive waste management facility at the CEA Saclay site</i>	23
6.2.6	<i>Event of 21 may 2008 in the radiopharmaceuticals production plant at the CEA saclay site</i>	24
6.2.7	<i>Event of 7 july 2008 in the uranium recovery and clean-up facility at the Tricastin site, operated by SOCATRI</i>	24
7	<u>CROSS-DISCIPLINARY ANALYSIS OF EVENTS OCCURRING IN LUDD BNI</u>	27
7.1	INTRODUCTION	27
7.2	ANALYSIS OF MAIN TYPES OF EVENT	28

7.2.1	<i>Events relating to the risks of dissemination of radioactive materials</i>	28
7.2.2	<i>Events relating to the risks of external or internal exposure from ionising radiation</i>	31
7.2.3	<i>Events relating to the risks of criticality</i>	32
7.2.4	<i>Events relating to the risks of fire</i>	34
7.2.5	<i>Events relating to the risks of explosion</i>	35
7.2.6	<i>Events relating to the risks from handling operations</i>	35
7.2.7	<i>Events relating to power or fluid supply failures</i>	37
7.3	CAUSE ANALYSIS OF EVENTS NOTIFIED TO ASN INVOLVING LUDD FACILITIES	38
7.3.1	<i>Technical causes</i>	39
7.3.2	<i>Organisational or human causes</i>	41
8	SUMMARY	47
	APPENDIX.....	50

1 INTRODUCTION

Maintaining high levels of safety in nuclear facilities requires constant vigilance by everyone involved, especially by plant operators who are first and foremost responsible for safety in their facilities. Safety can never be taken for granted; constant efforts must be made to improve it, by taking new knowledge and available operating feedback into account. In this respect, a substantial part of operating feedback is made up of lessons learned from analysing events, incidents or accidents occurring in France or in similar facilities abroad.



La Hague Site (AREVA)



Marcoule Site (CEA&AREVA)



Le Tricastin Site (AREVA)



Saint Laurent des Eaux site (EDF)

France has more than 70 civil basic nuclear installations (BNI) falling under the category "Laboratories, plants, facilities being dismantled, waste processing or interim storage facilities or disposal facilities" (LUDD). Unlike the nuclear power plants operated by EDF, the LUDD facilities are extremely diverse (type of activity, type of risk) and are run by a number of plant operators, the main ones being AREVA, CEA, ANDRA and EDF.

Although the diversity of LUDD facilities is a limiting factor in identifying generic lessons, all events occurring in these facilities must be examined to ensure that lessons from the operating feedback have been drawn and shared.

To encourage the diffusion of operating feedback, IRSN has produced a report concerning events notified to the Nuclear Safety Authority (ASN) by operators of LUDD facilities between 2005 and 2008. The main objective is to make general lessons for safety in this type of facility available based on a cross-disciplinary analysis of notified events and noted evolution trends.

IRSN has had tools for managing information concerning events occurring in France and abroad for many years. These tools are used to analyse the events in order to take into account the relevant lessons learned in the safety assessments performed on behalf of ASN and also to define study and research programmes to maintain its expertise and expand its knowledge.

The report has 4 sections:

- the first section (chapters 2 to 4) presents the LUDD facilities so that the facilities themselves, their diversity and the main associated risks can be better understood. It also includes a brief reminder of plant operator obligations in notifying events and describes the database used by the Institute to manage the data relating to the notified events;
- the second section (chapter 5) summarises the main changes noted in the events notified to ASN during 2005 to 2008 and provides an overall assessment of the consequences of these events for the environment, the population and the workers;
- the third section (chapter 6) describes significant events occurring in France and abroad. This part - which makes no claims to be exhaustive - aims to illustrate the Institute's analysis of the significant events brought to its knowledge, using concrete representative scenarios.
- the final section (chapter 7) presents a cross-disciplinary analysis of notified events, under two complementary angles (analysis of types of event and analysis of generic causes), to make general lessons available.

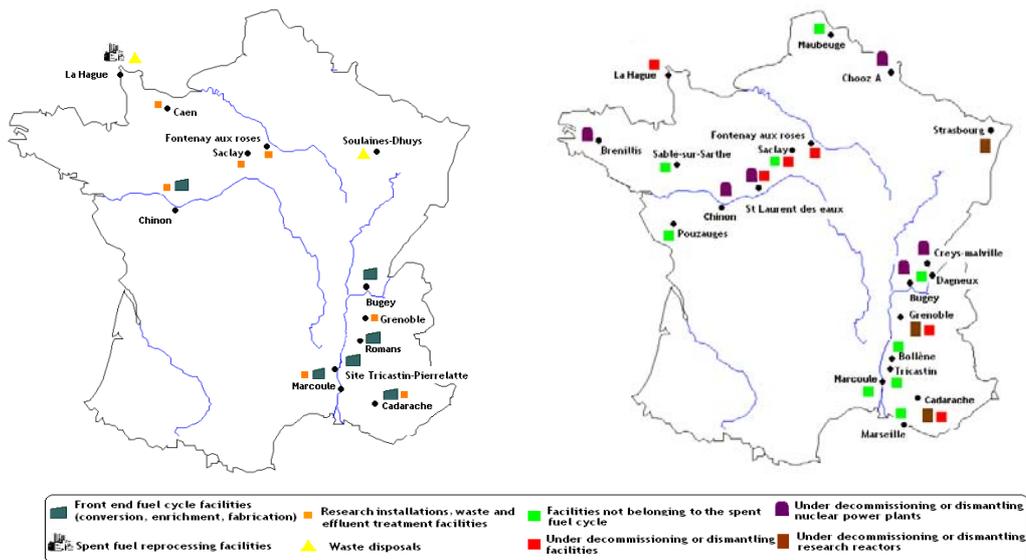
The Institute plans to provide this type of analysis report periodically in future years, in order to present a regular update on trends noted and areas for improvement with the overall goal of encouraging on-going enhancement of facility safety.

2 PRESENTATION OF "LUDD" FACILITIES AND THE SAFETY APPROACH

The classification criteria for basic nuclear installation (BNI) are defined in Decree 2007-830 of 11 May 2007 in application of Act 2006-686 of 13 June 2006 on "Transparency and Security in the Nuclear Field", referred to as the TSN Act in this report. The TSN Act stipulates that the key stages in the life of a BNI, from its creation to its dismantling (except for waste disposal facilities where the dismantling stage is replaced by a monitoring phase), are subject to authorisation by decree. Following dismantling, a facility can be decommissioned and removed from the list of BNI.

The BNI classified in the "Laboratories, Plants, Dismantling and Waste" category (called LUDD from now on) include all French civil BNI other than nuclear power and research reactors in service. The LUDD category therefore includes the nuclear reactors shut down definitively which do not contain any nuclear fuel. When the fuel has been removed from the reactor, the risks from these facilities are more akin to a "laboratory" or "plant" facility than a reactor in service (especially removal of risks from the residual power of the reactor).

There were 72 LUDD BNI in France at the end of 2008 (see the two maps below showing the location of the facilities of this type).



Under this report, these BNI have been classified into five major families detailed below (note: the processing and interim waste and effluent storage facilities are included in the family of the facility or facilities producing waste and effluents which are processed or stored temporarily there).

- *Nuclear fuel cycle facilities*



The operations to prepare and manufacture the nuclear fuel intended for use in nuclear reactors ("front end") and to reprocess the spent fuel after use ("back end") form the nuclear fuel cycle.¹

Facilities authorised for these activities are operated by the AREVA Group, except for two interim storage warehouses for new uranium oxide-based fuel operated by EDF. There were eighteen BNI in the "cycle facilities" family at the end of 2008²

¹ No enrichment of uranium from spent fuel reprocessing currently takes place in France.

² The mines and facilities to convert natural uranium into UF₆ are not classified as BNI.

This family of facilities includes:

- the Georges Besse 1 plant for uranium enrichment by gaseous diffusion, located at the Tricastin site and operated by EURODIF;
- the TU5 (AREVA) and COMURHEX plants at AREVA's Pierrelatte site, which converts the uranium from the processing of spent fuels into uranium sesquioxide (U_3O_8) or uranium hexafluoride (UF_6);
- the FBFC plant which manufactures uranium oxide-based fuel assemblies, located at the Romans-sur-Isère site;
- the MELOX plant which manufactures fuel assemblies based on a mix of uranium oxide and plutonium oxide (called MOX fuel), located at the CEA Marcoule site. The ATPu facility at the CEA Cadarache site, another manufacturer of MOX fuel, and the related LPC facility, which are now shut down and being prepared for dismantling, are associated with this family;
- two interim storage warehouses for new fuels, on the EDF sites at Chinon and Bugey;
- the AREVA spent fuel reprocessing plants, called UP3-A and UP2-800, located at the La Hague site; the former plant (called UP2-400), which is shut down and being prepared for dismantling, is attached to this family of BNI.

- *Industrial facilities not part of the nuclear fuel cycle facilities*

This family of facilities, called "out-of-cycle industrial facilities" in this report, included thirteen BNI with extremely diverse design, nature and missions at the end of 2008:

- the radiopharmaceuticals production facility located at the Saclay site, operated by CEA until the end of 2008;
- six industrial irradiation facilities located on six different sites, operated by IONISOS, ISOTRON France and CIS BIO INTERNATIONAL;
- three plants dedicated to maintaining (repairs, clean-up, etc.) equipment from other BNI (SOMANU facilities at Maubeuge, SOCATRI and BCOT at the Tricastin site);
- the CENTRACO facility which processes and conditions low-level radioactive waste, operated by SOCODEI at the Codolet site;
- a laboratory for expert assessments of materials from nuclear power reactors, operated by EDF at the Chinon site;
- an interim storage facility for underwater decay of spent fuels elements from the SUPERPHENIX reactor, operated by EDF at the Creys-Malville site.

- *Nuclear research facilities and related support facilities*

This family, called "research facilities" in this report, comprised fifteen BNI at the end of 2008. It includes:

- research laboratories operated by the Atomic Energy Commission (CEA) at the Cadarache site (LECA, STAR, CHICADE and LEFCA laboratories), Marcoule site (ATALANTE) and Saclay site (LECI) and support facilities, some specific to the management of radioactive waste and liquid effluents and others to the interim storage of fissile materials or irradiated fuels;
- two particle accelerators: the Large Heavy Ion Accelerator (GANIL) located near Caen and the Electromagnetic Radiation Laboratory (LURE) on the university campus of Orsay (facility shut down and being prepared for dismantling).

- *Facilities under final shutdown or being dismantled*

This family - 24 BNI at the end of 2008 - includes:

- 14 nuclear power plants or research reactors shut down definitively and no longer containing fuel elements; these reactors have very diverse characteristics (gas graphite reactors, heavy water reactor, pressurized water reactors and fast breeder reactor, various experimental reactors), located in the CEA sites at Cadarache, Grenoble and Saclay, at the EDF sites of Brennilis, Bugey, Chinon, Chooz, Creys-Malville and Saint-Laurent-des-Eaux and at the site of the Louis Pasteur University in Strasbourg;
- 10 "laboratory and plant" type facilities, covered by a final shutdown and dismantling (called MAD-DEM from now on) authorisation Decree; they are located in the CEA sites at Cadarache, Fontenay-aux-Roses, Grenoble and Saclay, the SICN site at Veurey-Voroize and the EDF site at Saint-Laurent-des-Eaux.

- *Radioactive waste disposal facilities*

France has two near surface disposal facilities for low and intermediate-level short lived waste. They are classified as BNI and operated by ANDRA. Operations at the La Manche waste disposal facility (CSM) near AREVA'S plant at La Hague, ceased in July 1994 and were put into a monitoring phase in January 2003. The Aube waste disposal facility (CSA), still in operation, is located in the municipality of Soulaines-Dhuys.

Main risks from the LUDD facilities

Given the diversity of facilities, the type and significance of risks associated with LUDD facilities and the potential consequences from their operation differ from one facility to the next.

The risks associated with these facilities are normally grouped into the following major categories:

- the risks due to radioactive materials in the facility: risks of these materials being disseminated both inside and outside the facility, risks of internal and external exposure to ionising radiation, criticality risks, risks of explosion caused by radiolysis and risks due to the heat releases induced by the radioactivity;
- the risks originating inside a facility which may disseminate radioactive materials, exposure to ionising radiation or a criticality accident, such as the risks of fire, explosion, overpressure, falling load, loss of auxiliary fluid (especially power supply), etc. ;
- the risks originating outside a facility, be they related to human activities (risks from neighbouring facilities, transport of hazardous materials nearby (gas pipes, tankers, etc.), aircraft crashes, etc.) or natural disasters (earthquake, flood, extreme climate conditions, etc.) ;
- the risks relating to organisational aspects and human factors.

The type of risks associated with the first three families of facilities described above (nuclear fuel cycle facilities, nuclear research facilities and "out of cycle" industrial facilities) and their importance in terms of potential consequences are linked strongly to the characteristics of radioactive materials used (radionuclides present and related physico-chemical forms) and processes used (type of reagents, content of the facility, etc.).

Some facilities have specific risks, for example:

- the nuclear fuel cycle plants using uranium in the form of UF₆ (front end of the fuel cycle) mainly present, apart from criticality risks when the ²³⁵U concentration is greater than 1%, risks relating to the toxicity of reagents used, the uranium and hydrofluoric acid resulting from the decomposition of the UF₆ in the event of a leak;
- the industrial irradiation facilities and particle accelerators present almost exclusively risks of worker exposure to ionising radiation.

However, the facilities using plutonium or spent fuel (reprocessing plants) present a set of risks linked to the use of highly-toxic irradiating materials; in case of an accident, they may have major radiological consequences for the population or the environment.

The facilities being cleaned up or dismantled have normally lower risks for the environment given the reduced quantities of radioactive materials. The risks for the workers increase, however, due to the nature of operations, which involve working closer to radioactive materials still on site (for example, removal of equipment providing containment or radiological protection). The basic risks are exposure of workers to ionising radiation and dissemination of radioactive materials, the risks of fire (from cutting operations, for example) and explosion as well as the traditional risks related to dismantling and transporting equipment. Controlling risks relating to human and organisation factors takes on special importance due to the co-existence of diverse operations and the sub-contracting of activities.

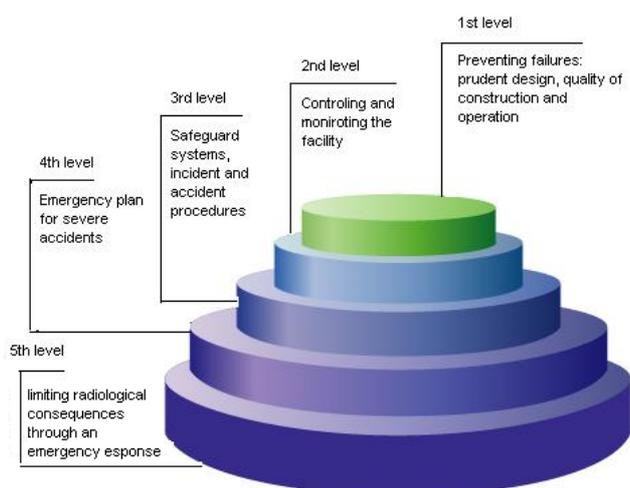
The radioactive waste disposal facilities have similar risks as BNI from other families during their operating phase (acceptance of raw or conditioned waste, possible conditioning and placing in engineered disposal structures). However, once a repository is closed, the risks are clearly different given the "passive" nature of the disposal.

In any case, IRSN sets out to evaluate, based on data provided by the plant operator, the safety of each BNI by considering firstly, its specific features and the reality and significance of associated risks and secondly, the operating experience feedback available on the facility, facilities of the same type and even all facilities.

It must be underlined that the safety of a BNI is based not just on the quality of its design and construction but also on the quality of its operation and maintenance. Suitable provision must be made to control the risks relating to human and organisational factors; this is especially true for the LUDD facilities, where the processes used normally require humans to work close to radioactive materials. In this respect, the operating experience feedback shows that a large proportion of events notified to ASN is caused frequently by one or more human or organisational factors (see chapter 7 of this report).

Definition of nuclear safety and general related approach

In accordance with the TSN Act, nuclear safety covers all technical provisions and organisational measures relating to the design, construction, operation, shutdown and dismantling of basic nuclear installations, together with the transport of radioactive materials, for the purpose of preventing accidents or limiting their effect. This covers in particular all the provisions made to guarantee the normal operation of facilities, especially in terms of protecting workers from ionising radiation, managing waste and controlling effluents and all types of nuisance harmful to the environment.



The safety and radiological protection provisions are determined under a fundamentally deterministic approach, based on the principle of defence in-depth to prevent accidents or limit their effects and on the approach of optimising radiological protection.

A fundamental element of the safety approach lies in the fact that safety can never be taken for granted; efforts must be made constantly to improve it by taking into account new knowledge available and operating experience feedback (dosimetry, waste and effluent management, incidents and accidents, etc.). A substantial proportion of the operating feedback is made up of lessons learned from analysing anomalies, incidents and accidents (in France and abroad), with especially the modifications and corrective measures resulting from this analysis. Operating experience feedback is an essential tool in improving defence in-depth applied to the operation of BNI.

3 NOTIFYING EVENTS

The regulations applicable to the BNI require plant operators to implement a suitable system to detect, manage and process deviations or anomalies occurring in their facilities. This system aims to detect minor deviations which do not justify individual in-depth analysis but which may be of interest inasmuch as their recurrent character could be the sign of a problem requiring in-depth analysis. The aim is mainly to detect "weak signals" which could give early warning of more serious events.

ASN has organised the events in a hierarchy so that the significant ones are treated in priority by the plant operators. For this purpose, ASN has defined criteria for notifying significant events. The criteria for these significant events "*involving the safety of BNI other than pressurised water reactors*", "*involving the radiological protection of BNI*" and "*involving the environment of the BNI*" are defined in appendices 5, 7 and 8 of ASN Guide of 21 October 2005 and are repeated in the appendix to this report. We must emphasise that certain events occurring in civil LUDD BNI can be classified as significant under the criteria defined for one or more families of significant events mentioned above.

When an event meeting established criteria occurs, the plant operator is required to notify ASN within two days of it being detected. He must in addition submit his analysis of the event in a report within two months at most. If the document is not final, the plant operator is required to submit a final version of this report at a later date. IRSN receives a copy of these documents submitted to ASN.



In April 1994, with the aim of informing the public about significant events occurring in the BNI, France adopted the INES scale (International Nuclear Event Scale) developed by the IAEA.

The INES scale is designed to cover the significant events occurring in civil or classified-secret BNI notified under "safety" and "radiological protection" and the radioactive material transport events. The significant "environmental" events are classified outside the INES scale. It is important to note that the INES scale is not a tool for evaluating the safety of BNI.

ASN performs an initial systematic analysis of significant events notified by the plant operators and rules on the classification of the events in the INES scale based on classification proposals made by the plant operators. Depending on the magnitude of the event, ASN can be called on to gather quickly more accurate information from the plant operator in question, especially under a "reactive" inspection, or request IRSN to carry out an in-depth safety assessment. For the civil LUDD BNI, IRSN carries out about ten safety assessments of this type every year. Based on the information compiled, with or without an IRSN assessment, ASN may have to formulate requests intended to supplement the measures taken or planned by the plant operators to prevent the recurrence of a similar event.

In accordance with the ASN Guide, the events not covered by the notification criteria are termed "safety-related" events. Information about these events, which represent a significant proportion of the operating experience feedback, are available to the ASN inspectors during inspections. We must underline that some operators ("cycle" facilities mainly) also notify certain of these events to ASN; they are then proposed "below the INES scale".

Lastly, under the nuclear safety and radiological protection reports submitted periodically to ASN, the operators present a summary of events occurring in their facilities ("significant" and "safety-related" events) and corrective measures resulting from their analysis.

This report deals with events notified to ASN ("significant" or "safety-related") involving the civil LUDD BNI.

4 THE IRSN APPROACH TO ANALYSING AND DEALING WITH EVENTS

One of the main IRSN missions is to carry out expert assessments of nuclear and radiological risks during civil and defence activities, in support of the public authorities charged with nuclear safety and radiological protection. This mission includes expert assessment of the safety of French civil or classified-secret BNI in order to provide the authorities the appraisal elements they require to make their decisions about these facilities in a timely fashion.

IRSN thus examines the safety cases submitted by the operators at the different regulatory stages in the life of facilities and also after modification or following events affecting their safety. In this context, IRSN monitors the safety of LUDD BNI to have the best knowledge possible of these facilities (monitoring their upgrades especially) and their operating experience feedback as accurately as possible. The safety assessment of these BNI can be adapted in the best possible way to the risks they present by capitalising on this knowledge.

