IRSN

INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

Annual Report 2004

>IRSN **missions**

Research and **public service** missions

Defining and implementing national and international **research programmes**

Contributing to training in radiation protection

Permanent monitoring in matters of radiation protection

Public **information**

Technical support and assistance for **public authorities**

Technical support with regard to **nuclear and radiological risk**

Operational support in the event of a crisis or **radiological emergency**

Contractual services of expert appraisal, research and measurement

Carrying out **expert appraisals, research and works** for public or private organisations

Annual Report 2004

1 News, strategy **and organisation**

Monitoring
for protection

>Expertise, independence of judgement and open-mindedness

IRSN's three priorities

Employees were granted a three-year right of return and now at the end of this period more than 80% of those who worked at IRSN under CEA status have opted for an IRSN contract. This success shows great support for our Institute's missions and definitively validates our new organisation and project. Together, the 1,500 IRSN employees now share the same priorities and the same choices: the Institute must show a high level of scientific and technical expertise; it must ensure independence of judgement in all circumstances; its open-mindedness towards all those concerned by its missions, the strengthening of relations thus formed and the quality of information circulated will make society place its trust in IRSN.

Good management and team confidence in the Institute's global project are the main keys to success. Having fulfilled the commitments made by IRSN, the financial year 2004 shows that the Institute is in good working order. More comprehensive than previous reports, the 2004 annual report also covers the numerous projects carried out.

The objectives were achieved. Three significant examples can be cited:

- the success of the last test carried out in the PHEBUS-FP research programme on the fission products that would result from a core meltdown accident in a nuclear reactor;
- the acceleration of ENVIRHOM, the research programme dedicated to understanding how humans and ecosystems react to chronic, long-term exposure to low-level radioactive contamination;
- the record number of dossiers presented to the standing advisory groups of experts who deal with safety and radiation protection issues for safety authorities.

Transparency is a further challenge. The excellence of IRSN's research and the quality of its expert assessments are well known. Yet, all scientific assertions deserve to be explained, analysed and compared. In the same way, an expert assessment should not put an end to discussions. It opens the debate and guides the decision. It should also help to enlighten the public opinion.

IRSN's 2004 annual enquiry into how French people perceive nuclear risks met with a great response from the ministries, the media and the public. This study particularly underlined the trust placed in the work of scientists and experts. However, the French would like to be better informed and more involved when there are decisions to be taken. This demand is particularly directed at IRSN, the public expert in nuclear and radiological risks. It must be addressed.

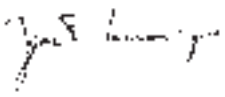
IRSN boasts many assets but it must fully accept its essential choice of opening up to the European and international scientific community. In the future, it will be the norm for researchers to

Jacques Repussard,
Director General

Jean-François Lacronique,
President of the Board
of Directors

exchange ideas and work together on shared projects regardless of national borders, for knowledge to be pooled and for investments to be shared in the most expensive test facilities and calculation codes. Risk assessment criteria, expert appraisal methods and safety standards are to be gradually harmonised within the European Union and worldwide. Sarnet, the European network of excellence, dedicated to modelling serious accidents in nuclear installations, demonstrates this desire to integrate. One could consider transposing this example to the field of radiation protection and radioecology. IRSN has a leading role to play in encouraging the development of networks devoted to research and expertise in Europe and beyond, and in exerting a growing influence within international scientific bodies.

> "Institute for Radiological Protection and Nuclear Safety has a leading role to play in encouraging the development of networks devoted to research and expertise in Europe and beyond, and in exerting a growing influence within international scientific bodies."



Jean-François Lacronique,
President of the Board
of Directors

Jacques Repussard,
Director General

>Part of IRSN's expertise is devoted to national defence and security issues

In fact the Institute's "nuclear defence expertise" covers two distinct areas in which the State is liable to be held directly responsible and for which defence secrecy often has to be implemented:

- nuclear safety and radiological protection in nuclear installations and activities related to national defence, whether of a military or civil nature;
- the security, and above all the physical protection of nuclear materials, installations and transportation nationwide.