In addition to this case-by-case examination of facilities, all facilities must be investigated to draw the more global lessons from operating experience feedback and to define, if appropriate, studies and research to boost the relevance of the safety assessment, especially for future facilities. This investigation identifies areas requiring more in-depth expert assessment (organisational and human factors, for example), topics deserving special attention during individual facility inspections (underground effluent transfer pipes, for example, given the events occurring in the cycle facilities in 2008) or study and research topics (behaviour of containment devices subject to temperature and pressure stresses in a fire, for example).

To capitalise on operating experience feedback, IRSN uses a database, called "SAPIDE LUDD", gathering information on events occurring in the LUDD BNI. It includes all events notified to the safety authorities and also known significant events in foreign facilities of the same type (in conjunction with the FINAS database managed jointly by IAEA and OECD/NEA). This base is intended for the Institute's specialists, to give them easy access to organised information on the events occurring in facilities so as to boost the quality of safety assessments carried out in support of the safety authorities. The SAPIDE LUDD database currently contains more than 4500 completed sheets; the oldest date back to the 1960s.

Beyond its function of archiving event information, this database has been developed as a tool for analysing the operating feedback from these events. With this in mind, the base includes a standard encoding and indicator system designed to codify each event and a research tool using logical operators.

The assessment of "significant" and "safety-related" events notified to ASN between 2005 and 2008 for LUDD BNI, discussed in this report, is largely based on the SAPIDE LUDD database.

5 GENERAL LESSONS FROM EVENTS NOTIFIED BETWEEN 2005 AND 2008

This chapter presents the main lessons learned from analysing the changes in the number and type of events notified and an overall assessment of the consequences of these events for the workers, the population and the environment. The analysis is obviously highly dependent on information available about the notified events. In this respect, the last part of this chapter assembles the general comments by the Institute on the documents submitted and the related notification practices as well as their impact on the analysis performed by the IRSN presented in this report.

5.1 CHANGES IN THE NUMBER OF EVENTS NOTIFIED TO ASN BETWEEN 2005 AND 2008

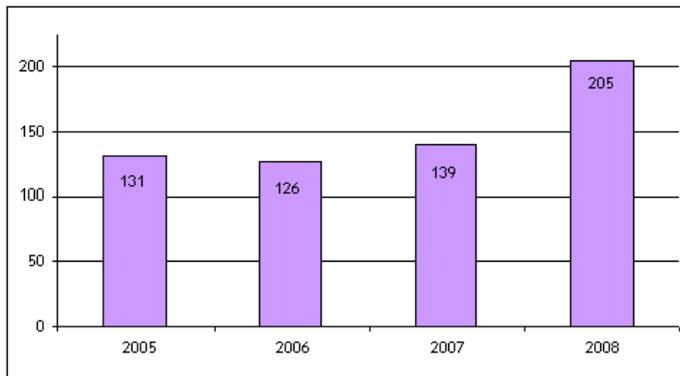


Diagram 1: Annual number of events notified to ASN

The total number of events notified to ASN ("significant" and "safety-related" events, diagram 1) was globally stable during the years 2005 to 2007. A significant increase (about 45%) was noted in 2008, on the other hand. This is linked especially to the increase in notified environmental events and notified safety events classified at level 0 on the INES scale.

For the classification of events on the INES scale, diagrams 2 and 3 show an increase in level 1 events in 2008, after the downwards trend noted in previous years.

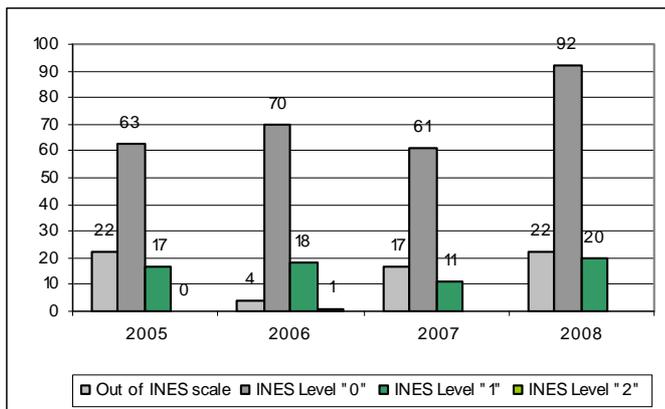


Diagram 2: Number of safety events notified annually for each INES level

A single significant event was classified level 2 in the period in question; this event, which occurred in 2006 in the CEA/Cadarache plutonium technology facility (ATPu) is presented in chapter 6 of this report.

The low annual number of significant radiological protection events notified (about twenty) must be emphasised. This has not changed significantly in the period in question.

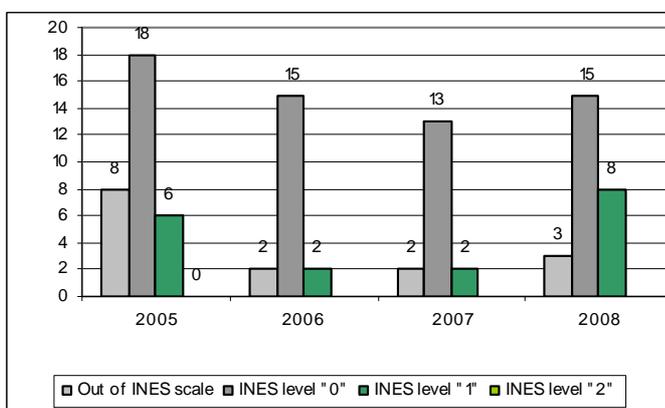


Diagram 3: Number of radiological protection events notified annually for each INES level

It is also important to remember that certain significant events are notified to ASN under several criteria (safety, radiological protection and environment). This explains why, for a given year, the sum of events illustrated in diagrams 2 to 4 is higher than all the events notified (see diagram 1).

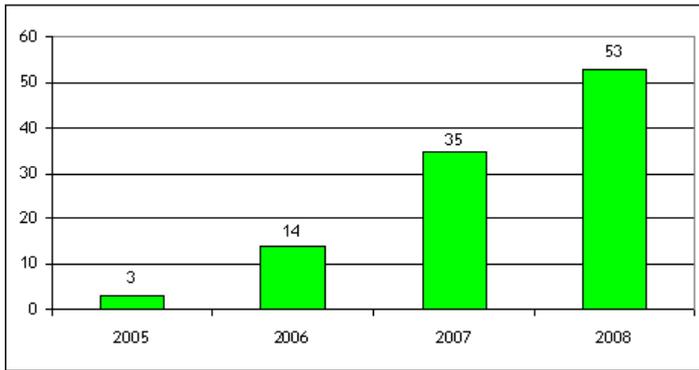


Diagram 4: Number of notified environmental events for the years 2005 to 2008

The on-going increase noted since 2006 suggests that the plant operators required some time to appropriate requirements for notifying environmental events (diagram 4), especially those leading to chemical or toxic releases which are the lion's share of these events. In this respect, it must be underlined that the ASN requirements in terms of notifying these events are more recent (October 2005) than their safety or radiological protection counterparts.

A majority of environmental events was notified in the fuel cycle facilities (La Hague and Pierrelatte sites in particular); an increase in this type of event has also been noted in the other families of facilities.

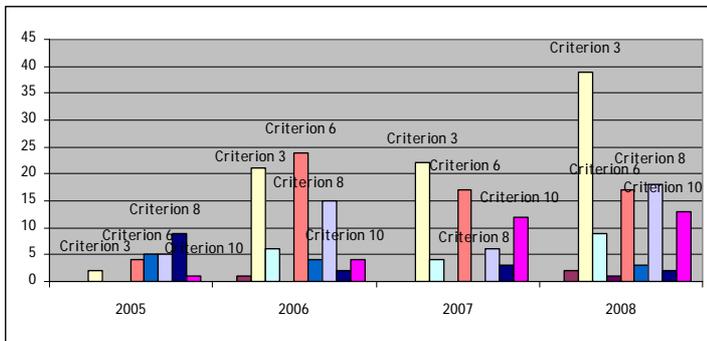


Diagram 5: Annual number of significant events notified based on safety notification criteria

In addition, an examination of the changes in the number of event notifications based on safety notification criteria (diagram 5) shows a major increase in the use of criterion 3 by the plant operators (events "leading to one or more safety boundaries being exceeded, as defined in the safety analysis report or the decree authorising the creation of the facility") during 2008; a 75% increase approximately is noted between 2007 and 2008.

It is reasonable to think that the increase in the number of safety events notified is linked, for a significant proportion, with improved detection and improved feedback of deviations to the safety reference framework by plant operators. The assessment of consequences of events notified to ASN, presented in section 5.2 below, shows that these changes are generally linked to events which have not had major consequences for the workers, the general public or the environment.

Changes in the number of significant events notified to ASN per family of facilities

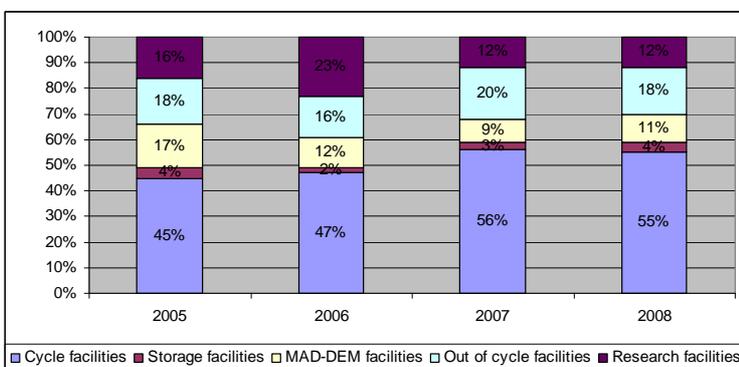


Diagram 6: Proportion of significant events per family of facilities and per year

Diagram 6 shows that about 50% of significant events notified to ASN involve nuclear fuel cycle facilities. This major proportion seems overall consistent with the industrial activities carried out in these facilities and the number of buildings making up some BNI; thus BNI 116 and 117 at the La Hague site include the twenty or so buildings of the spent fuel reprocessing plants UP3A and UP2-800.

Generally, the proportions of significant events for the various families of facilities do not show very marked changes; in addition, the increase in the number of events notified during 2008 cover all families of facilities.

Nevertheless, an increase in events notified to ASN has been noted for certain BNI in 2008; this increase was higher than the average increase noted for all facilities. Such increases may be linked to improved notification of minor events but, in a few cases, they need to be examined more in depth in order to detect any adverse trends likely to affect safety. Under its safety assessments of BNI, the Institute analyses these changes and alerts ASN when they could degrade the safety level. An opinion of this type was therefore submitted to ASN in 2008 following a significant increase in events notified for the radiopharmaceuticals production facility (BNI 29) located at the Saclay site (events caused by organisational and human factors and insufficient safety and radiological protection culture).

5.2 ASSESSMENT OF THE CONSEQUENCES OF EVENTS NOTIFIED TO ASN BETWEEN 2005 AND 2008

This section presents an overall assessment of the consequences of events notified to ASN between 2005 and 2008. It has three parts: an assessment of the consequences for the environment and the population, an assessment of the consequences for the workers and, lastly, an assessment of consequences in facilities concerned by these events.

5.2.1 CONSEQUENCES OF EVENTS NOTIFIED TO ASN FOR THE ENVIRONMENT AND THE POPULATION

The elements provided by the plant operators show that the vast majority of events notified to ASN between 2005 and 2008 (in the order of 72% to 90% depending on the year) had no impact inside or outside of the BNI sites (no release of radioactive materials or chemical substances into the environment especially).

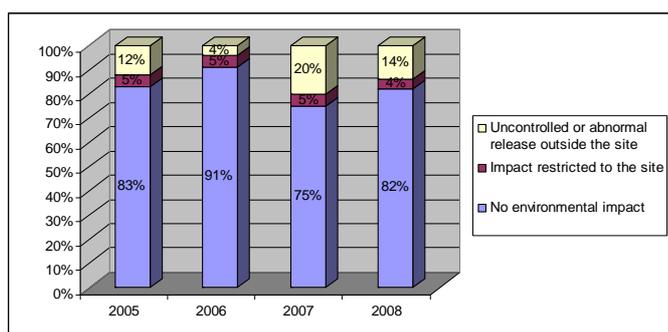


Diagram 7: Proportion of events based on their environmental consequences for 2005 to 2008

A low and overall stable percentage of events notified (in the order of 5%) led to relatively minor consequences inside the site in question. This involves very differing types of event occurring, for example, when handling devices containing radioactive or chemical materials outside buildings. Plant operator actions after detecting these events have limited the extent and the consequences.

An average proportion of about 12% of events produced releases outside nuclear sites : uncontrolled releases or discharge of effluent not complying with regulatory requirements (especially fixed limits in the release authorisation orders). None of these events had significant consequences for the environment or the population. The statistical analysis, performed by using the SAPIDE LUDD database, notes an increase in the percentage of these events in 2007 over the other years considered. The analysis shows that the increase noted in 2007 is very largely linked to a substantial increase of notified environmental events compared with previous years (35 events notified in 2007 compared with three in 2005 and fourteen in 2006); it basically involves (about 75%) releases of chemical or toxic, but non-radioactive, substances.

In addition, the analysis reveals an increase during 2008 of two classes of events: uncontrolled releases of liquid effluents; failure to comply with an operational provision fixed in a release authorisation order, for radioactive substances. These two points are analysed below.

5.2.1.1 Events causing limits fixed in the radioactive effluent release authorisations to be exceeded

Several events notified in 2008 caused the limit fixed in a radioactive effluent release authorisation to be exceeded. This type of event is on the up compared with previous years. The analysis does not reveal the causes generic to all the LUDD BNI, rather it seems to involve events specific to certain facilities. Note that a single event of this type was notified during the first half of 2009.

The two most significant events relate to the exceeding, during 2007 and 2008, of the annual limit authorised for carbon-14 releases (^{14}C) in BNI 138 at the Tricastin site, operated by SOCATRI (called SOCATRI facility). These recurring events occurred in the processing facility of radioactive waste from "small producers" (hospitals, universities, etc.) before their transfer to a disposal plant (disposal at the Aube Waste Disposal Facility for example). Note that the excesses noted were extremely limited in size. The safety assessment by IRSN confirmed the low radiological impact of these events on the general public and the environment. These events are linked to a poor assessment of the ^{14}C activity by the producers of waste³ and the shortage of resources in the BNI to detect such a deviation. In the final report on the event, SOCATRI described the provisions planned to prevent such an event recurring (improved provisions for controlling waste packages, defining limit activity values for the waste packages, improving release detection systems, etc.). Having implemented these improvements, SOCATRI restarted its waste processing activities in this facility at the end of June 2009. The monitoring provided for ASN should ensure that these provisions are both effective and sufficient.

In addition, several events involve exceeding limits set in the release authorisations related to CEA-operated BNI (exceeding the monthly tritium release limit, for example). They appear linked to insufficient appropriation of these requirements (normally recent) by the plant operators in question, who have not used sufficient resources to comply with the fixed limits (measuring device, for example). Note also that the limits exceeded are very low, which has therefore only led to a negligible health impact. CEA is currently working to prevent this type of event from recurring.

5.2.1.2 Events causing uncontrolled releases of radioactive or chemical liquid effluents

Compared with previous years, a higher number of events causing uncontrolled releases of radioactive or chemical liquid effluents were notified to ASN in 2008. These events caused releases directly into the ground or systems connected to water ways. They mainly concerned nuclear fuel cycle facilities at the Tricastin site.



Overview of the Tricastin site

One incident from all the events notified was the subject of intense media coverage during summer 2008. This involved the incident in the SOCATRI facility on 7 July 2008 (see description in chapter 6). This event caused a leak of about 20 m³ of uranium-bearing effluents outside the planned retention tanks. Some of these effluents leaked into the rainwater system then the La Gaffière water way; others infiltrated the ground underneath the facility. An expanded monitoring system in the Tricastin area (ground waters and surface waters), in which IRSN took part, was set up following this incident. Very synthetically, the measures under this monitoring plan showed the absence of persistent pollution in the environment linked to the uranium release of 7 July 2008.

This monitoring system⁴ also revealed the existence of older uranium contamination in certain points of an area bordered by the Lauzon, the Donzère-Mondragon canal and the Rhone (which could not be ascribed to the incident of 7 July 2008).

Apart from the event on 7 July 2008, several events have caused uncontrolled releases of liquid effluents. For example, we can mention the event notified on 17 July 2008 by FBFC for its plant at Romans-sur-Isère. This event relates to the discovery of a break in a pipe transferring effluents with a low uranium concentration, installed in an underground channel, which had been releasing effluents directly into the ground for several years. The other main similar events in 2008 involved the COMURHEX and EURODIF facilities. These events, which occurred in old facilities, were all caused by pipe failures linked to ageing mechanisms (especially corrosion or fatigue). This point is analysed more specifically in chapter 7 of this report.

³ It must be emphasised that the unreliable information submitted by waste producers has also caused other events notified to ASN (events occurring in the CENTRACO plant for example).

⁴ A full file on the monitoring plan, the measures taken and the monitoring assessments can be found on the IRSN Internet site (www.irsn.org).

Although these events had no significant consequences for the environment, they revealed design faults, highlighting a poor application of the defence in-depth concept (lack of or insufficient leak detection resources, for example) and not enough regular inspections. Improvement plans have been introduced by the various plant operators involved, following these events.

5.2.1.3 Events causing releases of chemical or toxic effluents into the environment

Apart from the liquid effluent leaks mentioned above, an increase in the number of events causing releases of chemical or toxic effluents into the environment has been noted since 2007. A substantial proportion of these events involved facilities or equipment used to support the operation of BNI, installed outside "nuclear" buildings (hot and cold water production facilities, emergency generator sets). IRSN has not analysed these events in this report⁵.

5.2.2 CONSEQUENCES OF EVENTS NOTIFIED TO ASN FOR THE WORKERS

Events causing abnormal external exposure for workers

There are relatively few significant events causing abnormal external exposure for workers between 2005 and 2008 (about ten). These events produced doses lower than the annual maximum doses set by the regulations (20 mSv for category A workers). Note also that fewer people were involved. These events are mainly caused by organisational or human factors. They mainly involve failure to comply with operating rules or poorly-prepared interventions (curative maintenance operations, for example).

Two events representative of these shortcomings (events of 10 September 2007 and 21 May 2008, occurring respectively in the radioactive waste management facility (BNI 72) and the radiopharmaceuticals production plant (BNI 29) at the CEA Saclay site are described in chapter 6 of this report. Poor monitoring standards of contracting company personnel are also the cause of several events, like those of 10 September 2007 and 18 September 2008. Note that the second of these events, in the radiopharmaceuticals production plant in the CEA at Saclay (BNI 29), is the only one to have caused abnormal exposure of contractors classified as "not exposed to ionising radiation"⁶.

Events causing contamination of workers

There were few significant events notified to ASN that caused contamination of people (bodily, clothing or internal contamination) between 2005 and 2008 (about 7% of events). Note that this number has remained relatively stable since 2000. In the vast majority of cases (about 75%), these events have not caused internal contamination, be it through inhalation or per cutaneous. There were few, even negligible radiological consequences of this contamination for the operators and, in any case, they were below the regulatory maximum annual dose for category A workers (20 mSv).

Note that a few specific facilities produce the majority of contamination events (nuclear fuel cycle facilities), which is in line with the type of work carried out inside them (working with glove boxes, etc.). In addition, **although a few events are due to technical causes (equipment failures), the vast majority of them are caused by organisational or human factors.** This involves especially breaches of operating or radiological protection procedures and shortcomings in preparing special interventions (failure to analyse risks or to take them sufficiently into account). These shortcomings are illustrated perfectly by the significant event of 20 October 2006 in the HAO building at the La Hague. It is described in chapter 6 of this report.

In conclusion, **none of the events notified to ASN between 2005 and 2008 have had significant consequences for the workers.** For the vast majority of "contamination" or "abnormal exposure" events, the provisions, which remained operational, restricted the radiological consequences to a low level. Nevertheless, a large proportion of these events could have been avoided by improving preparations for interventions and complying with operation and radiological protection rules. **Although plant operators have started work to improve the control of risks from organisational and human factors in recent years, efforts are still required in this area.** These aspects will be dealt with more specifically in chapter 7.3 of this report.

⁵ IRSN analyses the risks from chemical/toxic materials when they are directly associated with radioactive materials (UF6, especially).