The corresponding activities, including basic studies and research, are carried out in a specific operational division, with the support of the entire Institute.

In 2004, the framework agreements between the Institute and State authorities were carefully drawn up. They concern the provision of direct assistance (inspections, operational command of transportations, etc.) or technical support (processing dossiers, preparing exercises, etc.).

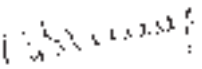
As far as activities are concerned, there was a significant increase in the work due to:

- the ongoing modernisation of France's deterrent force which is adopting a very strict approach to safety;
- the strengthening of the international fight against the proliferation of nuclear weapons (additional protocol to IAEA's safeguard agreement and new EURATOM regulations).

Nuclear defence expertise is a specific application and, for obvious reasons, does not lend itself to development on the national and international markets.

Michel Brière,
Assistant Director General,
in charge of missions related to defence

In the present context when the demand for expertise is increasing but budgetary resources cannot be increased, good relations and mutual trust between the Institute and State authorities are a major advantage.



Michel Brière,
Assistant Director General,
in charge of missions related to defence

>IRSN **missions**

IRSN's articles of association (Decree No. 2002-254 of 22 February 2002) laid down seven missions for the Institute, relating to radiation protection and nuclear safety. They are organised into three fields:

Research and public service missions

Defining and implementing national and international research programmes
IRSN defines and conducts research programmes aimed at maintaining and developing the skills necessary for expert appraisal in its fields of activity. It either carries them out itself or entrusts them to other French or foreign research institutes.

Contributing to training in radiation protection
As a research and expert assessment establishment, IRSN has a duty to contribute to teaching in the areas in which it has competence: nuclear safety and radiation protection. The radiation protection training courses it organises are directed at professionals working in the health sector and people exposed to risk in their jobs.

Permanent monitoring in matters of radiation protection
IRSN carries out permanent monitoring in matters of radiation protection by assisting in the radiological monitoring of the environment and by managing and processing dosimetric data on workers exposed to ionising radiation and managing the inventory of ionising radiation sources.

Public information
IRSN informs the public of nuclear and radiological risks via publications, the Internet, a travelling exhibition jointly organised with DGSNR, conferences, etc.

Technical support and assistance for public authorities

Technical support with regard to nuclear and radiological risk
IRSN provides technical support in the field of nuclear and radiological risk to public authorities that so request it. Its scope of intervention includes civil nuclear facilities, secret classified installations, the transport of radioactive substances, the application of treaties on the control, physical protection and security of industrial and medical applications. In the fields of safety and radiation protection, the Institute carries out tests, research, development experimentations, and develops models, codes and safety tools.

Operational support in the event of a crisis or radiological emergency
In the event of an incident or accident involving ionising radiation, IRSN carries out measures of a technical, health and medical nature for public authorities, in order to ensure the protection of the population, workers and the environment, and restore the security of the facilities.

Contractual services of expert appraisal, research and measurement

Carrying out expert appraisals, research and works for public or private organisations
IRSN carries out contractual services of expert appraisals, research and works – analysis, measurement and dosing – for French, European and universal organisations in the public and private sector. In addition, the Institute carries out third-party expertise for ICPE outside the nuclear sector.

>IRSN in 2004

Report and perspectives

In 2004, IRSN, a public establishment created in 2002, strived to implement all the strategic actions set out by the Director General in 2003. They are based on a system of management through quality aimed at contributing to the efficient running of the Institute. Within this framework and in order to carry out its missions properly, IRSN has started to draw up a contract of objectives between IRSN and the State (2006-2009).

As leading public expert, the Institute should make proposals on matters concerning radiation protection and nuclear safety. A strategy of action, in both research and expertise, is developed through internal and external discussions, approved by the establishment's supervising authorities. IRSN has identified about 10 strategic and multidisciplinary programmes corresponding to fields in which the stakes are high and in which the Institute shall have to evolve in the coming years.

IRSN's main lines of development in 2004

1. OPTIMISING SUPPORT MISSIONS FOR PUBLIC AUTHORITIES

■ Formalising relationships with public authorities

In 2004, IRSN signed nine framework agreements with the administrations to which it provides technical support (DSND, DGSNR, DRT, DPPR, etc.). Two agreements remain to be drawn up with the authority in charge of defence-related safety.

■ Clarifying operating methods with administrations

This involves adapting the "code of practice" drawn up with DGSNR to improve the efficiency of relations and practices when evaluating the safety of basic nuclear installations.

An inventory of current practices was carried out in 2004 with the administrations concerned. It led to the implementation of working groups in charge of identifying lines of progress while taking the constraints of all parties into account. This work will be completed in 2005.

■ Implementing public service missions

Within the limits of the resources allocated to it, IRSN continued setting up a national network for environmental measurements, the SISERI (a database on doses received by workers), the sources management system, etc.

Strategic investment scheme

At the end of 2004, IRSN developed an investment plan of 40 M€ intended to finance the renewal of equipment. One of its aims is to bring the network of environmental measurements up to standard requirements and to make it denser.
It also aims to renew the emergency vehicles used in crisis situations, the SIPA simulator, etc.

2. REWORKING ITS RESEARCH PROCESS IN CONSULTATION WITH ITS MAIN PARTNERS

■ Promoting scientific and technical excellence

The Scientific Board was put together and held its first meeting in 2004. It is in charge of ensuring the quality of the Institute's scientific production in research and expertise: the quality of projects (upstream and downstream) and the quality of teams and researchers. As well as the Institute's

internal evaluation tools (audits, commissions, project reviews, etc.), the Scientific Board judges the scientific and technical interest of the programmes and their results.
Moreover, the Institute wanted to assess the research programmes it conducts with the manufacturers that use them and who sometimes contribute financially to them. It was with this approach to quality and pertinence that IRSN and EDF decided to organise a discussion seminar on research in 2004.

3. OPENING UP ITS EXPERTISE TO TAKE THE EXPECTATIONS OF SOCIETY INTO ACCOUNT

▪ Giving an impulse to pluralist expertise

The Institute has started to set up groups bringing together manufacturers, associations and outside experts with which it can discuss the technical challenges of complex and controversial subjects. In 2004, the first discussions were held at the Bois-Noirs mining site in the Loire department. These discussions could be extended to all mining sites via a group of pluralist experts.

▪ Developing the Institute's activities

Actions have been conducted within the Institute both to inform teams (seminars to promote industrial awareness) and to formalise the range of services provided by the Institute (40 data sheets were drawn up).

Preparing the corporate project

In September, IRSN organised a forum that brought together 200 employees to discuss: "What strategy and actions should be undertaken in the future?" The aim was to get working groups to build IRSN's corporate project for the years ahead – a project that would enable it to carry out its public expert missions for the benefit of society.

Drawing up the contract of objectives with the State

Discussions on the contract of objectives between IRSN and the State started in January 2004, and involved numerous internal projects and meetings with the supervising authorities. Organised around the four main lines of development set out in 2003, the contract of objectives should eventually lead to the strengthening of the Institute's position in the field of nuclear and radiological risk control, nationally and internationally, taking into account the expectations of the different parties involved.

4. DEVELOPING THE EUROPEAN AND INTERNATIONAL DIMENSION

▪ Continuing international research programmes

In 2004, IRSN took the position that the 7th FPRD should support research on existing reactors and distinguish between support projects for public policies and projects for manufacturers.

▪ Adopting common policy in relation to expert appraisal

IRSN, AVN and GRS have started to write common guidelines on how to evaluate the safety of nuclear facilities. In 2004, they completed the first chapter devoted to harmonising the principles applied by the three organisations.