⁶ The radiological protection of workers is governed by the Decree of 31 March 2003 and its application orders. Worker classification is based on doses they are likely to receive (categories A or B). Personnel classified "not exposed" are considered as members of the general public; a regulatory maximum annual dose of 1 mSv applies to them.

5.2.3 CONSEQUENCES IN THE FACILITIES

As indicated in previous chapters, the percentage of significant events notified to ASN causing real consequences for the environment, the general public or the workers is low. This is explained by the event notification criteria (see the appendix to this report) that do not consider only the noted effects; they also consider the actual degradation of the in-depth defence and aim especially to detect events giving early warning of more serious events.

The significant events notified to ASN have had consequences in the facilities in a significant number of cases. These consequences are basically functional (unavailability of equipment or facility units) or radiological (basically room contamination). An illustration of this is the event on 2 June 2006 in the T2 facility (UP3-A reprocessing plant at La Hague), where the evaporator in a tritiated acid recovery unit was punctured (degradation of the first containment barrier). Although there was no consequence for the environment, the population or the workers, the punctured evaporator contaminated the cell where the equipment is installed and put the unit out of service for about two months (time needed to repair the evaporator).

According to the information from the plant operators in the significant event reports, the events equipment or units out of service for extended periods are overall few and far between (about 10% of events rendering equipment unavailable for longer than one week and 3% longer than one month). In the vast majority of cases, the non-availability periods of facilities are short.

5.3 GENERAL COMMENTS ON THE SIGNIFICANT EVENT REPORTS AND THE NOTIFICATION PRACTICES BY OPERATORS OF LUDD FACILITIES

The analysis of events notified to ASN depends strongly on elements sent by the plant operators in the significant event reports. Given the large number of events notified annually, a detailed analysis of all these events, which would require gathering additional information, cannot be envisaged.

Additional information is, however, compiled for the notified events deemed the most significant; this involves especially events where ASN has requested an IRSN safety assessment (about ten a year) and events undergoing ASN inspections.

The analysis carried out in the context of this report has confirmed that the reports of significant events submitted in recent years by LUDD plant operators overall comply with the standard framework presented in the ASN guide. Nevertheless, the elements presented in these reports do not always entirely satisfy certain objectives of the framework. This concerns particularly:

- identifying "root" causes of events, especially organisational; this identification aims to seek out fundamental, potentially generic, causes which can be used to define relevant corrective actions to improve safety,
- analysing "potential" consequences of events (i.e. consequences in the event of supplementary failures), which provide a more accurate evaluation of the facility's in-depth defence.

Better formalisation of these two aspects in the significant event reports submitted by the plant operators will improve the overall analysis of operating experience feedback from events notified to ASN.

In addition, the analysis of events notified to ASN between 2005 and 2008 shows a certain heterogeneity in applying notification criteria for some types of event (events relating to the containment of radioactive materials especially) by the LUDD facility operators. For events of little importance for safety in particular, some criteria are subject to interpretation inasmuch as they are not quantified. This heterogeneity in notification practices can also be explained by the large number of plant operators involved and the huge diversity of LUDD facilities with a tremendous variety of risks.

Thus, events with a "similar" impact on safety can be considered, according to the plant operators, as significant events or "safety-related" events. Similarly, some events of minor importance cannot be notified depending on plant operator practices and appraisals. Although the basic objective is that the plant operators process the events occurring in the facilities appropriately, **greater homogeneity in applying significant event notification criteria would facilitate cross-disciplinary analysis of operating experience feedback.**

The aspects evoked above have an impact on the cross-disciplinary analysis of events notified by the operators which is presented in chapter 7 of this report. In particular, in certain cases, the shortfall or the lack of precise identification of "root" causes of some events is detrimental to learning all the lessons from the operating experience feedback.

6 DESCRIPTION OF SIGNIFICANT EVENTS NOTIFIED BETWEEN 2005 AND 2008

This chapter presents a series of events from among the most significant occurring in LUDD facilities between 2005 and 2008. The first section presents three significant events in foreign LUDD facilities (INES level higher than or equal to 3). The second section describes events occurring in France, with a wealth of lessons to be learned from the operating feedback; the aim is principally to illustrate the main types of event occurring in French facilities during the period in question which are subsequently analysed in chapter 7.

6.1 DESCRIPTION OF SIGNIFICANT FOREIGN EVENTS

6.1.1 EVENT ON 21 APRIL 2005 IN THE THORP PLANT AT THE SELLAFIELD SITE IN THE UNITED KINGDOM

THORP, operated by the British Nuclear Group Sellafield Limited (BNGSL), is a specific spent fuel reprocessing plant. Its process is globally similar to the one implemented in the plants at La Hague site.



Sellafield site, United Kingdom

The operations in the plant include shearing fuel rods into sections a few centimetres long, dissolving the fuel in nitric acid at boiling point then clarifying the solutions obtained by centrifugation to separate the insoluble matter. The uranium and plutonium are then separated from fission products and other actinides and purified by a liquid-liquid extraction process using a selective solvent - tributyl phosphate. The finished products are then stored temporarily as uranium oxide and plutonium oxide before being used to manufacture new fuels.

The event of 21 April 2005 affected one of two "accountancy" tanks in the plant; these tanks are installed in a closed cell inaccessible to the personnel given the irradiation risks. They are used to account for quantities of uranium and plutonium in the "clarified" solutions prior to the chemical separation operations. As the accounting process is based in particular on the solution contained in the "accountancy" tanks, these tanks are suspended from the roof of the cell via a weighing system. Following three fuel reprocessing campaigns in succession, on 14 April 2005 the plant operator revealed major deviations in the accountancy of processed materials and detected solution in one of the sumps in the cell. On 20 April 2005, a camera inside the cell showed clearly the presence of large quantity of solution (an estimated 83 m³) in the collector pan (a secondary containment consisting of a thick walled concrete cell lined with stainless steel) and a clean break in a feed pipe to one of the two tanks. According to information from the plant operator, this event had no radiological consequence for the workers or for the environment (no environmental release)⁷. **Nevertheless, given the numerous failures identified, this event was rated 3 on the INES scale.**

Following investigations, BNGSL estimated that the leak had probably started in July 2004. It stated that the break in the "accountancy" tank feed pipe was linked to mechanical fatigue induced by the side movements of the suspended tank in relation to the piping centreline during solution homogenisation operations.

These side movements caused mechanical stresses in the piping between its last anchoring point in the cell (fixed point) and its connection point to the tank (moving point). These stresses initially caused fissuring in the piping and subsequently (further stresses due to an increase in the duration of tank homogenisation cycles) a clean break. The plant operator determined that this event was caused by a modification to the initial design of the "accountancy" tanks during construction, without these consequences being analysed. In addition, the investigations revealed a series of human and organisational errors which precluded early detection of the incident. The signs giving early warning of the event were not exploited (deviations in the material balances, samples taken in the sumps, abnormal level measurements in the sumps, etc.).

⁷ The lack of consequence relates to the design of the plant which had taken this type of accident situation into account. The consequences of the failure of the first containment barrier were limited by other existing "barriers" (retention system underneath the tanks, cell and building walls, ventilation and filtering systems). In addition, the arrangements to control other nuclear risks (especially criticality risks) proved sufficient.

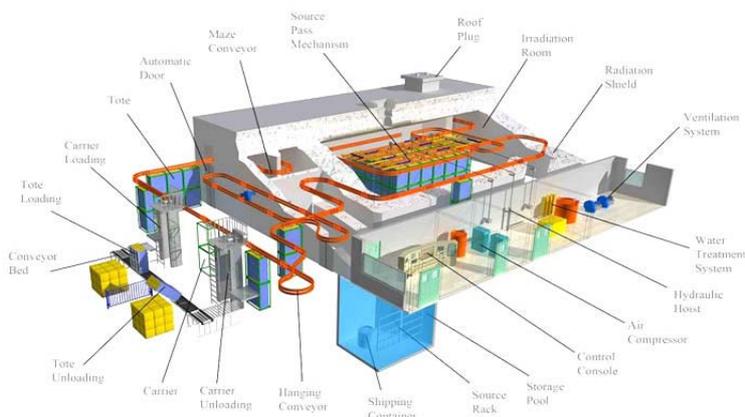
Following this event, BNGSL has adopted a major improvement plan to prevent the event recurring in the plant. Firstly, BNGSL checked the state of equipment which could be subjected to similar mechanical stress as that causing the incident. In addition, many technical modifications were carried out in the plant, the main ones being a modified balancing method (weighing deleted) and tank homogenisation provisions, the addition of leak detection resources and improved monitoring in service of the leaktightness of fabricated equipment (tanks, piping, etc.). In addition, improvements were adopted to prevent the human and organisational errors noted, especially in terms of operator training (alarm management, etc.), team management and operating procedures.

IRSN has analysed this event to determine whether safety improvements are necessary in the La Hague plants⁸. It appeared initially that this event could not be transposed directly to the plants mentioned inasmuch as they have no suspended equipment (quantity of materials are evaluated by a "volumetric" method). However, the plants do have equipment with similar risks of fissuring through the fatigue of materials subjected to mechanical or thermal cycles. In this respect, following events which caused leaktightness failures in fabricated equipment (dissolvers in the former UP2-400 plant for example), AREVA re-examined the existing monitoring methods used for early detection of low flow rate leaks. After assessment of the additional detection arrangements adopted by the operator, IRSN considered that the improvements were satisfactory overall and recommended a few additional studies.

Overall, the event in the THORP plant shows the importance of having available suitable methods for monitoring the first containment barrier. Under its safety assessments of LUDD BNI, IRSN sets out to check that the lessons from this event have been well learned by the plant operators.

6.1.2 EVENT OF 11 MARCH 2006 IN THE IRRADIATION FACILITY OPERATED BY STERIGENICS AT THE FLEURUS INDUSTRIAL SITE IN BELGIUM

Sterigenics sterilises medical instruments and foodstuffs in its plant at the Fleurus industrial site by irradiating them with sources of cobalt-60.



This facility comprises two irradiation cells called GAMMIR 1 and GAMMIR 2. Each cell has a pool five to six metres deep in which the sources of cobalt-60 are stored temporarily outside irradiation phases, thereby giving personnel access. The personnel are kept from the risk of exposure to ionising radiation when the sources are on the surface (irradiation phase) by radiological protection provided by the two metre-thick concrete walls in the cells and the closing and locking of doors to prevent all personnel access.

Standard diagram of an irradiation facility

On the morning of Saturday, 11 March 2006, alarms were set off in the ambient irradiation monitoring units installed inside and outside the GAMMIR 2 cell. This cell was no longer in product irradiation phase and the door to the cell was open.

As they could not acknowledge the alarms, the personnel present in the facility called an experienced person at home who arrived at the facility about an hour later. This person quickly managed to acknowledge the alarms and then decided to close the door to the cell. Before the door can be closed, the procedure is to check that the cell is empty of people; the operator has to go to the back of the cell to achieve this and having checked that nobody is in the cell, he activates a specific device (system designed to ensure that the check has been made). It was during this short operation (an estimated twenty seconds) that the operator was seriously irradiated.

About three weeks later, the operator reported a variety of symptoms (vomiting, hair loss) to the occupational doctor who diagnosed irradiation. The examinations estimated the dose received at about 4.5 Gy, i.e. over two hundred times

⁸ For further information on this event, visit the IRSN Internet site (www.irsn.org).

the regulatory maximum annual dose for a category A worker. Checks on other people in the facility on 11 March 2006 showed no abnormal exposure. The event was rated 4 on the INES scale.

The investigations revealed that the main cause of the irradiation was a failure of the hydraulic source handling system (called source carrier), which caused random upwards and downwards movements of the source carrier which therefore left its position of temporary safe storage. The assumption is that these movements were linked to disturbances between the hydraulic systems of the two irradiation cells.

The analysis of this event also revealed other failures, especially human and organisational, such as the failure to respect the procedures for personnel access to an irradiation cell (in particular, checking in advance for any abnormal dose flow rate in the cell).

At the request of the Federal Agency for Nuclear Control (FANC), an action plan was implemented to remedy the failures and shortfalls revealed during the event of 11 March 2006, in particular to make the source handling systems reliable and improve the application of operating procedures (writing procedures, training personnel in the new procedures especially).

IRSN has analysed the operating feedback from this event insofar as several irradiation facilities similar to the Sterigenics facility are operated in France. Given the severity of radiological consequences which can result from the presence, however short, of people in an irradiation cell when the sources are not in their position of temporary safe storage, it is important that such an accident situation is made virtually impossible.

Although an undetected failure of the source handling system similar to the one which caused the event of 11 March 2007 seems highly unlikely in the French irradiation facilities given their design, it must be remembered that the provisions made when designing these facilities to guard against such risks come from general design principles presented in Basic Safety Rule I.2.b applicable to them. In particular, this rule requires that the safety systems for these facilities are designed so that the presence of a person in the irradiation cell when the sources are not in a safe position requires a double equipment failure (compliance with the single failure criterion). IRSN checked for compliance with this requirement during the safety examination of these BNI before their being put into service.

6.1.3 EVENT OF 26 AUGUST 2008 IN THE RADIONUCLIDE INSTITUTE (IRE) ON THE INDUSTRIAL SITE OF FLEURUS IN BELGIUM

The Radionuclide Institute (IRE) at Fleurus isolates, purifies and conditions the radionuclides most commonly used in nuclear medicine.

The IRE activities include the production of metastable molybdenum-99/technetium-99 used in a large number of nuclear medicine examination and the production of iodine-131, xenon-133, strontium-90 and yttrium-90 used for diagnosis and therapy. These radionuclides come from the fission, in a nuclear reactor, of nuclei of uranium-235 (targets in uranium highly enriched with isotope-235).



Fleurus industrial site in Belgium

The radionuclides are extracted and purified in shielded cells located in a building of the IRE. The radioactive solutions resulting from these operations are stored temporarily in small tanks (maximum volume of 50 litres) installed in the basement of this building before being transferred, when these tanks are full, to larger tanks in another building. The acid and alkaline solutions are stored temporarily in separate tanks. The tank vents are connected to ventilation systems fitted with filters and iodine traps.

On 25 August 2008, the IRE management advised the Federal Agency for Nuclear Control (FANC) of an abnormal release of iodine-131 (with a radioactive half-life of eight days) via the building's chimney. The plant operator stated that this release had started on 22 August following the transfer of solutions from three small tanks to a 2700-litre tank.

The delay in detecting this event was due to the failure of the system monitoring gaseous releases through the chimney. The plant operator immediately introduced measures to limit the amount of releases (additional iodine traps in the tanks' ventilation systems, in particular).

FANC suspended production activities on 26 August. In addition, given the levels of radioactivity measured in the environment around the site, the national nuclear and radiological emergency plan (level U2) was activated on 28 August. On this date, recommendations were broadcasted to populations living around the Fleurus site (initially at a distance of 5 km to the north-east of the site) advising them not to consume locally-produced leaf vegetables and milk or rainwater⁹; these recommendations were lifted completely on 6 September. The emergency plan was subsequently lifted on 12 September.

The measures put in place by the plant operator confirmed that only iodine-131 had been released into the environment. The release was estimated at 48 GBq (i.e. about the annual authorised limit for releases of this radionuclide by the IRE). The bulk of the release (90%) took place between 22 and 28 August, with the later residual releases coming from the desorption of the iodine present in the ventilation systems. The event was rated 3 on the INES scale.

Investigations by the plant operator showed that the considerable desorption of the iodine in the faulty tank was linked to an unscheduled chemical reaction from the mix of acid solutions coming from three small tanks in two production units using different chemical reagents. This reaction appeared due to unusual circumstances, especially the almost simultaneous transfer of solutions from the three small tanks and the weak dilution of these solutions in the receiving tank which was barely filled (about two hundred litres).

This event revealed other failures and shortcomings, especially the facility's release monitoring and ventilation systems.

Improvements have been introduced by the plant operator to remedy the causes of this event; they cover the solution transfer procedure, the monitoring and alarm systems and the ventilation and filtering equipment.

FANC authorised the IRE to re-start production on 3 November 2009, on condition that it complied with specific stipulations⁹.

The operating feedback from this event cannot be transposed directly in France inasmuch as there is no nuclear facility carrying out the operations behind the August 2008 event at the IRE. In particular, extracting radionuclides from irradiated uranium and purification targets does not take place in the radiopharmaceuticals production facility located at the Saclay site.

Nevertheless, this event illustrates how important it is for BNI operators to analyse in depth risks linked to possible mixes of chemical products in liquid or gaseous form. This analysis should deal with all phenomena likely to occur during these mixes in normal or incident operation (exothermic reactions, formation of explosive materials, formation of precipitate elements, etc.). The analysis should take place during the design phase of BNI as well as when a facility is being modified (modification of an existing process or addition of a new one). IRSN examines these aspects as part of its safety assessments of LUDD BNI.

In this respect, it is interesting to note that the operating feedback from French BNI has recently underlined the existence of such risks. Thus, a few years ago, the plant operator of an "front end" cycle facility noted the formation of a material which could induce an explosive reaction in a ventilation duct, resulting from an unplanned mix of incompatible gaseous effluents. Under its assessment of the modification proposed by the plant operator, IRSN suggested that ASN request other BNI operators to take into account the lessons from this operating feedback.

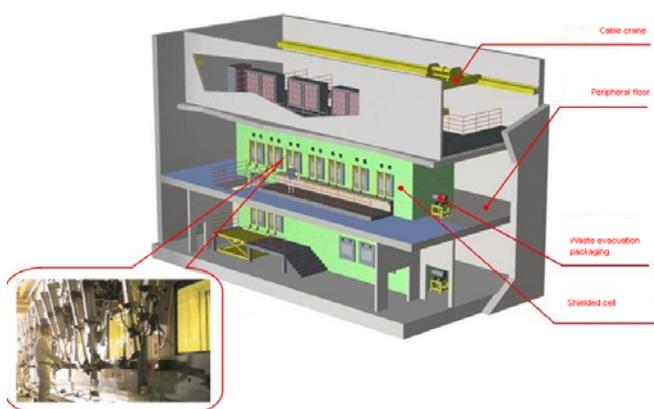
⁹ Visit the FANC Internet site (www.fanc.be) for detailed information on these provisions.

6.2 DESCRIPTION OF SIGNIFICANT FRENCH EVENTS

6.2.1 EVENTS OF 22 JUNE 2006 AND 13 DECEMBER 2006 IN THE STAR AND ATALANTE LABORATORIES RESPECTIVELY LOCATED AT THE CEA CADARACHE AND MARCOULE SITES

The operations performed in the STAR and ATALANTE research laboratories uses radioactive materials with powerful radiation or neutron emissions; the laboratories are equipped with shielded cells, especially for radiological protection of the personnel.

A number of handling operations take place in rooms around the cells to receive, unload, transfer and evacuate radioactive materials used in these cells and to evacuate by-products and solid waste created by operation on these materials. These handling operations involve very heavy packaging (up to several tens of tons) due to the very thick radiological protection used in it (up to several centimetres of dense or hydrogenated materials).



Cable cranes are used for some of these handling operations; the loads are suspended from a cable via a hook and additional accessories (slings, etc.). There is a risk of loads falling during these operations; such a fall could disperse radioactive materials, cause a criticality accident or exposure to ionising radiation should major damage occur to the packaging containing the radioactive materials, the facility structures (shielded cells, floors, etc.) or safety-related equipment installed directly in line with the fall.

Overview of the "process" shielded system in the Atalante facility at the CEA Marcoule site

Under a deterministic approach to these risks, the plant operator must study through calculations and tests the potential falling loads and determine the consequences of the most serious falls in terms of safety. During studies prior to safety review¹⁰ in the STAR and ATALANTE laboratories, CEA found insufficient dimensioning of floors in some rooms surrounding the shielded cells in case of fall of the packages potentially handled in these rooms. This insufficient dimensioning relates to errors in the hypotheses or calculations during facility design. For the STAR laboratory, this event was declared to ASN on 22 June 2006, for the ATALANTE laboratory, on 13 December 2006.

These events had no real consequences, but they represent failures which could cause the loss of a safety function; they were classified level 1 on the INES scale.

Having analysed the situation, CEA has, in the first instance, made provision to limit the probability of occurrence and the consequences of a load falling in the rooms in question. These provisions are to reinforce checks on crane apparatus and components and increase the frequency of regulatory routine inspections of these cranes by an approved body. In addition, organisational, operational and inspection provision has been made to supervise more strictly (limiting the weights handled or handling heights, clearing potential obstacles, etc.) or even ban certain handling operations, or to reduce the risks of human error when preparing and handling packages. Secondly, CEA has planned to modify the STAR and ATALANTE laboratories, replacing certain handling operations using cable cranes by operations with greatly-reduced risks of falling loads (removal of handled loads on travellers, use of positioning tables, etc.) or by lessening the consequences (installation of fall shock absorbing systems).