▪ Getting involved in international organisations

The ICRP, whose radiation protection recommendations form the basis of international regulations, renewed its composition in 2004. IRSN is represented within the main commission and within four of the five theme-based committees, the most recently created being dedicated to environmental protection. This subject is related to the strategic programme "Chronic risks". IRSN also tries to be present and active in the other international bodies involved in nuclear safety and radiation protection.

> Main events

JANUARY

- 8
  Launching of the TACIS project whereby technical support was given to the Ukrainian safety authority in the analysis of the dossier authorising start-up of the Rovno 4 and Khmelnitski 2 VVER 1000 reactors.
- 22
  The standing advisory group for nuclear reactors examined an IRSN report on the safety of CABRI, the experimental reactor, and the pressurised water loop that CEA intends to install in this reactor.
- 31
  Meeting to summarise the 2nd international inter-comparison campaign for laboratories that calibrate radon measuring instruments (EUROMET, No. 657).

FEBRUARY

- 4-5
  Awareness course on the treatment of risks related to earthquakes for members of the standing advisory group for nuclear reactors and the standing advisory group for plants.

MARCH

- 3
  The standing advisory group of experts on installations intended for long-term storage of radioactive waste examined an ANDRA dossier concerning the mechanical behaviour of a possible storage facility at the Bure site (Meuse).
- 16
  In-house seminar on scientific and technical excellence held at the Le Vésinet site (Yvelines).
- 16-19
  Participation in the Medec trade fair for the medical world.
- 18
  Creation of Sarnet, a European network of excellence devoted to research on severe accidents, organised by IRSN.
- 23
  IRSN organised a seminar devoted to "concerted approaches". This seminar assembled about a hundred players from society (industrialists, operators, experts, administrations, unions, associations, CLI and ANCLI) with a view to improving concerted action around high-risk industrial sites.
- 24
  - ANCLI and IRSN organised a seminar to describe the main lines of their cooperation following an enquiry previously carried out with CLI.
  - The standing advisory group of experts on installations intended for long-term storage of radioactive waste and the standing advisory group in charge of the basic nuclear installations other than nuclear reactors examined an EDF dossier concerning the dismantling of first-generation reactors (Saint-Laurent-des-Eaux – Loir-et-Cher and Bugey – Ain).
- 26
  The HFD from the Ministry of Industry signed two agreements concerning IRSN's technical assistance in the implementation of the convention prohibiting chemical weapons and the regulations on the protection and control of materials.
- 29
  - Jacques Repussard presented the supervisory authorities with the stakeholders' committed approach, particularly through the pilot initiatives in pluralist expertise.
  - The framework agreement whereby IRSN provides technical assistance and support to DSND was signed.

APRIL

- 20
  The CD-Rom "Information on nuclear risk and how it is managed" was sent to prefectures and EDF nuclear power plant CLIs.
- 28
  - The Reactor Safety Commission examined an IRSN report on the security systems of *Barracuda*, the future nuclear attack submarine.
  - Renewal of Cofrac accreditations for IRSN metrology laboratories.
  - The TACIS RF/TS/39 contract for SEC/NRS (Russian safety authority) started up with the participation of IRSN, GRS and APAT. It covers: evaluation of the procedure to authorise storage of radon-type waste, writing of a safety report planning guide for the safety of waste

storage and evaluation of the safety report on the creation of a new storage facility that could in the long term (fifty years) become a surface waste disposal site at the Serguiev Posad site located in the north of the Moscow region.

MAY

■ 24-28

▪ An IRSN expert chaired the meeting on social aspects and public involvement in radiation protection at the IRPA congress in Madrid.

▪ A contract was signed with SNCF, involving a study of workstations with regard to nine types of transported radioactive materials.

▪ The "Kursk 1 safety report review" project was completed and the results were presented to the Safety Review Group (EBRD).