Under the assessment of safety re-examination files for the STAR and ATALANTE laboratories, IRSN considered that the "immediate" corrective measures adopted by CEA were suitable, provided certain additional operating restrictions were added. IRSN considered that the modifications planned by CEA would effectively help control the risks of falling loads.

¹⁰ The regulatory framework and the objectives of a safety re-examination are defined in the summary of the safety re-examination of the solid radioactive waste management facility located at the CEA Saclay site (BNI 72); this can be found on the IRSN Internet web site (www.irsn.org).

IRSN considers that the two events examined here highlight the importance of regular, in-depth safety re-examinations of BNI. Such an exercise could, among other things, detect potential design errors or the appearance of operating configurations which had not been envisaged during the design phase and which had not been analysed sufficiently when they were implemented.

6.2.2 EVENT OF 20 OCTOBER 2006 IN THE HAO/SOUTH FACILITY OF THE UP2-400 PLANT AT LA HAGUE

The UP2-400 plant has been in its final end of operations phase since the end of 2003. Since then, the operator of the HAO/South facility¹¹ has been draining the radioactive materials contained in the process and rinsing equipment. On 6 October 2006, the plant operator had embarked on clean-up operations consisting of rinsing the process equipment in the clarification unit comprising two settling tanks.

Rinsing one of the two settling tanks scheduled for 20 October 2006 required the entry into service of an ejector to stir the solution contained in the equipment; for this, the steam feed line had to be connected between the ejector and the facility steam system using a hose. The hose was connected to both systems underneath a ventilated hood; the end piece of the ejector steam feed line, locked out by a padlock, was blocked by a plug when the line was not in use. In addition, a take-off in the ejector steam feed line was used to sweep this line with compressed air released into the settling tank via the steam ejector.

Two operators carried out the ejector connection operation on 20 October 2006. The operator who removed the plug felt a puff of air characteristic of an overpressure in a line, which prompted him to replace the plug immediately. Surprised by this overpressure, he repeated the operation; he replaced the plug again when the same phenomenon occurred. The two operators therefore decided to halt the operation and left the premises to check whether they had made a mistake in identifying the line. About twenty minutes later, the atmosphere monitoring system of the room with the ventilated hood set off an alarm. In addition, the operators found themselves to be contaminated during the radiological checks prior to their leaving the facility. According to the estimations carried out separately by the plant operator and IRSN based on the results of radiotoxicological analyses practised on the two operators, the commitment effective dose over fifty years received by each employee was less than the annual regulatory limit of 20 mSv. **This event, which had no environmental consequence, was rated 1 on the INES scale.**

The investigations revealed that the overpressure was caused by a plug left in the body of the ejector for over ten years, thus preventing the normal circulation of the sweeping air. According to the plant operator, this plug had not been removed after specific rinsing operations of a primary settling tank (no return to normal configuration after the operation). The plant operator also revealed the lack of a detailed risk analysis prior to removing the lockout padlock; such an analysis would normally have raised questions over the actual state of the ejector which had not been used for a long time. In addition, the plant operator stated that the internal contamination of operators and the contamination of the workshop were linked especially to breaches of radiological protection rules (not wearing a protective breathing mask, failure to comply with rules on radiological checks, etc.).

The operating feedback from this event has prompted the plant operator to make provision for a series of improvements (introducing an analysis of changes in risks relating to the end of operations, including especially checking the compliance of the facility against the initial operating situation, provisions to be taken if the normal configuration for facility cannot be achieved, radiological protection training plan for operators, etc.).

Following an assessment of this event, IRSN considered that the provision made by the plant operator, for both human and organisational factors and technically, were satisfactory overall and recommended additional improvements in a few points.

IRSN considers that this event illustrates the importance of preparing intervention in BNI (a detailed risk analysis and checking the actual state of the facility in particular). Insufficient preparation for special operations frequently results in events; this is especially important when equipment unused for lengthy periods is involved or where the plant operator only has partial information.

¹¹ The main functions of the HAO/South facility were shearing fuel elements, dissolving the uranium and plutonium oxide contained in the cladding sections and clarifying the solution before transfer to the U and Pu separation and purification cycles.

6.2.3 EVENT OF 6 NOVEMBER 2006 IN THE ATPu FACILITY AT THE CEA CADARACHE SITE

The main operations of the ATPu facility was until 2003 the fabrication of fuels for the Phénix and Superphénix fast breeder reactors, then MOX fuels for the pressurised water reactors. Once its operations were shut down, the radioactive materials were evacuated and the BNI was cleaned up. The event on 6 November 2006 relates to the conditioning of MOX fuel manufacturing scraps so that they can be evacuated from the facility. The different equipment required for this operation (grinder, mixer, etc.) is installed in separate glove boxes. The scraps are conditioned in containers called "jars"; transfers take place on a conveyor belt. Before each jar is moved, the fissile material it contains must be weighed. This weighing ensures compliance with fissile material weight limits in different equipment, limits defined to prevent criticality risks. A computer application is used to manage these weights.

On 6 November 2006, a batch of scrap was inserted into the grinder which still contained part of the previous batch. The fissile material in the grinder therefore weighed more than the maximum permitted limit for this equipment. It is important to note that the sub-criticality of the grinder would not have been compromised even if it had accidentally contained double of the permitted weight limit of fissile materials. The weight limit for fissile materials in the grinder was based on a study in which various potentially abnormal situations were examined, in particular double loading of the grinder. This event was rated 2 on the INES scale due to the failures noted concerning the provisions for preventing criticality risks.

Following his investigations, the plant operator was specific about the scenario leading up to this event. It turned out that due to a breakdown in the scales used to weight the jar receiving the fissile materials after grinding, the Shift Manager decided to change the operating procedure and replace these scales at the grinding station outlet with scales at the next "mixer" station. To transfer the jar to the "mixer" station, an operator input into the computer application mentioned above a weight of fissile material for the jar (a weight which should have been given by the faulty scales); this "fictitious" weight was numerically equal to the weight of the scrap inserted into the grinder. The computer application automatically removed this "fictitious" weight from the "grinder" station and allocated a nil residual weight of fissile material to it. Fissile material weights were supposed to be updated in the computer application after the actual weighing of the suspect jar at the "mixer" station.

However, due to an unidentified dysfunction, the grinder was not emptied correctly into the jar; part of the fissile material remained in the grinder. Other dysfunctions (conveyor breakdown delaying the transfer of the jar and incomplete transmission of information between operating teams especially) resulted in the jar not being weighed and therefore the fissile material contained in the jar and the residual weight in the grinder were not rectified in the computer application before a new batch of scrap was inserted into the grinder. The error was detected when the jar was weighed at the "mixer" station.

The plant operator considered that human and organisational factors were the major causes of this event. He indicated that the event was linked to insufficient safety culture by the personnel; the operating procedure had been altered without analysing safety and without applying the change management procedure provided for in such circumstances; organisation shortcomings (checking operations, transfer of information between teams, etc.) were also highlighted. The plant operator launched a major action plan to remedy the shortcomings identified (strengthening teams responsible for safety, improving operating provisions, boosting training and the safety culture, etc.). IRSN considers that this event illustrates how important it is for plant operators to make provision for controlling the risks of modifying operating conditions as well as the human and organisational factors in their facilities, especially for the management of operating contingencies.

6.2.4 EVENT OF 8 NOVEMBER 2006 IN THE HIGH-LEVEL LABORATORIES AT THE CEA SACLAY SITE

As part of the dismantling of high-level laboratories at the CEA Saclay site, a vinyl mobile containment system was fitted in a room to contain radioactive materials during the cutting operations intended to reduce the volume of dismantled materials. The cutting operation took place in a compartment inside the mobile containment system; the floor was covered with steel plates and the side walls and ceiling were constituted of fire-retardant, spark-arrester panels. The side walls stopped 20 cm from the ceiling to allow natural light into the compartment. This was fitted with a system to collect fumes during cutting (initially with a plasma torch), which releases the air after filtering into the atmosphere of the mobile containment system, and an air extractor fitted with a pre-filter and a HEPA filter, which releases the ambient air from the mobile containment system, after filtering, into the general collector for gaseous effluent releases from the facility.

On the day the incident occurred, with the plasma torch having broken down the day before, some metal ventilation ducts were cut inside the compartment by an operator using a grinder without the fire permit being reviewed in advance.

A second operator, who was monitoring the operation from outside the confinement system, noticed a gleam at the pre-filter inside the containment system. He alerted the operator doing the cutting work, then stopped the ambient air extraction unit and left the room to call CEA's Local Safety Unit (FLS). A fire detector was set off just before the operator's call.



Cutting operation with a grinder

The operator in the mobile containment system tried unsuccessfully to put out the fire outbreak affecting the pre-filter with a powder extinguisher. The fire spread through the whole room. The FLS arrived on the premises seven minutes after being alerted. The fire was controlled by the FLS using a water jet and the fire was declared out forty minutes after it broke out.

The fire caused material damage in the room, in particular the working containment system was destroyed and the static containment was lost in the room due to windows being broken and the FLS intervention. This event had no radiological consequences for the personnel or the environment due to the lack of labile contamination in the ducts being cut. Radiological inspections of the surface areas of the room after the fire confirmed the lack of detectable contamination. The water used to extinguish the fire remained contained in the room until it was evacuated.

The event was rated 1 on the INES scale. The causes of the fire were:

- sparks being projected outside the cutting compartment through the space left free between the spark-arrester panels and the ceiling, as these projections were clearly more substantial when cutting with a grinder than with a plasma torch,
- the ineffective extinguishing of the outbreak of the fire with the powder extinguisher, with the fire encouraged to start up again by the flow of air extracted through the pre-filter (despite shutting down the ventilation of the containment system, as this was connected to the general air extraction collector in the BNI) and through the presence of combustible materials (vinyl, plastic gloves, etc.) near the filtration unit.

The analysis of this incident shows that the work station was unsuitable for the type of work: in particular, the containment system was too small for the planned cutting operation, the ventilation system was too close to the cutting area to be protected from projections of incandescent particles and the spark-arrester protection using fire-retardant panels was incomplete. This incident shows the importance of a specific safety study for each configuration (type of cutting and environment); it is therefore important to avoid using generic fire permits or covering too long a period and the study should be repeated if modifications potentially influencing its conclusions are made to the operating conditions. The organisation set up by the plant operator must ensure that operating conditions and protective provisions comply with the conditions and conclusions of the safety analysis. In particular, the lack of combustible materials not strictly necessary must be checked when working with hot spots.

6.2.5 EVENT OF 10 SEPTEMBER 2007 IN THE RADIOACTIVE WASTE MANAGEMENT FACILITY AT THE CEA SACLAY SITE

The radioactive waste management facility (BNI 72¹²) is composed of several buildings. In one of them, a cell enables to produce packages in which radioactive waste is packaged with mortar. Concerning the radiation protection, this cell is classified in a so-called "red" regulated area. Therefore, the access to this cell, which is composed with concrete walls providing radiological protection for workers, is prohibited during normal operations, given the risks of irradiation from the radioactivity contained in the waste. In this cell, one of the tasks is to pour mortar, using an injection lance, into a 200-litre pre-concreted drum, which is in turn placed in packaging called RD16. CEA has entrusted the concreting operations to a subcontractor company.

On Monday, 10 September 2007, during an operation, a drum rose to the surface of the pre-concreted drum when the mortar was being injected, despite the "anti-floating" system in place. To prevent producing a non-compliant, irradiating package, the operator stopped the injection from the control station and held the waste drum down with the injection pipe. The operator then entered the cell to keep the waste drum in place using a metal bar so that the pipe could be freed from the rapidly setting concrete. Contrary to requirements for access to a prohibited area in normal operation, he

¹² BNI 72 collects, stores temporarily, conditions, controls and ships to the appropriate sectors solid radioactive waste or "not-to-be-used" fuel from the nuclear facilities at the CEA Saclay site.

did not advise the Facility Head or someone from the CEA ionising radiation protection department. The event was rated 1 on the INES scale.

Although this event had no major radiological consequences for the operator in question (the dose received during the working day was in the order of 60 μSv), it showed that CEA should reinforce the supervision of sub-contracted operations. The safety assessment by IRSN¹³ showed especially that CEA should reinforce the organisation of service provider monitoring in BNI 72 and the training of personnel in charge of this monitoring with a view to acquiring and maintaining the skills necessary to exercise this function. In addition, in technical terms, CEA has learned to improve the "anti-floating" device for drums to be concreted and to make provision so that access into a "red" area is impossible without prior authorisation (physical lockout of access, for example). Note that CEA has passed on the lessons learned from this event to all its facilities ("red area" improvement initiative).

6.2.6 EVENT OF 21 MAY 2008 IN THE RADIOPHARMACEUTICALS PRODUCTION PLANT AT THE CEA SACLAY SITE

This event occurred during a maintenance operation on the conveyor belt of a shielded cell used for production of technetium-99 generators. It was necessary to remove a radiological protection from this cell to carry out the intervention. During the operation, an operator working on an adjacent shielded cell transferred to the cell undergoing maintenance, via another conveyor belt, a trolley containing seventeen columns of molybdenum-99¹⁴. As the radiological protection had been removed, this transfer increased the dose rate in the work area, especially for the operator working underneath the cell.

He did not immediately hear the audible alarm from his working dosimeter due to the ambient sound level. No other alarm was sounded (dosimeters of three other workers and ambient irradiation monitors) due to the configuration of the premises. Even when they had heard the audible alarm from the dosimeter, the operators continued working and remained near the cell for a certain time.

This event meant that four workers were exposed to doses higher than the estimated doses in the works file (1.3 mSv for the most exposed). It was rated 1 on the INES scale. This event was basically caused by human and organisational factors. The main cause was an insufficiently in-depth safety analysis of the intervention, which led to the absence of physical lockout of the conveyor belt used to transfer the molybdenum-99. In addition, although the ambient sound level prevented the workers from being alerted quickly, they broke the radiological protection rules which insist on stopping work in progress when an irradiation alarm is sounded.

The IRSN safety assessment of this event, and of seven other events notified since the end of 2007, showed that they were mainly caused by human and organisational factors and insufficient safety and radiological protection culture. The Institute therefore recommended that the plant operator quickly complete the overall analysis of risks from human and organisational factors that he had undertaken and establish an improvement plan.

6.2.7 EVENT OF 7 JULY 2008 IN THE URANIUM RECOVERY AND CLEAN-UP FACILITY AT THE TRICASTIN SITE, OPERATED BY SOCATRI

In the uranium recovery and clean-up facility at the Tricastin site, SOCATRI processes its own uranium-bearing effluents (with an isotope uranium-235 concentration lower than or equal to 1%) and those from other facilities at the Tricastin site. The liquid effluents from this processing are released in the canal of Donzère-Mondragon, in accordance with the release authorisation order of 16 August 2005. The processing station for uranium-bearing effluents (STEU) has four main sub-assemblies, including one which stores temporarily uranium-bearing effluents before processing in tanks called "upstream storage units".

The STEU has been undergoing renovations since 2006; when the event occurred, four sectors could be distinguished in the facility: a "new" sector, including the building for new "upstream storage units", a "renovated" sector, including the rooms containing the effluent processing equipment, a sector comprising a "deconstruction" site of part of old "upstream storage units" and lastly an "old" sector adjoining the site area, housing the old storage units still in use. In addition, the plant operator was carrying out final testing of "new" and "renovated" sectors in the STEU under actual conditions.

At 10.15 p.m. on 7 July 2008, following a transfer of effluents to one of the old "storage units" (unit T303), the Station Supervisor entering the room to isolate the transfer system noted the presence of liquid in the "storage unit" retention pan. It was decided to move this liquid to an available "storage unit" (T300) at 10.59 p.m., an operation which terminated

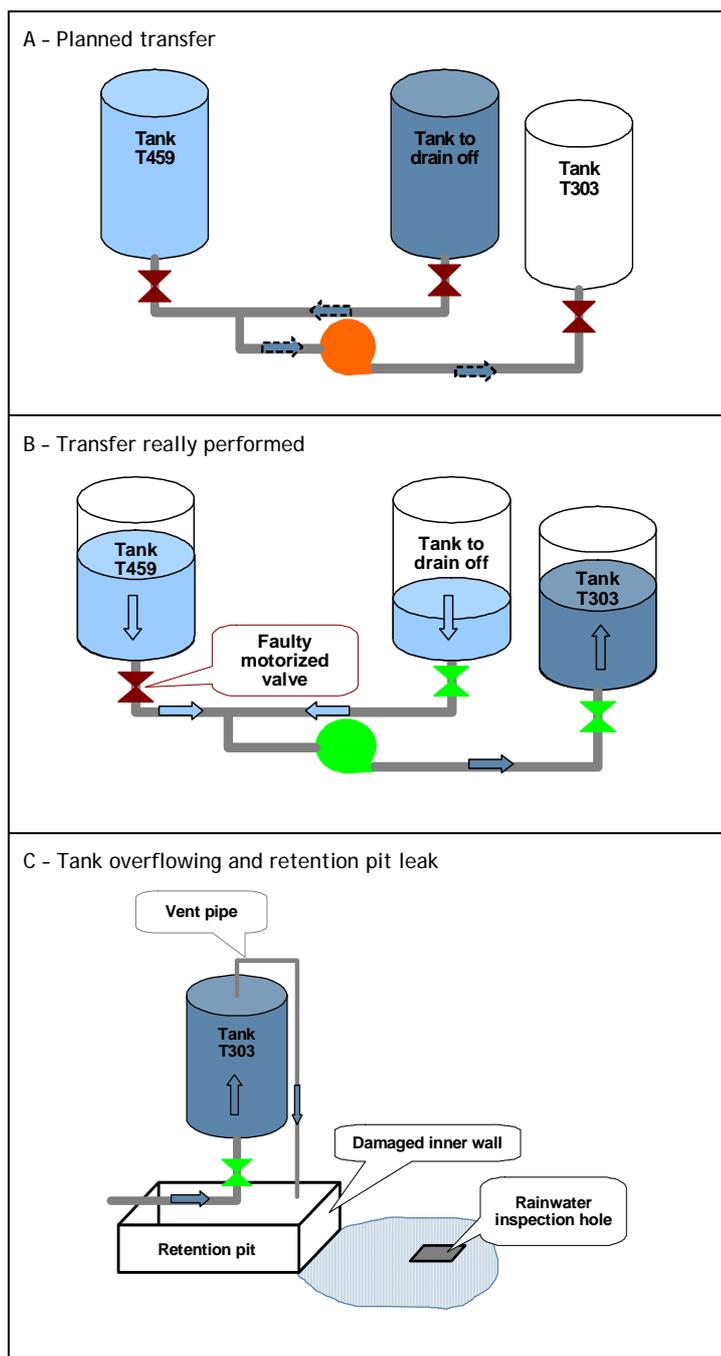
¹³ The summary of the IRSN assessment on the safety review of BNI 72 may be consulted on the IRSN Internet site (www.irsn.org).

¹⁴ Technetium-99 is obtained by radioactive fission of molybdenum-99.

at 11.24 p.m. At 12.01 a.m. on 8 July, when checking the filling state of the tanks, the plant operator noted the absence of liquid in one of the new storage unit (T459) whereas it should have contained 45 m³ of uranium-bearing effluents. At about 5 a.m., the investigations by the shift operators and those called as reinforcements (management and operational duty officers, technical crisis team) concluded that part of these effluents had been released through the rainwater system into the south Eurodif canal which passes to the north of the STEU and rejoins the river La Gaffière to the south of the Tricastin site.

The plant operator therefore launched his on-site emergency plan (PUI) at 6.15 a.m.¹⁵. Based on initial and final volumes in the "storage units", the plant operator estimated later on that about 20 m³ of effluents had escaped from the retention pan, corresponding to 240 kg of uranium in weight; the plant operator estimated that 75 kg of uranium could have reached the river¹⁶.

The event was rated 1 on the INES scale.



The plant operator's investigations show that the event was caused by a combination of five major dysfunctions:

1 - a defect in the motor-driven valve of "storage unit" T459 (unsuitable and poorly-fitted isolation component), which caused the unscheduled emptying of this unit into "storage unit" T303, in addition to the scheduled transfer of effluents, then the overflow of "storage unit" T303 via its venting piping into the retention pan (see diagrams A, B and C);

2 - the failure by the operators to react to the high-level alarm of "storage unit" T303, set off in the control room;

3 - the failure by the operators to react to the retention pan sump alarm of "storage unit" T303, set off in the control room;

4 - loss of leaktightness of this retention pan, due to work carried out in the "deconstruction" sector (see diagram C);

5 - no isolation of an inspection hole in the rainwater system near the defective pan discovered during work on the "deconstruction" sector (see diagram C).

The immediate corrective provisions involved cleaning up the contaminated areas (retention pan, nearby site, rainwater system) and making the old "storage unit" sector safe.

Having been shut down following the event, the STEU only re-started its activity on 1 October 2008 after authorisation granted by ASN.

¹⁵ Crisis management aspects are not addressed in this report.

¹⁶ The consequences for the environment and the monitoring programme in place are described in a file which can be found on the IRSN Internet web site (www.irsn.org).

To avoid this type of event recurring, the plant operator took the following measures:

1. from a technical point of view:

1. isolated the old "storage unit" building, ultimately scheduled for dismantling,
2. checked all the retention systems and related instrumentation,
3. sought a new type of motor-driven valve for the "storage units";

2. from the human and organisational point of view:

1. modified operating provisions, by making mandatory a minimum of three operators in the STEU, one operator permanently in the control room and an alarm log (alarms displayed in the control are also backed up by an audible signal),
2. modified provisions for isolating "storage units", which now include manual isolation valves outside transfer operations,
3. altered the works authorisation form which now includes an analysis of induced risks, especially the possible impact on the main safety-related elements,
4. updated working documents applicable to the STEU,
5. introduced a procedure for equipment requalification after operation.

After assessment, IRSN considered that the numerous dysfunctions apparent in an unfavourable context (the renovation of the STEU caused an operating delay which in turn caused an increase in the volume of effluents awaiting processing and the need to maintain old "storage units" near a site area in service) revealed digressions in taking into account risks from organisational and human factors and major defects in safety culture (unsuitable and poorly-fitted isolation component, poor alarm management, delay in carrying out work on safety-related equipment, no risk analysis prior to work in a context of mixed normal operating activity and intervention. In this respect, IRSN considers that the provision made by the plant operator after the event (renovation or shutdown of old equipment, restrictions on minimum staff and operating team organisation, additional operating and supervision procedures for modification work) should remedy the shortcomings noted.

More globally, this event illustrates the importance of the care BNI operators must take in managing modifications to their facilities and maintaining a good level of safety culture by their personnel.

7 CROSS-DISCIPLINARY ANALYSIS OF EVENTS OCCURRING IN LUDD BNI

7.1 INTRODUCTION

This chapter presents a cross-disciplinary analysis of events notified to ASN between 2005 and 2008 concerning French LUDD BNI.

The analysis is broken down into two complementary axes to draw general lessons from all LUDD BNI taking their huge diversity into account.

1. The first axe covers an analysis of the main types of event with similar, generic or recurring characteristics. To produce a relevant cross-disciplinary analysis, it has been structured per type of risk, focusing on the most significant safety and radiological protection-related risks in LUDD facilities, with a significant number of events notified to ASN. The types of event considered, covering more than 80% of events notified, relate to the following risks:

- dissemination of radioactive materials (especially the events affecting the static or dynamic containment systems);
- exposure to ionising radiation;
- criticality;
- fire and explosion;
- handling operations;
- losses of power or fluid supplies.

The events involving the other risks (risks relating to heat releases, for example) are only a small proportion of all events notified; they have not been examined under this analysis.

It must be stated that the tremendous diversity of LUDD facilities makes it difficult to produce a cross-disciplinary analysis of certain types of event (on the containment of radioactive materials, in particular) and identify general lessons. The diversity of facilities means a wide variety of provisions implemented to control certain risks (especially for static containment equipment).

In addition, the consequences for safety from a same type of event (failure of a ventilation system for a short period, for example) can differ widely from one facility to the next. This results, for example, in some "abnormal" situations constituting, for some facilities, significant events notified to ASN, whilst for others, they are simply minor events which may or may not be notified depending on the plant operators' procedures.

2. The second axe aims to draw cross-disciplinary lessons from the cause analysis of events notified to ASN. The first part of this analysis involves the technical causes; the second relates to the organisational or human causes.

Lastly, it must be remembered that the resulting cross-disciplinary analysis depends largely on information available on events notified to ASN and current notification procedures of plant operators. The conclusions drawn from this cross-disciplinary analysis are therefore sometimes limited, given the heterogeneity and tremendous inequality of available information.

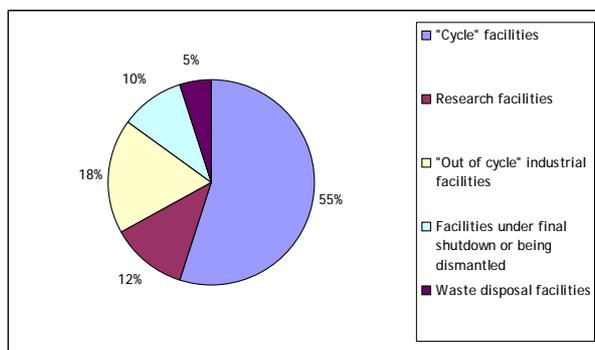
7.2 ANALYSIS OF MAIN TYPES OF EVENT

7.2.1 EVENTS RELATING TO THE RISKS OF DISSEMINATION OF RADIOACTIVE MATERIALS

The risks of dissemination of radioactive materials are controlled by setting up static and dynamic containment systems and devices to monitor that these systems are functioning correctly. Given the tremendous diversity in LUDD facilities, the provisions adopted to contain radioactive materials differ from one facility to the next. Nevertheless, the general principle is that radioactive materials are contained by one or more containment systems, each one with one or more static containment barriers, with or without a negative pressure cascade generated by ventilation systems, aiming to compensate for any weaknesses or discontinuities in static containment barriers. Radioactive material releases into the environment through the ventilation systems are restricted by purification systems appropriate to the substances being treated (particle filters, iodine traps, gas washing column, etc.).

7.2.1.1 Events relating to static containment barriers

About 160 events relating to static containment barriers were notified to ASN between 2005 and 2008, which corresponds to between 20% and 30% of all events notified every year. There has been no particularly significant change noted in the annual number of events notified during the period in question.



Breakdown of significant events per family of BNI for the 2005-2008 period

The graphic opposite shows a predominance of significant events notified in the family of nuclear fuel cycle facilities ("cycle" facilities).

It is important, however, to underline that these notified events are classified very differently according to the "cycle" facilities, as some make a more significant contribution than others, especially in the "front end" cycle (facilities on the Tricastin site in particular).

About 50% of notified events relating to defects in static containment involve process equipment as well as liquid or gaseous effluents management equipment. More specifically, about 65% of events covered a wide variety of process equipment (furnace, evaporator, heat exchanger, vessel, etc.) and some 35% covered effluent management equipment, mainly piping conveying liquid effluents and, to a lesser extent, interim storage tanks.

In decreasing order of frequency, the notified events are leaks or breaks in equipment causing dissemination of radioactive materials (mainly liquid), overflows or over-filling of equipment. These events have had extremely few consequences for the workers and the environment. Note however an increase in 2008 of leaks from pipes resulting in environmental releases (piping outside buildings, leading or otherwise into underground ducts); these events, which involved the vast majority of BNI belonging to the "front end" of fuel cycle are a consequence of defects caused by phenomena of corrosion, wear or ageing (see the comment in chapter 5.2.1 of this report). In November 2008, IRSN sent ASN an opinion recommending making these various events known to BNI operators so that the lessons learned could be taken widely into account; this opinion presented the main points that IRSN felt required analysing by the plant operators. These points were examined by ASN during inspections of the BNI in question. In any case, IRSN considers that the operating experience feedback from these events should be used to design new BNI and in the context of periodic safety review (PSR) of existing facilities.

About 40% of events resulting in the dissemination of radioactive materials are due to technical causes (equipment failure, design fault), with the remaining 60% due to organisational or human factors. These cover both normal operations and interventions (2/3 and 1/3 of events respectively). Scheduled routine inspection and testing times have been overrun on a few occasions due to defective organisation or specific impossibilities in carrying out such operations. Given their generic nature, these types of organisational failure are discussed in chapter 7.3.2 of this report.

About 20% of notified events are containment faults in containers; they covered various types of equipment (drums, canisters, etc.) A large third of these events follow on from handling operations (especially falling loads)¹⁷; the other events have no generic cause. Note nevertheless the few events occurring during tank filling operations (UF₆ crystalliser, ClF₃ container, etc.), especially in the EURODIF facility, relating to connection components or valves; a significant proportion of these events are linked to human causes (failure to comply with docking procedures or pre-operation checks).

About 12% of notified events involved containment chambers, especially glove boxes. About 60% of these events involved the "cycle" facilities, basically the MELOX facility at the CEA Marcoule site.



Glove box handling

The predominance of the MELOX facility is explained by the huge number of glove box operations, where the process equipment is installed (operating and "auxiliary" operations such as waste evacuation and maintenance). These events are almost exclusively failures of the most "fragile" components - the handling gloves and the plastic bags used to transfer radioactive materials or substances (materials, waste, etc.); this basically involves gloves punctured during handling (mainly linked to sharp or sticking-out items). A single case of a glove being pulled off has been noted, due to a faulty glove fixing. Events involving bags were related either to poor fixing or too much weight in items transferred.

It is interesting to note that, despite the ventilation systems functioning in the glove boxes, the vast majority of notified events led to surface and/or atmospheric contamination of rooms containing these glove boxes (with an alarm tripped by monitors in many cases). Operator compliance with planned measures (wearing protective breathing apparatus, for example) or the required behaviour in an event of this type helped limit the consequences for the personnel.

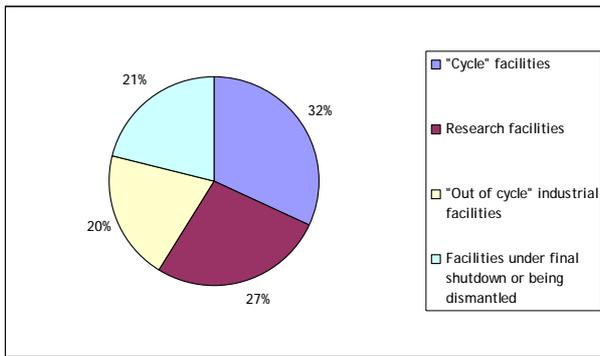
The events notified are "classic" incidents of working with glove boxes. Given the potential radiological consequences for the operators, IRSN considers that the efforts made by the most affected plant operators (MELOX for example) to improve the safety of working with glove boxes (limited sharp and pointed edges, improved glove box working conditions (ergonomics, tools, etc.), search for stronger gloves, etc.) are well worth pursuing. In addition, the Institute considers that taking better account of actual working conditions and the strengthening of the safety and radiological protection culture of the personnel and outside contractors are also necessary, as a significant proportion of these events were caused by human factors (breaches of radiological protection procedures, etc.), especially during auxiliary operations.

The remaining notified events cover very diverse cases. Note a few events relating to leaktightness faults in temporary containment devices (mobile containment system, etc.) or premises. The technical causes of these events do not have a particularly generic nature.

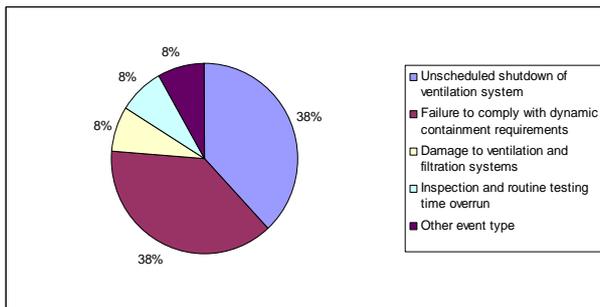
7.2.1.1 Events relating to ventilation systems

About 110 events relating to ventilation systems were notified to ASN in the period in question, including about eighty significant events. This corresponds to about 17% of all events notified to ASN and about 15% of all significant events.

¹⁷ This type of event is examined in chapter 7.2.6 on the risks from handling operations.



Breakdown of significant events per family of BNI for the 2005-2008 period



Breakdown of events relating to ventilation systems for the 2005-2008 period

The significant events are split relatively uniformly between the four large BNI families. Taking all notified events ("significant" and "safety-related"), the "fuel" facilities dominate (about 45%), which is linked to the fact that the "below scale" events mainly involve the "cycle" BNI, especially those at the La Hague site.

Note the considerable increase in events notified during 2008 compared with previous years (doubling the INES scale level 0 events notified).

The various families of BNI are involved in different types of event. Thus, the ventilation losses mainly involve research and "out-of-cycle" industrial facilities, few "cycle" facilities. The design differences in these facilities and the related safety requirements can explain this observation.

On the other hand, the events due to breaches in safety requirements for dynamic containment (negative pressure cascades or filter efficiency in particular) were notified mainly by "cycle" nuclear facility operators.

About forty notified events are unscheduled shutdowns of a ventilation system. In the vast majority of cases, these events have not had significant consequences for the workers and especially for the environment; they have basically involved contamination of rooms. Note that about 75% of these events caused a total failure of ventilation systems in an BNI or one of its buildings; the other events basically caused partial failures of an ambient ventilation system (ventilation system for room ventilation).

Note that about one quarter of all these events involved the CENTRACO facility alone (about three events per year). IRSN therefore considers that the operator of this facility should continue with the efforts he has been making in recent years to reduce the number of incidents (ventilation system design and maintenance intervention preparation especially).

Note also an increase in 2008 of the number of events of this type in the "research" facilities compared with previous years (seven significant events in 2008 against just six in the two previous years); there seem to be diverse causes for these events, which involve several facilities. This type of event is monitored by IRSN to assess whether or not it is a temporary situation or a worrisome trend.

About 60% of ventilation system failures are caused by electrical faults. Of these, about half involve failure of electrical power supply equipment¹⁸ (failure of general power supply due to external causes, failure of facility's switchboards, etc.); the other cases are failures of diverse equipment (poor cable connections, for example). About 40% of technical causes of ventilation system failures are mechanical (broken belt, etc.), including 15% linked to ageing of equipment. According to the available information, there is no sign of a "generic" problem like shortcomings in controlling or maintaining equipment.

About forty events notified to ASN are breaches of safety requirements related to dynamic containment; they had no notable consequences for the workers. About a quarter of these events involved air purification systems (failure to comply with the minimum efficiency required for HEPA filters or iodine traps). Note that the cause of these losses in efficiency of this equipment is rarely mentioned by the plant operators in the documents submitted and therefore no lessons can be drawn. Although there are few notified events, IRSN considers that the plant operators should give the causes of losses in efficiency of purification systems in the documents they submit.

The three quarters of remaining events are breaches in requirements, like the differences in negative pressure between

¹⁸ Chapter 7.2.7 deals with events relating to power supply failures.

different at-risk areas, minimum air flow rates or minimum air velocities. About 75% of these events mainly involved the first containment system (process equipment, containment chambers, etc.); not many covered the second containment system (especially premises).

Almost ten events notified relate to damage to filtration systems (site ventilation, for example) by incandescent particles generated by operations using hot spots. This type of event is developed in chapter 7.2.4 of this report on the events relating to fire risks. About ten events notified involve failures to comply with routine inspection and testing times of dynamic containment system equipment.

A large proportion of events mentioned above are linked to interventions (maintenance work, routine inspections and tests, etc.). Thus, about a third of ventilation system failures can be matched with interventions; this proportion is bordering on 50% in 2008, especially in "research" facilities. These events are linked to organisational or human failures: they are caused mainly by defective preparation, monitoring or the post-intervention inspection. Given their generic nature, these types of failure are discussed in chapter 7.3.2 of this report.

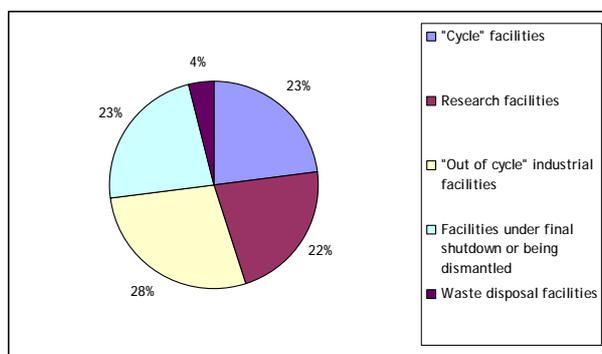
7.2.2 EVENTS RELATING TO THE RISKS OF EXTERNAL OR INTERNAL EXPOSURE FORM IONISING RADIATION

The provisions for controlling risks of exposure to ionising radiation aim to limit the doses received by the personnel working in the nuclear facilities. Two exposure paths must be considered: external exposure to an irradiating source and internal exposure by inhalation or per cutaneous.

7.2.2.1 Events relating to risks of external exposure to ionising radiation

These risks are mainly controlled by collective (radiological protections at work stations, radiological zoning, etc.) or individual prevention measures and collective (monitoring the ambient irradiation in premises) or individual (passive or active dosimeters) monitoring methods. Specific provision is normally made for operations requiring interventions very close to radioactive materials, for example when radiological protection has to be removed (dismantling operations, for example).

About forty events were notified to ASN during the period in question, which accounts for about 8% of all events. The annual number of events of this type has been very stable since 2006 (eleven to twelve events a year).



Breakdown of significant events per family of BNI for the 2005-2008 period

These events are split relatively equally between the four large BNI families. Note that the proportion of "cycle" facilities is about twice as low compared with the general statistics for all significant events.

No particular changes were noted in the notifications of events per family of facilities during the period in question.

About 30% of significant events relate to radioactive sources or materials; it mainly involves discovering low- or very low-level sources in unplanned locations, source losses or degradations. These events cover many facilities and are mainly caused by organisational or human factors (basically defective traceability and human error due to breaches of procedures). The provisions introduced by the plant operators following these events have reduced the consequences.

About 15% of significant events involve defective radiological protection. About 80% of these events are basically linked to interventions (renovation or maintenance work, etc.) involving a substantial proportion of personnel from outside contractors. Two events, rated 1 on the INES scale, illustrate this type of incident.

- The event of 5 January 2007 in the fuel evacuation facility at Creys-Malville was partial draining of the water from the fuel assembly temporary storage pool; closing a drain valve was forgotten during a maintenance intervention. This event is mainly linked to organisational causes, especially gaps in preparatory work documents (no risk analysis for the

pool draining, no hold points defined, etc.) and faulty management by personnel in contracting companies responsible for producing them.

- The event of 18 September 2008 in the radiopharmaceuticals production plant at the CEA Saclay site was abnormal exposure of eight workers from contracting companies (collective dose of 2 mSv) when working at a height near a shielded production cell with insufficient radiological protection in its upper section. This shortcoming was due to a previous maintenance operation without special preparations and when the radiological protection was not reinstated after its completion. The abnormal exposure of workers is also linked to defective organisation in preparing the intervention (insufficient analysis of work-related risks, insufficient plant operator checks, intervention by contractors without dosimetric monitoring and prior training, etc.).

About 15% of significant events are connected to collective monitoring equipment failures (especially centralised monitoring equipment). These events are linked mainly to errors in re-configuring equipment for operation following repairs or maintenance (failure to remove alarm inhibitors installed prior to the interventions in particular) and failures in the BNI internal power supplies.

About 10% of significant events relate to non-compliance with the radiological zoning or technical access conditions in a controlled area. One of the most significant event of this type recently involved someone from a contracting company working during routine operation in a "red"-classified radiological protection area without prior authorisation from the Facility Head (event of 10 September 2007 on the radioactive waste management facility at the CEA Saclay site, described in chapter 6.2.5 of this report).

The other types of event relating to risks of external exposure to ionising radiation have similar causes to the types of event evoked above. These events are mainly linked to defects in the safety analysis prior to special operations (maintenance, radiographic testing, etc.), defective preparatory operation (equipment lockout failure, for example) and breaches of radiological protection procedures.

In conclusion, the events occurring show that efforts must still be made to improve the organisational provisions for preparing, performing and controlling interventions (see chapter 7.3.2 of this report).

7.2.2.2 Events relating to risks of internal exposure to ionising radiation

Risks of internal exposure to ionising radiation are mainly controlled by the same measures taken to control risks of dissemination of radioactive materials used in the facilities. For interventions very close to radioactive materials, provision is made for specific containment and individual protection equipment for workers (garments, gloves and protective breathing apparatus).

The vast majority of events relating to the risks of internal exposure to ionising radiation are linked to failures in provisions to control risks of dissemination of radioactive materials; these events are discussed in chapter 7.2.1 of this report.

A few significant events relate to individual protection equipment of workers: equipment failures or breach of rules on wearing it. Most of these events involve workers' hand protection (gloves) during standard routine operations (working with glove boxes) or interventions; events involving other protection means (protective breathing apparatus, garments) are less frequent. In the vast majority of cases, these events have had very slight consequences for the workers (bodily contamination and a few causes of internal contamination of little significance). The most significant events (pricking of fingers of a worker during a handling operation, damage to the protective garments of a worker and back injury to a worker caused by falling equipment) led to effective doses of no more than a few mSv.

7.2.3 EVENTS RELATING TO THE RISKS OF CRITICALITY

The risk of criticality is the risk of developing an uncontrolled nuclear chain reaction inside materials containing fissile atoms (uranium and plutonium). Such a chain reaction results in particular in very strong emissions of gamma radiation and neutrons (which can be fatal near the point of emission if there is no radiological protection) and a release of fission products with relatively slight consequences.

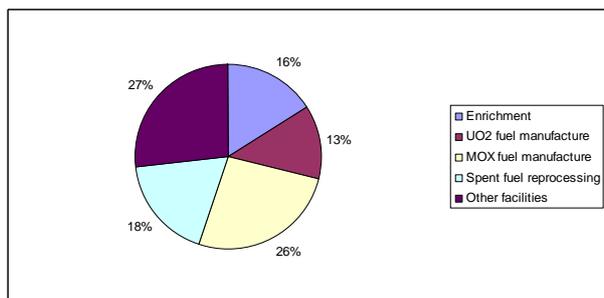
Criticality risks are controlled in a facility by maintaining it in a sub-critical configuration, with margins in relation to conditions creating a chain reaction both in normal operation and in potential degraded, incident or accident situations. The control involves such provisions as limiting the amount of fissile material used at the work stations, limiting the water

content in the fissile material, limiting the size of equipment receiving the fissile material or limiting the concentration of fissile material in solutions used. Provision must be made to control criticality risks so that a criticality accident can only occur when two independent failures occur, each one with low probability and quickly detectable.

No criticality accident has occurred in the French facilities (note that the last criticality accident worldwide affected the JCO plant at Tokai-Mura (Japan) on 30 September 1999 where uranium was used). The incidents notified between 2005 and 2008 correspond to dysfunctions affecting the provisions set up to control the risks of criticality.

About forty events linked to controlling criticality risks were notified to ASN, representing about 7.5% of notified events.

The significant increase in the number of events relating to criticality risks in 2008 compared with previous years (50% increase) must be underlined. It will be important to check during subsequent analyses whether this is a temporary situation or if the increase is confirmed, therefore requiring more in-depth analysis.

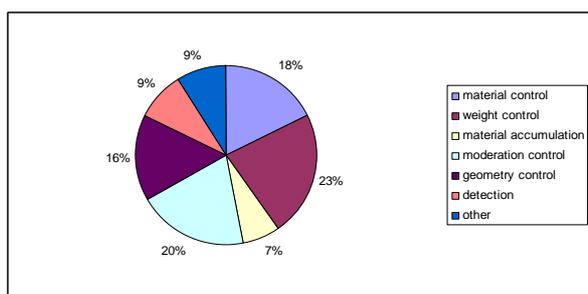


Breakdown of events per family of cycle facilities for the 2005-2008 period

An analysis of the breakdown of events according to the type of facility shows that about 3/4 of these events occurred in nuclear fuel cycle facilities, themselves distributed fairly evenly between enrichment plant, UO2 fuel manufacturing plant, MOX fuel manufacturing plant and spent fuel reprocessing plants.

It must be noted that 70% of notified events involving the Georges Besse I fuel enrichment plant relate to water leaks affecting the heat exchangers in the diffusion stages. Monitoring provision has been made to detect these leaks and drain the heat exchangers quickly to limit the amount of water penetrating the process circuit. The operating experience feedback from notified incidents shows the effectiveness of these measures. In addition, this type of event will disappear once the gaseous diffusion process is replaced by a centrifugation process in the next few years (future Georges Besse 2 plant).

7.2.3.1 Type of event relating to the risks of criticality



Breakdown of events relating to the risks of criticality for the 2005-2008 period

About 23% of events relating to the criticality risks involve defective control of the quantity of fissile material and 16% defective control of the nature of this material or its containers.

This large proportion of events (about 40% of criticality risk events) shows the need to maintain careful watch when carrying out these operations, which must be governed by procedures and robust management methods.

About 20% of events involved accidental water inputs, with more than half relating to leaks in the heat exchangers in the enrichment process mentioned earlier. Note that two events occurred despite seemingly robust prevention provisions (locking, checking for the absence of liquid).

About 16% of events involve changes in geometry with diverse causes (overflow, leak, interim storage in an unauthorised location, unscheduled dismantling of equipment), so that it is impossible to draw generic lessons.

About 9% of events involve the criticality detection and alarm system (false alarm due to the presence of radioactive materials near the probes, false alarm or defective operation following work on the equipment, etc.). These events show that the tests and interventions on the equipment must be prepared and monitored with the greatest care.

About 7% of events relate to an accumulation of fissile material (for example, following a leak not immediately detected) or its presence in an unexpected form (formation of precipitate, for example). The other events involving the risks of criticality are of miscellaneous types.

7.2.3.2 Causes of events relating to the risks of criticality

Defective equipment is the main cause of only a small proportion (about 18%) of events relating to the criticality risks; note that over half these events are leaks from heat exchangers equipping the uranium enrichment process by gaseous diffusion. In addition, about 11% of events caused by defective equipment, occurring mainly in 2008, involve defects in the software programs used to check the weights of fissile materials and, more especially, to manage special situations outside the normal process sequence. This type of event occurs mainly in the MELOX plant which manufactures MOX fuels has to be examined carefully. Lastly, in a certain number of cases (about 18% caused by defective equipment), design defects or events not considered in safety analysis can be seen.

The main cause of events involving the risks of criticality relates to organisational and human factors (about three quarters of events). About one third of them are caused by organisational factors, like unsuitable procedures or insufficient preparation for interventions. The other two thirds are caused by human factors, including half caused by breaches of procedures or lockouts and the other half caused by errors like confusion in the equipment identification. IRSN considers that this operating experience feedback shows especially the importance of training the personnel and developing the safety culture to reduce the number of human errors. It also emphasises the need to monitor the organisational quality of routine operations and working conditions to make them less sensitive to such failures.

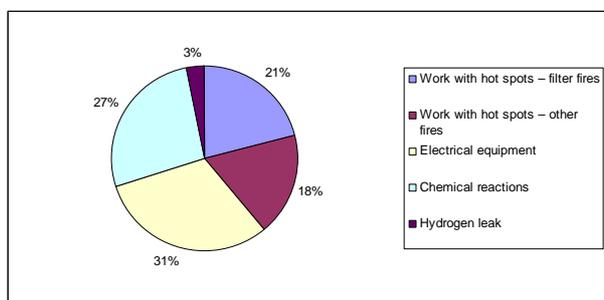
Lastly, it must be underlined that about one quarter of events occurred in special situations (following changes to procedures, during interventions or during degraded situations caused by defective equipment). The event on 6 November 2006 at the ATPu described in chapter 6.2.6 of this report is a perfect illustration. IRSN considers these events show that plant operators can still make further progress in managing special situations.

7.2.4 *EVENTS RELATING TO THE RISKS OF FIRE*

No major fire outbreak occurred in the French facilities during the period 2005 - 2008. However, controlling risks of fire plays a major role in the safety of LUDD facilities given firstly, the materials used in these facilities and the type of operations carried out and secondly, the potential environmental consequences a fire in such a facility could cause.

About sixty events involving a fire risk were notified to ASN between 2005 and 2008, which corresponds to about 10% of all notified events. Note that about one quarter of these events occurred in facilities being dismantled, a proportion approximately twice that obtained for all events notified to ASN; this is because of the particular activities carried out in the facilities being dismantled (cutting work, etc.).

About half the events relating to fire risks involve actual outbreaks of fire or overheating releasing fumes. These fires have also been quickly brought under control and, in any case, have not extended beyond the room where they started, nor did they release radioactive materials into the environment.



Breakdown of various types of fire outbreak for the 2005-2008 period

About 40% of fires broke out during operations with hot spots on work sites (cutting, grinding, welding, using plasma torches, etc.); about 50% of these led to combustion of filters equipping the first filtration level of air extraction systems. It must be underlined that over half the fires involving filters broke out despite the presence of protection devices (spark arresters). IRSN considers that these cases require in-depth analysis to protect filters better when working with hot spots. In February 2009, ASN requested plant operators to provide operating experience feedback on this type of event.

About a quarter of the fire outbreaks were due to chemical reactions between incompatible products, including about half due to reactions between an acid or oxygenated water and organic matter. IRSN considers this confirms the need to keep the personnel aware of the corresponding risks which are already known thanks to past incidents and which

normally have resulted in provisions being made to prevent them. In this respect, after two fires caused by mixing nitric acid and organic matter, in July and September 2006 at the COMURHEX plant at Pierrelatte, IRSN sent ASN an opinion pointing out the potential generic nature of these events and suggesting that BNI operators be requested to draw lessons from them. ASN included the corresponding information from plant operators in a letter sent in January 2007. In February 2009, following a subsequent event, ASN requested the plant operators to study the risks of fire associated with possible reactions between organic matter and strong oxidising agents (oxygenated water for example) and to make sure that sufficient provision was made to control these risks.

About one third of fire outbreaks are caused by equipment dysfunctions (mainly electrical equipment, motors and compressors, etc.).

Concerning the causes of events listed above, it must be underlined that organisational and human factors dominate in the first two outbreaks of fire evoked above (working with hot spots and chemical reactions between incompatible products); these cover about three quarters of events starting a fire. IRSN considers that these events show that particular attention must be given to writing fire permits and the associated safety analysis as well as to organisational arrangements which exclude this type of work without a fire permit (30% of fires induced by working with hot spots were not covered by a fire permit).

About a quarter of events relating to the fire risks involve dysfunctions in fire protection systems (detection and alarm systems, extinguishing systems, etc.). Two thirds of these events are failures in the monitoring system, where the main causes are electrical power failures of monitoring cabinets and defective transfers to facility control stations or emergency services centres. Only two events involve the failure of fire dampers occurring during periodic test.

About 8% of events relating to the fire risks involve deviations from operating rules, helping to increase these risks and especially their possible consequences (overrunning of a calorific load limit or a radioactive material weight limit in a room, abnormal presence of flammable liquids, etc.) and about 6% of events involve overrunning the scheduled time for a routine inspection of a fire fighting system (organisational failure).

Lastly, one particular event must be underlined for the purposes of operating experience feedback: the opening of a fire door under the pressure induced by the injection of an extinguishing gas in a room where a fire has broken out.

7.2.5 EVENTS RELATING TO THE RISKS OF EXPLOSION

In the LUDD nuclear facilities, the risks of explosion are linked to the presence of radiolysis gas produced by the decomposition of certain materials under the effect of radiation, the use as reagents of products likely to create explosive atmospheres, such as hydrogen, the possible formation of explosive products or the uncontrolled development of a chemical reaction in the processes used and, more traditionally, the use of gas in boiler houses or the presence of pressurised gas tanks.

Nine events involving risks of explosion were notified to ASN between 2005 and 2008.

Two events were explosions causing material damage, but which occurred outside areas with the potential to cause radiological risks, nor did they have any consequences for the personnel.

Two events correspond to leaks or accidental production of explosive gases which were detected and controlled before an explosive atmosphere could form. Lastly, five events were breaches in applying procedures to control risks of explosion or defects in equipment used to detect situations potentially causing an explosion. Note that one third of events relate to risks of explosion caused by radiolysis.

The operating experience feedback confirms the reality of risks of explosion in LUDD nuclear facilities, even though few events have been notified given the prevention provisions adopted. In this respect, even if there are few defects in preventing or detecting abnormal situations potentially leading to risks of explosion, it seems that the efforts made in this area must be maintained, even reinforced, given the possible consequences of an explosion affecting equipment ensuring a safety function.

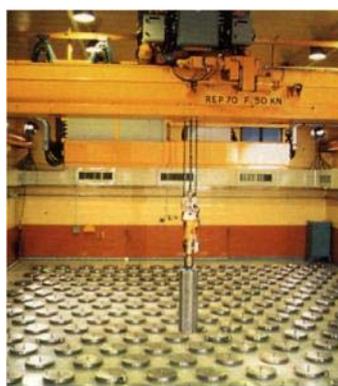
7.2.6 EVENTS RELATING TO THE RISKS FROM HANDLING OPERATIONS

In the LUDD nuclear facilities, extremely large numbers of handling operations are carried out under routine operation and maintenance and during dismantling. A wide variety of handling equipment is used (see photographs below - gantry cranes and lifting trolley), operated manually up to fully automated. In all cases, a failure in the handling machine used

or an operator error (poor gripping of the load, collision with an obstacle, machine coming off its track, break in its kinematic lifting chain, etc.) can cause the load handle to fall, damaging it or the facility.



ADT area- interim storage of concrete waste packages (AREVA La Hague)



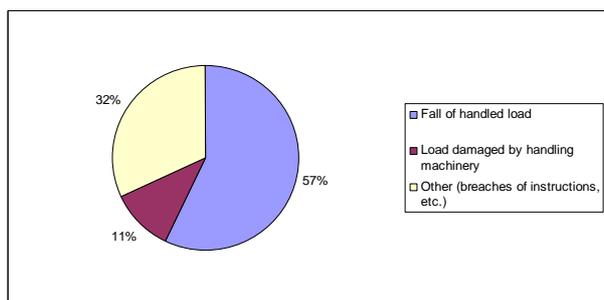
CASCAD facility - interim storage of spent fuel in containers (CEA Cadarache)



EURODIF plant - interim storage of UF₆ containers (AREVA Pierrelatte)

Under a deterministic approach to these risks, provisions are made for prevention in the nuclear facilities (ensuring the reliability of the handling machinery, restricting its movements, etc.) and for limiting the consequences (limiting the handling height or the weight of the load, dimensioning structures damaged if the load falls, installing shock-absorbing devices, etc.).

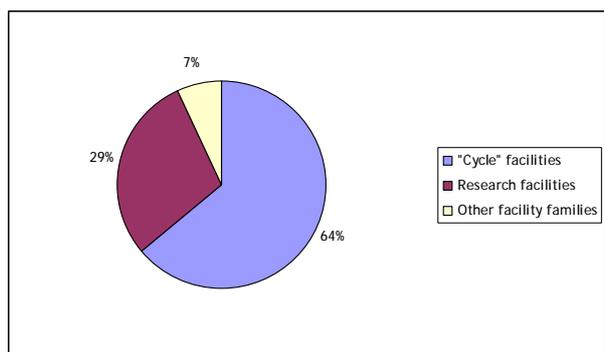
About thirty events relating to the risks from handling operations were notified to ASN between 2005 and 2008, which represents about 5% of all notified events.



Breakdown of "handling" events for the 2005-2008 period

The analysis shows that about 60% of events notified to ASN are actual dropped loads (see diagram opposite) and that only 10% relate to the load damaged by the machine used to handle it.

About one third of events relating to handling risks are caused by miscellaneous failures (breaches in procedures, etc.).



Breakdown of events per family of facilities for the 2005-2008 period

The analysis shows that about two thirds of events involved "cycle" facilities. This high proportion compared with the other families of facilities must be correlated with the large number of handling operations carried out in production activities in these facilities and the number of facilities involved. This number of notified events must therefore be put into perspective by taking into account the large number of handling operations performed.

In this respect, note that about half the "cycle" facility events involve the La Hague site and one third the Tricastin site. The analysis shows that there are specific features to the events notified by both these sites.

For the La Hague site, about two thirds of events notified to ASN involve process operations and half of these are caused by a failure in the gripping device. For the Tricastin site, the events notified to ASN only relate to handling by the lifting trolleys, which can be explained inasmuch as this is the most frequently used handling resource.

It must be underlined that about three quarters of events at the CEA sites relate to damage or falls of technological waste drums.

The analysis of these events reveals diverse technical causes for half of them, depending mainly on the handling machinery used (gripping devices for the handling cranes, break in the lighting chain for the trolleys, etc.), which is a higher proportion than for all events notified to ASN. Nevertheless, given the small number of events for each of the sites mentioned above, no cross-disciplinary lessons have been revealed.

In addition, it is important to underline that a major proportion of events were the result of both technical (break in a mechanical component, dysfunction of the instrumentation and control system, etc.) and human (equipment operating error, failure to comply with planned operating conditions, etc.) failures.

7.2.7 EVENTS RELATING TO POWER OR FLUID SUPPLY FAILURES

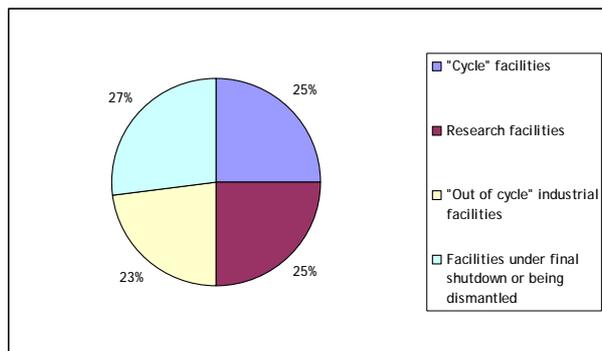
To operate, LUDD nuclear facilities require electricity, fluids for cooling (cold water, iced water) or heating (hot water, overheated water, steam) and other miscellaneous fluids: air (compressed, breathable), water (demineralised, drinking...), gas (oxygen, nitrogen) and chemical reagents (soda, nitric acid, formol). For large sites with many facilities, electricity, liquid coolants and utility fluids are supplied and distributed through common resources, which mainly include main production units (high-voltage transformers connected to the EDF/RTE network, boilers producing heating fluids, compressed air supply units, tanks for the temporary storage of chemical reagents, etc.) and internal distribution networks to the final users (see photograph below - electricity supply and distribution).



Main electrical power station (AREVA La Hague)

Electricity, liquid coolants and utility fluids are involved in the safety functions provided by active equipment (cooling, "inerting", ventilation, fire detection, etc.). A failed power or fluid supply can therefore cause the failure of one or more safety functions, which could result, after a certain time, in dispersion of radioactive substances or exposure to ionising radiation.

About thirty events relating to these risks were notified to ASN between 2005 and 2008, which represents about 5% of all notified events. These events had no significant consequences for the workers, the facilities or the environment.



Breakdown of events per family of facilities for the 2005-2008 period

Unlike other types of event (failures of static containment, events relating to handling risks, etc.) notified between 2005 and 2008 or all events notified during the same period, the "cycle" facilities do not account for the major share (a quarter of events notified).

However, the respective contributions from research facilities or those under final shutdown or being dismantled (called MAD/DEM facilities) seem slightly higher than those relating to the general average for all events notified to ASN; note that the MAD/DEM facilities concerned are all located at CEA sites.

Half the events relating to a loss of power or fluid supply correspond to "research" and MAD/DEM facilities; the proportion is even higher for power supply losses only. It must be underlined that more than half the events notified by "out-of-cycle" industrial facilities involve the CENTRACO plant; however, the number of events at issue is small (less than five).

About 90% of notified events are losses of power, with the remaining 10% involving a loss of compressed air. Given their small number, the events involving a loss of compressed air are not analysed in more detail.

About 80% of power losses reveal at least one technical cause or are linked to external hazards (especially storms). For about one third of these events, the resources provided to compensate for the failure of the normal power supply and distribution system were operational and maintained the safety functions in the nuclear facilities concerned or moved them in "normally planned" degraded mode.

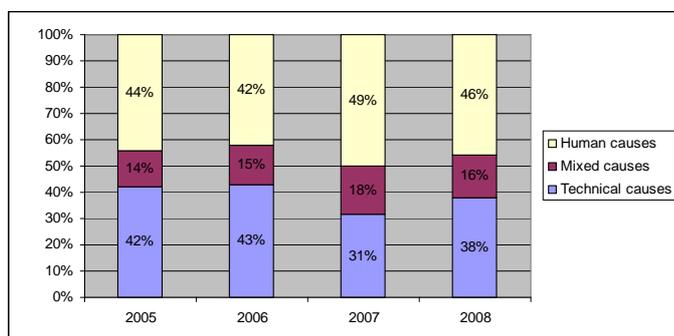
For the remaining two thirds, the planned emergency resources were also defective (at least partially), which caused a temporary failure or move into "final" degraded mode of the safety functions of facilities affected. These events of loss of power distribution, combining failures in normal and emergency supply and distribution systems, basically involve facilities located at the CEA sites (about 80% of cases) and are due to dysfunctions of miscellaneous electrical components (transformers, inverters, contact switches, circuit breakers, etc.).

About half the power loss events caused ventilation system failures in nuclear facilities involved. These events involved, firstly, facilities at the CEA sites (about 60% of cases) and, to a lesser extent, the CENTRACO plant (about 25% of cases). In the majority of cases (about 60%), these ventilation system losses were caused by combined failures of normal and emergency power supply and distribution systems.

About a quarter of power loss events caused partial failure of monitoring or radiological control resources for facilities or the environment. In all cases, these failures of monitoring or radiological control resources were caused by combined failures of normal and emergency power supply and distribution systems. Note that these events only involved facilities located at CEA sites. Nevertheless, note that only a few events occurred (about three a year) and that the corresponding partial losses of monitoring or radiological control did not last long (a few hours at most).

The global analysis of causes of power loss events shows that over half of them were technical, which corresponds to a higher proportion than that of all events notified to ASN (see chapter 7.3 of this report). More specifically, it appears that the events affecting the CEA sites show a higher proportion of technical causes (about 70% have at least one technical cause) than the industrial facilities ("cycle" and "out-of-cycle"). This could be explained by design differences between power supply and distribution systems on the various sites, given their safety requirements, which depend on the facilities involved.

7.3 CAUSE ANALYSIS OF EVENTS NOTIFIED TO ASN INVOLVING LUDD FACILITIES



Breakdown of causes of significant events for the years 2005 to 2008

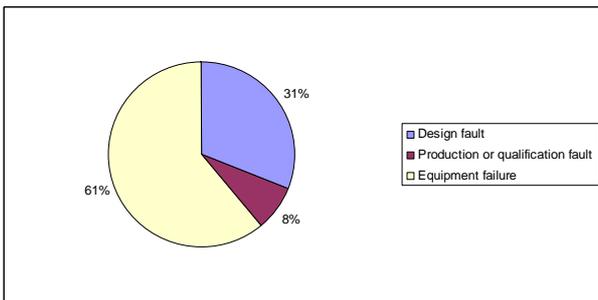
The analysis of main types of event by type of risk, presented in chapter 7.2 above, shows that a large proportion of them have different causes (technical, organisational or human). According to available information, merely a large third of events have technical causes (equipment failures, design or production faults). In any case, the organisational and human components are significant in a majority of notified significant events.

The cause types distribution varies little between all the BNI families.

This chapter presents a more specific analysis of generic causes of events notified to ASN. The first part deals with all the technical causes; the second relates to the organisational or human causes.

7.3.1 TECHNICAL CAUSES

7.3.1.1 General statistics for technical cause events

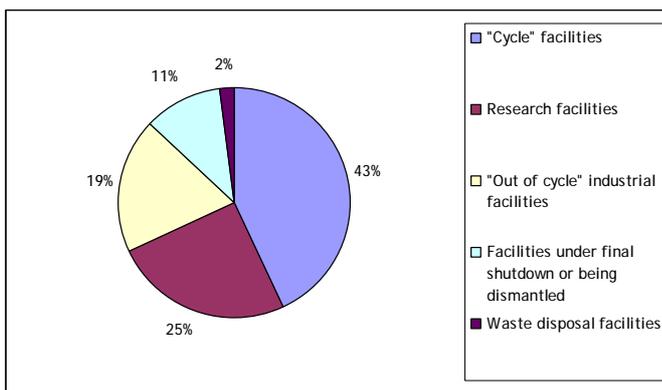


Proportion of events per family of technical causes for the 2005-2008 period

Based on available information, the majority of events with technical causes are failures of equipment or components in safety functions (see diagram opposite). About one third of these events are caused by a design fault in equipment or a safety function. Concerning the remaining cases (less than 10% of the total), the technical causes identified are faults in producing or qualifying equipment or components. Lastly, it must be stated that this breakdown of events per family of technical causes remains relatively stable year on year.

The statistical data presented in the diagram above must nevertheless be used cautiously, insofar as they depend closely on information submitted by the plant operators in reports of events notified to ASN. According to the plant operator and depending on the progress in analysing the event when the report is submitted, the identification of technical causes is more or less flowing and accurate.

In this respect, it seems entirely plausible that some of the equipment failures identified in the documents submitted as causes of events notified to ASN in fact relate to more "root" design, production or qualification faults. An equipment or component failure is often detected in the initial analysis of the event, which aims mainly to identify repairs to be made to be able to start operations again under satisfactory safety conditions. Beyond that, detecting a design, production or qualification fault normally requires a fully-fledged expert assessment of the equipment or defective component. This assessment can take a long time (over a year) or not even produce a usable result or, if the safety issues are insignificant, it may not be carried out at all. In this respect, it is important to underline that, as required by the ASN Guide of 21 October 2005, the plant operators should submit updated report on significant events more systematically following in-depth analyses. This would improve the global analysis of operating feedback from events notified to ASN and therefore the safety of facilities.

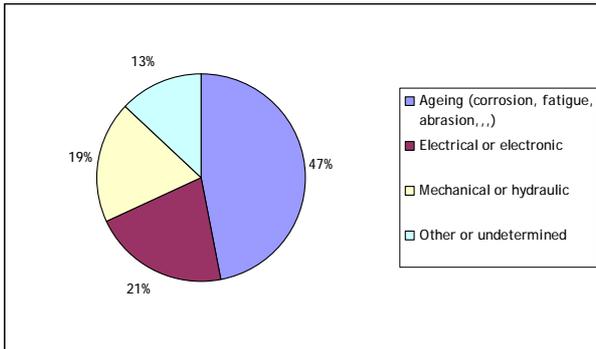


Breakdown of events linked to a design fault per family of facilities for the 2005-2008 period

The breakdown per family of facilities of events with technical causes linked to a design fault is shown in the diagram opposite. It appears that, despite the high proportion of « cycle » facilities, the proportion of « out of cycle » industrial and research facilities is slightly higher than that of the total events with technical causes. Although it is difficult to draw conclusions based on available elements, this could be explained by the design differences between risk control equipment in facilities, which depend on safety requirements allocated to this equipment.

Given the information available, only an analysis of technical causes of equipment failures is presented below.

7.3.1.2 Analysis of events linked to equipment failures



Breakdown of causes of equipment failures

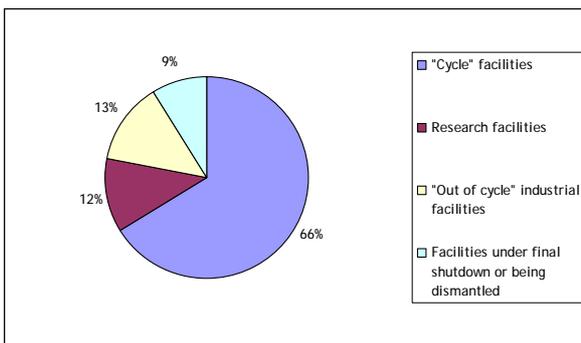
There are very diverse causes of failures of equipment or components providing a safety function. A small half of equipment failures are the result of relatively slow change phenomena (corrosion, abrasion, mechanical fatigue, etc.), which are grouped below under the term "ageing".

About 20% of equipment failures are electrical or electronic (short-circuit during an intervention, programming fault in a programmable controller, etc.). About 20% are due to occasional mechanical or hydraulic loading (abnormally high force, overpressure, etc.).



Break due to mechanical fatigue in the accountancy tank feed pipe in the Thorp plant

It seems that the ageing mechanisms are behind a large proportion of events causing equipment failures. These can be difficult to detect and have significant consequences. As an illustration, remember that the incident in the THORP plant on 21 April 2005 (see chapter 6.1.1 of this report) was initially caused by fissuring due to mechanical fatigue, then a break in the pipe transferring very active solutions (see photograph opposite); this phenomenon of fatigue had not been assessed correctly in the design phase (design fault).



Breakdown of equipment failures due to "ageing" per family of facilities

The equipment failures due to "ageing" noted between 2005 and 2008 basically involved the "cycle" facilities (more than half the notified events). More specifically, a majority of these failures occurred in facilities at the Tricastin site (in the order of 60%); the remainder of these failures mainly involved the facilities on the La Hague site. Half the events at the Tricastin site were heat exchanger leaks in the Georges Besse 1 plant. The fact that a large proportion of these failures involves facilities at the Tricastin and La Hague sites must be correlated with the large number of facilities installed there, including some of dated design (commissioned in the 1960s or 1970s).

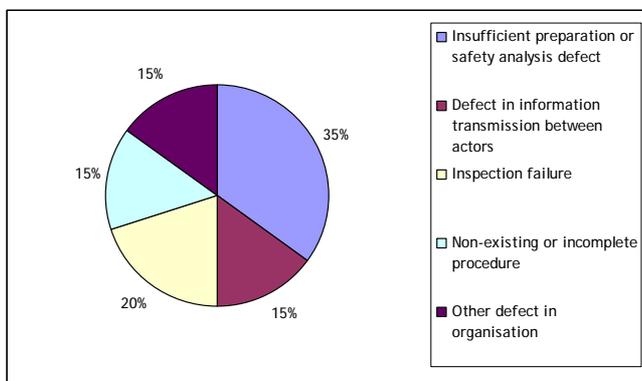
Apart from the increase noted in 2008 in the number of events linked to leaking pipes due to ageing (see chapter 7.2.1 of this report), the analysis has not revealed any significant changes in the "ageing" mechanisms behind the notified events.

7.3.2 ORGANISATIONAL OR HUMAN CAUSES

The analysis of organisational or human causes of notified events, presented below, is based extensively on information supplied by the plant operators in event reports. According to the plant operators, identifying these causes is more or less accurate; in particular, the organisational causes underlying certain events ("root" causes) are not always identified. The analysis is therefore not always able to identify the precise cause of failures. Given that about two-thirds of notified events show at least one organisational or human cause, improved safety in LUDD facilities will be made easier by more detailed identification of such causes and lessons will be drawn.

Given the available information in the reports of events notified to ASN, classifications of events per type of organisational or human cause presented below must be viewed cautiously. This statistical analysis, using the "SAPIDE LUDD" database, basically aims to estimate the relative importance of main types of organisational or human cause for the events notified.

7.3.2.1 Classification of organisational or human causes



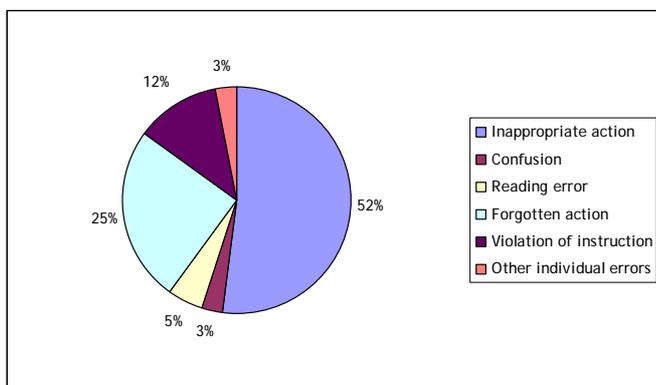
Breakdown of events per family of "organisational" causes for the 2005-2008 period

According to available information, the shortfalls in preparation and safety analysis prior to the activities are the most extensive cause. The other types of organisational causes are spread equally.

A more detailed analysis shows that the shortfalls in preparing, monitoring and inspecting interventions (modifications, maintenance, etc.) are a major organisational cause of events notified to ASN. These aspects are examined in detail in chapter 7.3.2.2 of this report.

In addition, the analysis shows that some organisational defects led to non-respect in the times scheduled for periodic tests of equipment. The analysis presented in chapter 7.2 underlines the recurrent nature of this type of event. Organisational defects leading to these events are examined in chapter 7.3.2.3 of this report.

Lastly, the analysis of events notified to ASN shows an on-going increase between 2005 and 2008 in the number of events involving personnel from outside contractors. A large proportion of these events seem to be caused by organisational failures in managing and controlling these personnel. This aspect is addressed in chapter 7.3.2.4 of this report.



Proportion of events per family of "human" causes for the 2005-2008 period

The information available suggests that the principal human failures are linked to inappropriate or forgotten actions.

A more detailed analysis shows that these events are predominantly caused by non-respect - involuntary or deliberate - of the working document, safety or radiological protection recommendations. Defects in the "man-machine" interfaces are also a major cause of events. Both these aspects are discussed in chapters 7.3.2.5 and 7.3.2.6 of this report.

7.3.2.2 Organisational failures associated with interventions

The assessment of events notified to ASN between 2005 and 2008 shows that an average of twenty to thirty events every year have an organisational defect during interventions (work, modifications, maintenance operations, tests, etc.) as their main identified cause. This type of event affects the various LUDD BNI families. The deficiencies noted involve a variety of areas, such as risk analysis before interventions, provision made to control risk following this analysis, performing works, inspecting operations and correct re-configuration of facilities after intervention.

7.3.2.2.1) Prior risk analysis and carrying out interventions

Deficiencies in terms of risk analysis prior to interventions are noted for most types of event examined in chapter 7.2 of this report; there was no prior analysis for some events. These deficiencies have in several cases resulted in insufficient prevention or protection measures being implemented. Several events occurring between 2005 and 2008 result from insufficient or no analysis of fire risks (analysis to be carried out for fire permits), especially when working with hot spots (cutting work). They led to several actual fire outbreaks. Lastly, several events are the result of insufficient preparation in circuit alignment, causing undesirable transfers of materials.

The risk analysis deficiencies cover many aspects. Nevertheless, they often lead to a failure to take sufficiently into account requirements of the safety reference framework for facilities, the actual state of the part of the facility where the intervention is taking place or potential interferences, even incompatibilities with other activities carried out in the BNI. On this last point, note that the type of risk is particularly important in facilities where numerous interventions take place simultaneously (facilities under final shutdown or being dismantled, for example).

Causes of deficiencies are not always stated in the significant event reports, which often only present observations. Thus, certain deficiencies result from a failure to check risk analysis or an insufficient check "in the field" of the actual state of the facility; the cause of these deficiencies is nevertheless rarely given. Apart from these failures, a large proportion of events seems to be linked to faulty procedures or defects in the analysis approach (resulting in a partial analysis) and defects in internal organisation (defective internal control of the relevance or sufficient nature of the analysis carried out, not enough security or safety engineers, etc.). It is important to underline that the greatest number of interventions are often performed by workers from outside contractors. The gaps in managing and controlling these workers are a major cause of events; these are examined in chapter 7.3.2.4 of this report.

In terms of carrying out interventions, several events result from deficiencies in checking the implementation of provisions defined when preparing interventions (checking compliance with defined rules, creating hold points, etc.) and defective communication between the workers responsible for carrying out the work and those who have produced the corresponding studies and analyses (no feedback on difficulties encountered in the field, for example).

Special case of "lockout" operations

Equipment "lockout" (making provision to prevent it from being manipulated) may be necessary for certain interventions (maintenance, modifications, tests, etc.). It must be underlined that "lockout" provisions are also installed under normal operation in some BNI, especially to prevent criticality risks in order to avoid the transfer, without prior examination or agreement, of products to a unit with specific criticality requirements, such as limiting the quantity of hydrogenated materials.

In terms of intervention, the number of events notified to ASN linked to the no "lockout" or defective "lockout" (insufficient or unsuitable provisions) of equipment increased in 2008 compared with previous years (ten or so events notified in 2008 against five or six in previous years). A large number of these events relate to the failure of the risk analysis to identify equipment to needing lockout.

The deficiencies of "lockout" operations can also be illustrated by the event on 21 May 2008 in the radiopharmaceuticals production plant at the CEA Saclay site (see the description of the event in chapter 6.2.6 of this report); the lack of "physical" lockout of the conveyor belt linking two production cells led to the transfer of an irradiating product shuttle causing abnormal irradiation of an operator.

Events are also linked to breaches of equipment "lockout" provisions; these are evoked in chapter 7.3.2.5 below.

Conclusion

The preparation of each intervention, based on a detailed risk analysis, is a mandatory requirement adopted by all LUDD BNI operators. The highlighting in recent years of deficiencies in preparing interventions by the majority of plant operators (AREVA and CEA especially), in particular in producing risk analyses in advance, has prompted these operators to make improvements in this area (modifications to the documents required for interventions, to improve the formalisation of the risk analysis and protection provisions to be adopted, definition of a common reference framework for interventions, for example).

IRSN considers that the assessment of events notified between 2005 and 2008 shows that the plant operators should pursue their effort to improve the preparation of intervention. In particular, the Institute considers it important that the organisational provisions adopted by the plant operators exclude interventions being carried out without a prior risk analysis. Efforts should also continue to improve the risk analysis performed, to take fully into account safety requirements for the facilities and their actual state, especially potential interferences or even incompatibilities with other activities in the BNI. IRSN considers that more comprehensive identification of equipment for lockout is another major area for improvement in these analyses.

Lastly, the organisational provisions by plant operators should include suitable control of carrying out interventions (compliance with defined rules, hold points, etc.) and facilitate exchanges between the various units involved in these interventions (especially service providers).

7.3.2.2.2) Controlling operations and re-configuring facilities after interventions

Interventions (work, maintenance, tests, etc.) in some cases require special provisions such as equipment "lockout", "inhibition" of control systems or alarms or special equipment configurations (move into "forced mode", specific circuit alignments, etc.). Inspecting the desired re-configuration of equipment once work has been completed is an essential stage, insofar as deficiencies here could lead to possible "latent" source defects or aggravating factors of subsequent incidents. These re-configuring defects can seriously degrade the safety levels in facilities when safety-related equipment is involved.

Despite the fact that plant operators are clearly aware of the importance of this verification stage, it remains a recurrent cause of events notified to ASN. Ten or so events of this type were notified in 2007 and 2008 involving facilities belonging to all BNI families. They mainly involved power supply equipment and "active" equipment (ventilation systems, pumps, etc.).

In addition, a few events notified to ASN are linked to insufficient checks on modifications to equipment or facilities in the context of interventions, especially compliance with requirements to be provided by the modified equipment (insufficient or lack of restart tests); note that some events involved software programs (radiological monitoring equipment or fissile material weight monitoring equipment, programmable controllers, etc.), where detailed tests are often necessary given their complexity.

The operating experience feedback in recent years underlines the importance that the plant operators must give to systematic, suitable inspections when interventions have been completed. In particular, given the potential consequences, IRSN considers it important that the organisational provisions adopted by the plant operators ensure full, systematic checks on correct re-configuring of equipment after an intervention.

7.3.2.3 Organisational failures associated with periodic inspections and tests

The periodic inspections and tests aim to ensure periodically the correct operation of BNI equipment, especially safety-related equipment. The characteristics of these inspections and tests (type, safety criteria to be respected, frequency, organisation, etc.) are indicated in the safety related documents of every LUDD BNI.

Events relating to the failure to carry out periodic tests at the correct intervals are notified to ASN every year; they increased in 2008 compared with previous years. Ten events of this type were notified in 2008 (against six in 2007) involving different facilities belonging to all LUDD BNI families. These breaches are mainly caused by organisational factors; note, however, a few events linked more specifically to human errors. This type of event is basically caused by:

- undetected errors in the data entered in the tools used to manage inspections and tests (mainly scheduling). There are various types of error noted: forgotten inclusion in the scheduling tool of certain equipment to be inspected, especially after modifications to facilities, inconsistencies between the frequencies adopted in the

scheduling tool and those shown in the safety documents, errors over the equipment to be inspected or scheduling errors, use of tools independent of the centralised management tool;

- **insufficient analysis of modifications to a facility, creating technical difficulties in carrying out planned periodic inspections and tests.** This involves in particular equipment to be inspected unavailable or difficult to access or inspections which are impossible to perform. In addition, shortfalls in communication between the plant operator and the workers (often people from outside contractors) has in a certain number of cases meant that the facility heads have been advised late of difficulties encountered. Note also that these shortfalls in transferring information can delay detection by the plant operator of deviations in the requirements to be respected, noted by the workers during routine inspections and tests (deviations causing significant events notified to ASN).

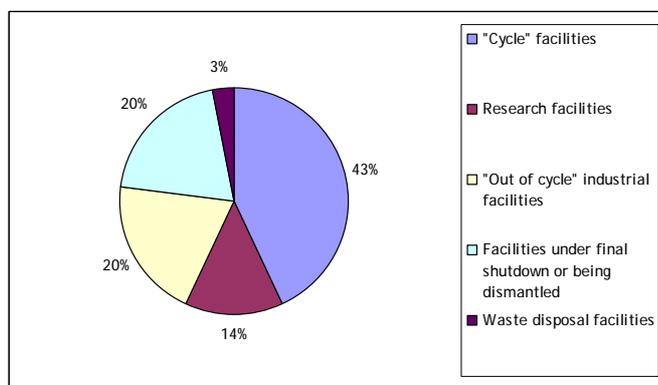
Note that a significant number of cases of overrunning scheduled inspection and testing dates were detected in 2008, during internal audits but also during ASN inspections. It appears therefore that the plant operators' tools for managing routine inspections and tests are still not enough to prevent deviations from scheduled dates.

IRSN underlines the need to reinforce corrective actions to deal with the causes evoked above (especially checking periodically that the inspection and test management tools contain accurate information, especially following modifications). This is in addition to the audits which should be maintained.

In any case, the provisions for managing periodic inspections and tests should ensure rigorous monitoring, especially when the inspections and tests are performed by outside contractors, to detect quickly the difficulties encountered or the deviations and thus introduce suitable corrective provisions.

7.3.2.4 Organisational failures linked to managing workers from outside contractors

The number of events notified to ASN involving workers from outside contractors has increased steadily between 2005 and 2008. Note that it is difficult to identify these events precisely insofar as the reports of significant events submitted by some plant operators to ASN do not always provide the necessary information.



Breakdown of events involving workers from outside contractors per BNI family and for 2008

According to the available data, it seems that the number of events involving workers from outside contractors has increased from around ten in 2005/2006 to thirty or so in 2008.

These changes are consistent with the increased sub-contracting of activities noted in recent years in the LUDD facilities, for all BNI families considered, even if differences can exist depending on the plant operators.

Although outside contractors are normally used for their very specific skills (maintenance operations, routine inspections and tests, radiological clean-up and dismantling activities, etc.), the LUDD BNI operators are calling on such companies more and more to manage projects or run facilities. Some operators feel that these changes relate to the growth in project management activities (facility shut down or dismantling, renovation of old facilities, entry into service of new facilities, etc.). The logical result of these changes is that the events notified to ASN involving personnel from outside contractors cover both interventions (clean-up or dismantling sites, maintenance, routine inspections and tests, etc.) and operating activities (see for example the event of 10 September 2007 in BNI 72 at CEA/Saclay, described in chapter 6.2.5 of this report).

The organisational or human causes of these events are very diverse (defects in intervention preparation, breaches of procedures, etc.). Although the reports submitted do not always show the "root" causes of these events, it seems¹⁹ that a large number of them result from organisational deficiencies, especially in intervention preparation (risk analysis, managing risks linked to interferences or incompatibilities with other activities in the facility, etc.), monitoring and

¹⁹ The summary of the IRSN expert assessment on the safety review of BNI 72, where managing outside contractors is a major issue in controlling risks from human and organisational factors, is presented on the Institute's internet site (www.irsn.org).

supervising service providers and in the interfaces with the plant operator in the "everyday" work (exchanges over difficulties encountered, reminder of rules and requirements to be respected, etc.), in particular in facilities where numerous sub-contracted activities are taking place simultaneously.

In terms of these deficiencies in managing and controlling outside contractors, the plant operators have made provision for improved management of sub-contracting and further provisions are currently being instated. IRSN considers that for the safety of BNI, this aspect merits special attention from plant operators inasmuch as constant recourse to outside contractors is inconceivable without suitable organisation and sufficient, competent human resources, so that the plant operators retain control of the safety of their facilities and ensure that these contractors comply with the safety and radiological protection rules and requirements.

7.3.2.5 Breaches in procedures and rules and insufficient documentation

The analysis of events where one principal cause is an inappropriate or forgotten action shows that they are mainly linked to breaches in procedures or rules by operators (working documents, radiological protection instructions, etc.). These breaches involve all BNI families (forty or so events notified in 2008). The cause of these breaches (insufficient training, etc.) is rarely given in the significant event reports submitted to ASN.

The proportion of events linked to deliberate "violations" of instructions or operating procedures (about 12% of events, where one cause is human failure, i.e. six to seven events in both 2007 and 2008) must be considered cautiously; it relates to events where this cause is clearly identified as such in the event reports. It could prove under-estimated inasmuch as it is not always possible, when examining reports, to identify the causes of breaches (individual errors, insufficient knowledge due to defective information or training, organisational failures, deliberate actions, etc.). The deliberate "violations" of procedures or rules seem nevertheless to be increasing in the LUDD BNI. According to the information available, about half of clearly identified "violations" of procedures or rules are by workers from outside contractors.

Several events described in chapter 6 of this report relate to breaches or to "violations" of operating rules or radiological protection procedures (event of 20 October 2006 in the HAO/South facility of the UP2-400 plant in the La Hague site, event of 10 September 2007 in the radioactive waste management area at the CEA Saclay site and event of 21 May 2008 at the radiopharmaceuticals production plant at the CEA Saclay site).

It would also seem that several events are the result of worker "violations" of equipment "lockout" provisions, which do not totally prevent manual manipulation of the equipment in question. Two events during recent years in two facilities at the La Hague site illustrate this type of event:

- the event of 4 March 2006 in the T1 facility in the UP3A plant, due to the opening of a valve closed by a padlock and chain to prevent risks of criticality. The operators opened the valve using the gap left by the chain;
- the event of 16 May 2008 in the R7 facility in the UP2-800 plant, which involved the entry into service following a maintenance operation of a handling gantry whose power supply isolating switch had been locked using padlocks. The workers activated the isolating switch using the available mechanical gap, without requesting a "lockout removal" from the plant operator.

The operating experience feedback from events notified to ASN show that one possible area for improving BNI safety is to reduce the causes of breaches of rules or procedures. For IRSN, this is based mainly on suitable training for personnel and workers from outside contractors (and more globally by developing a safety culture) and by regular checks on compliance with rules and procedures during operations or interventions. This seems especially important in "unusual" operations infrequently performed by the operators (during interventions, in the event of an operating contingency or degraded situation, etc.). IRSN considers that it is also necessary to monitor the organising quality of routine operations to make them less sensitive to such failures.

IRSN considers that "lockouts" merit special attention, firstly in terms of the reliability of the physical "lockout" provisions adopted, to prevent them from being "violated" by workers, and secondly, in terms of raising the awareness of operators to strict compliance with "lockout" rules.

Apart from events linked to breaches of the procedures or rules, a certain number of events (corresponding to about 15% of organisational causes) relate to a lack of documents or inappropriate or insufficient documents. The lack of documents was noted especially for a few events relating to particular interventions or unusual operating phases. A

shortage of a wide variety of documents (operating and installation procedures, "criticality" instructions, maintenance documents, etc.) is due to a number of reasons, without genuine generic causes. It nevertheless seems important for the plant operators to remain vigilant in this field, especially in terms of interventions and for the infrequent phases in facility operation (operating contingency, restarting process equipment, etc.).

7.3.2.6 Failures linked to "man-machine" interfaces

About thirty events are caused by a man-machine interface defect or shortfall or poor ergonomics. It must be underlined that the number of events of this type must be viewed cautiously, as the plant operators rarely identify this type of cause explicitly in their reports.

The defects in man-machine interfaces or ergonomics mainly involve operating or monitoring stations for process equipment (defective displays, control wordings causing confusion, defects in alarm prioritisation, etc.). In this respect, note that early in April 2009, ASN requested every LUDD facility operator to submit his thoughts on this subject and any actions carried out. There are no generic lessons to be learned at this stage.

8 SUMMARY

The main objective of the analysis of "significant" and "safety-related" events notified to ASN between 2005 and 2008 in LUDD basic nuclear installations (Laboratories, plants, facilities being dismantled, waste processing or interim storage facilities and disposal facilities), the subject of this report, was to highlight general lessons to reinforce the safety of these installations. This analysis is part of IRSN's overall objective to encourage on-going enhancement of safety in basic nuclear installations.

The analysis of available operating experience feedback, especially in terms of the anomalies, incidents and accidents occurring in France or abroad, is a fundamental element in maintaining a high level of safety in nuclear facilities. The safety of nuclear facilities can never be taken for granted; constant efforts must be made to improve it, by taking new knowledge and available operating experience feedback into account. The diversity of the LUDD BNI is nevertheless a limiting factor in identifying general cross-disciplinary lessons.

The Institute assesses the safety of these facilities as part of its mission of technical support to the Nuclear Safety Authority, by considering the specific features of each facility and the operating experience feedback on the facility assessed, facilities of the same type and even all facilities. With this in mind, and using appropriate tools, the Institute capitalises on the operating experience feedback produced by analysing events occurring in France in LUDD facilities and the most important incidents in similar facilities abroad. The lessons learned from this analysis are also considered when establishing study and research programmes carried out by the Institute to maintain its expertise and expand its knowledge.

The overall examination of events notified between 2005 and 2008 shows, firstly, a significant increase - on the order of 45% - in the number of events notified to ASN in 2008 compared with the three previous years. In the light of available information, this increase could be largely explained by improved notification of events by LUDD BNI operators. This trend seen in 2008 should be considered in light of the approach taken by ASN in recent years, aiming that the plant operators apply the criteria for notifying significant events more rigorously.

The BNI safety improvement approach discussed above assumes as full an analysis as possible of all available operating experience feedback, including "minor" events which could give early warning of more serious events. To be effective, this approach requires plant operators to carry out a sufficiently detailed analysis of these events to enable identification of useful information. On this point, IRSN considers that the global analysis of operating experience feedback from events notified to ASN could be improved further by better formalisation, in the significant event reports submitted by plant operators, of the analyses, especially those related to identifying the root causes of events and the weaknesses in the provisions for defence in-depth applied in the facilities.

In terms of consequences, it seems firstly that no event notified to ASN between 2005 to 2008 had serious consequences for the workers, the general public or the environment. It is also important to underline that no regulatory dose limits for workers or members of the general public were exceeded, and therefore notified, in the LUDD facilities during this period. This positive observation must not however overshadow the fact that a proportion of events producing limited consequences for the workers or the environment could certainly have been avoided if better account had been taken of lessons drawn from the operating experience feedback, especially involving organisational or human causes. In this respect, IRSN's cross-disciplinary events analysis favours identifying areas for improving the safety of LUDD facilities.

The IRSN analysis shows that only about one third of events notified to ASN between 2005 and 2008 are caused purely by technical factors. It seems therefore that the organisational and human factors play a significant role in a majority of notified events. This observation is globally consistent with the type of operation carried out in the LUDD facilities, which normally involves frequent human interventions on equipment and close to radioactive materials.

Identifying general lessons learned based on the technical cause analysis of events notified to ASN is difficult due to the diversity of process equipment or equipment performing a safety function (containment of radioactive materials, especially) used in the LUDD facilities and by the available analysis elements on the "root" causes of these events. Nevertheless, IRSN notes that the ageing mechanisms (corrosion, fatigue, wear, etc.) are the largest identified cause of equipment failures leading to the events notified to ASN. In this respect, 2008 saw an increase in the number of leaking pipes in old-design nuclear facilities linked to corrosion or fatigue phenomena which caused releases of liquid effluents into the environment. In a certain number of cases, the detailed analyses have revealed links between events and design faults, due to insufficient application of the concept of defence in-depth, or to operating deficiencies (especially routine inspections and maintenance).

Thus, IRSN considers that one way of improving safety in LUDD BNI is to widen the study of ageing phenomena specific to the different type of equipment, including investigation as part of the periodic safety review required by the TSN Act. More widely, IRSN underlines the importance of "robust" design of nuclear facilities, based on the concept of defence in-depth. This leads to provisions being made to prevent potential equipment failures, detect any abnormal event quickly and limit its consequences.

About 60% of events notified to ASN have at least one main cause identified as organisational or human. The IRSN analysis of these events has revealed the main elements below.

- ◆ A significant number of events notified to ASN present as the main identified cause, a defective organisation of interventions, such as modifications, maintenance operations or tests. In particular this concerned deficiencies in preparing these operations and especially in producing a risk analysis in advance. These deficiencies caused, for example, missing equipment "lockout" or defective "lockouts", events which increased in 2008 compared with previous years.

The highlighting in recent years of deficiencies in intervention preparations by the majority of plant operators has prompted them to initiate improvements. For IRSN, the operating experience feedback shows that the plant operators should continue their efforts in this way. In particular, the Institute considers it essential that the organisational provisions adopted exclude interventions being carried out without a prior risk analysis. IRSN also considers it important to improve the risk analysis carried out (by identifying equipment requiring "lockout" for example) and formalise associated intervention documents (especially fire permits).

The operating experience feedback also shows the importance of monitoring interventions during execution (compliance with defined rules, hold points, etc.) and of systematic suitable inspections when these operations have been completed. On this last point, the operating experience feedback shows deficiencies in the checks of correct re-configuration of equipment covered by special provisions during an intervention (lockouts, specific circuit alignment, etc.). "Latent" defects potentially causing subsequent incidents may not be eliminated due to gaps in end-of-intervention inspections prior to equipment re-entering into service. IRSN also considers it important that the organisational provisions adopted by the plant operators ensure full, systematic checks on correct re-configuration of equipment after interventions.

- ◆ The analysis of organisational or human causes of events notified to ASN has revealed continuing increase between 2005 and 2008 in the number of events involving personnel from outside contractors.

This trend is consistent with the increase noted in recent years in sub-contracting activities in the LUDD facilities, extending to full project management or facility operation. Despite the uneven level of information about the "root" causes of these events, it seems that many of them result from organisational deficiencies in terms of monitoring and supervising workers from outside contractors, especially in facilities where numerous activities take place simultaneously.

It must be underlined that the main operators of LUDD facilities have made provision, or are currently doing so, to improve the management of sub-contractors. IRSN considers that for the safety of BNI, this aspect does indeed merit special attention from plant operators inasmuch as constant recourse to outside contractors is inconceivable without suitable organisation and sufficient, competent human resources, so that the plant operators retain control of the safety of facilities and ensure that these contractors comply with the safety and radiological protection rules and requirements.

- ◆ Regarding the other organisational defects, the analysis has highlighted gaps resulting in recurrent non-respect of the intervals scheduled for periodic inspections and tests on equipment involved in the safety of facilities. It is important for safety to comply with these intervals inasmuch as these operations check that equipment used to control risks is functioning correctly. In this respect, IRSN considers that LUDD facility operators should boost the corrective actions implemented to deal with the causes (for example, checking systematically that inspection and test management tools contain accurate information, especially following modifications to the facility).

In any case, IRSN considers that the provisions for managing periodic inspections and tests should ensure rigorous monitoring, especially when the periodic inspections and tests are performed by outside contractors, to quickly detect the difficulties encountered or deviations from the expected results and thus introduce suitable corrective measures.

- ◆ Breaches in following procedures and rules (working documents, radiological protection instructions, intervention documents, etc.) by the personnel are a major cause of events notified to ASN. While a majority of these events are involuntary errors, an increasing proportion involve deliberate breaches. Several "violations" of "lockout" provisions for equipment must be singled out, especially in situations where these provisions did not prevent the manual manipulation of locked equipment.

For IRSN, this operating feedback shows especially how important it is to train personnel and workers from outside contractors properly in the rules and procedures to be respected and, more globally, to develop their safety culture. This involves more especially in "unusual" operations infrequently performed by the workers (during interventions, in the event of an operating contingency or degraded situation, etc.). It also seems necessary to monitor the organisational quality of routine operations to make them less sensitive to human failures.

In addition, IRSN considers that "lockouts" merit attention, firstly in terms of the reliability of the physical "lockout" provisions adopted, to prevent them from being "violated" by workers, and secondly, in terms of strict compliance with "lockout" rules.

- ◆ Lastly, a large proportion of events are caused by a lack of documents or by using inappropriate or incomplete documents. Given the available elements, it has not been possible to identify generic causes for these documentary shortfalls due to their variety. It nevertheless seems important for the plant operators to be vigilant on this point, especially in terms of interventions and for infrequent phases in facility operation (operating contingency, degraded situation, restarting process equipment, etc.).

APPENDIX

NOTIFICATION CRITERIA FOR SIGNIFICANT EVENTS RELATING TO SAFETY, RADIOLOGICAL PROTECTION AND THE ENVIRONMENT, PRESENTED IN THE ASN GUIDE OF 21 OCTOBER 2005

<i>Notification criteria for significant events involving the safety of BNI other than pressurised water reactors:</i>
1 - Nuclear or non-nuclear event causing death or serious injury and requiring the hospitalisation of the injured person(s), when the death or injury is caused by a failure of process-related equipment.
2 - Manual or automatic, unintentional or intentional, activation of protection and/or safeguard systems, except for intentional activation resulting from scheduled actions to maintain a major safety function.
3 - Event leading to one or more security limits being overrun as defined in the safety reference framework or the decree authorising the creation of the facility.
4 - Internal or external hazards for facilities: occurrence of a natural external phenomenon or one linked to human activity, or internal flooding, a fire or another phenomenon likely to have significant consequences or to affect the availability of equipment involved in a major safety function.
5 - Actual or attempted malicious act likely to affect the safety of the facility.
6 - Event interfering with or potentially interfering with the integrity of hazardous materials containment.
7 - Event causing or potentially causing multiple failures: unavailability of equipment due to a same failure or affecting all the trains of a redundant system or equipment of the same type involved in one or more of the facility's safety functions.
8 - Defect, degradation or failure affecting a safety function, which has had or could have serious consequences, whether detected during facility operation or outage.
9 - Event not meeting the previous criteria and affecting a safety function but which is likely to give early warning of an accident or which is repetitive without the cause being identified.
10 - Any other event likely to affect the safety of the facility deemed significant by the plant operator or the Nuclear Safety Authority.

<i>Notification criteria for significant events involving radiological protection of BNI:</i>
1 - Exceeding the regulatory annual individual dose limit or unforeseen situation which could, in representative and likely conditions, have resulted in exceeding a regulatory annual individual dose limit, regardless of the type of exposure.
2 - Unscheduled situation causing the exceeding of the quarter of a regulatory annual dose limit during random exposure, regardless of the type of exposure.
3 - Any significant deviation involving radiological cleanliness.
4 - Any activity (operation, work, modification, inspection, etc.) comprising a major radiological risk, carried out without a formalised radiological protection analysis (justification, optimisation, limitation) or without taking exhaustive account of this analysis.
5 - Actual or attempted malicious act likely to compromise the protection of workers or the general public against ionising radiation.
6 - Abnormal situation affecting a sealed or non-sealed source with a higher level than the exemption thresholds.
7 - Defective signalling of or failure to comply with technical conditions for access or spending time in a specially regulated or prohibited area (orange and red areas).

8 - Uncompensated failure of radiological monitoring systems for protection of personnel present during activities with a major radiological risk.
9 - Exceeding the inspection interval for a radiological monitoring device: - more than one month if a permanent collective monitoring device is involved (regulatory interval of one month); - more than three months if other devices are involved (when the verification intervals provided for in the RGE or the radiological protection reference framework are between twelve and sixty months).
10 - Any other event likely to affect the radiological protection deemed significant by the plant operator or the Nuclear Safety Authority.

<i>Notification criteria for significant events involving the environment of BNI :</i>
1 - By-passing normal channels for releases with a major impact, proven overrunning of one of the environmental release limits fixed by an order authorising samples and releases by the facility for radioactive substances or release of an unauthorised radioactive substance.
2 - By-passing normal channels for releases with a major impact, proven overrunning of one of the environmental release limits fixed by an order authorising samples and releases by the facility for chemicals or major release of a chemical (excluding substances depleting the ozone layer).
3 - Proven overrunning of one of the release or concentration limits present fixed by the health regulations or an order authorising samples and release by the facility for microbiological substances.
4 - Failure to comply with an operational provision fixed in an order authorising samples and releases by the facility which could have had a major environmental impact.
5 - Actual or attempted malicious act likely to affect the environment.
6 - Failure to comply with the provisions of the order of 31 December 1999 on technical recommendations for equipment or facilities classified for environmental protection, which could have had a major environmental impact (except deviations from release orders, waste studies).
7 - Failure to comply with the waste study of the site or facility resulting in the elimination of nuclear waste in a conventional chain or compromising the conventional nature of the area.
8 - Discovery of a site heavily polluted by chemicals or radioactive materials.
9 - Any other event likely to affect environmental protection deemed significant by the plant operator or the Nuclear Safety Authority.

Photo credits: Noak/Le Bar floéral/IRSN page 29 - CEA media library: page 23, 36 - AREVA media library: page 3, 36, 37 - IAEA media library : page 4, 8