JUNE

■ 4

The agreement with DGSNR was signed – it describes the conditions under which IRSN provides technical support to DGSNR and the methods used to launch and conduct the technical support actions.

■ 8

The standing advisory group of experts on installations intended for long-term storage of radioactive waste examined an ANDRA dossier concerning the geo-chemical phenomena governing the release and transportation of radionuclides in a deep geological disposal at the Bure site (Meuse).

■ 9

▪ The standing advisory group for nuclear reactors examined EDF's method of taking aspects related to human factors into account when modifying installations.

▪ Seminar summarising the REP-Na programme: assessment of the first 10 tests of the CABRI REP-Na programme and unanswered questions that will be addressed in the next CABRI-water loop programme.

■ 10-11

Organisation of the final seminar of the OECD MASCA international project on the behaviour of corium at tank bottom.

■ 14

A Eurosafe seminar was held in Cologne (Germany) on knowledge management in institutes that conduct research and expertise in nuclear safety.

■ 18

The agreement with DPPR was signed: it describes the conditions under which IRSN provides technical support to DPPR and the methods used to launch and conduct the technical support actions.

■ 23-25

IRSN gave its first training course on "radon metrology" as part of its radiation protection training mission.

JULY

■ 1

The standing advisory group on nuclear reactors examined certain aspects related to the safety of the EPR (command-control, radiation protection, containment building, etc.).

■ 6

Members of IRSN's Scientific Board were appointed.

■ 8

▪ Presentation of IRSN's radiation protection action plan *(Maison de l'Amérique latine*, Paris*)*.

▪ The national inventory of uranium mining sites put together by IRSN was published (from the end of the Second World War to May 2001).

▪ A seminar on waste was organised in Havana (Cuba) by CPRH, IRSN, CSN, SSI – six Central American countries took part.

AUGUST

▪ Signing of a cooperation agreement with CEREGE (European Centre for Research and Education in Environmental Geosciences) on the paleoseismic programme in Provence.

▪ The cooperation agreement with the Ukraine on the Chernobyl experimental platform project was renewed for four years.

SEPTEMBER

■ 6-10

IRSN organised the second Ecorad Conference aimed at taking stock of the

> Main events

knowledge that enables us to assess how radioactivity impacts the environment.

■ 20-21
IRSN in-house forum – "What strategy and actions should be undertaken in the future?"

■ 22
Signing of a BfS/NRPB/IRSN tripartite agreement concerning dosimetric assistance (biological analyses) in the event of a crisis.

■ 22-23
■ Organisation of an SFRP day on exposure to natural radioactivity due to human activities.
■ A report on the radiological consequences of flooding in the Petite Camargue in December 2003 was given to the PACA and Languedoc-Roussillon DRASS, the Bouches-du-Rhône, Vaucluse and Gard DDASS, the DSND, the DGSNR, the Gard CLI, the DPPR and the PACA DRIRE.

OCTOBER

■ 1-2
IRSN participation in the *Journées françaises de radiologie* (French Radiology Congress).

■ 4-6
IRSN Thesis Presentation 2004 in Aussois.

■ 5-6
IRSN, GRS and ICC organised a seminar in Kiev at which FGI (Franco-German Chernobyl Initiative) results were presented.

■ 6
■ The PHARE contract with the Lithuanian safety authority came to an end and another contract was signed with this same authority and with the European Commission, concerning the dismantling of the Ignalina power plant.
■ The Reactor Safety Commission examined an IRSN report on the security baseline of *Barracuda*, the future nuclear attack submarine.

■ 14
■ The agreement with DDSC was signed – it describes the conditions under which IRSN provides technical support to DDSC and the methods used to launch and conduct the technical support actions.
■ The standing advisory group for reactors and its German counterpart (RSK) met to discuss the recommendations on the safety of nuclear power reactors issued in 2003 and 2004.
■ The Safety Assessment Guide, a document common to IRSN, GRS and AVN, was circulated.

■ 19
A crisis situation exercise involving a nuclear material inventory was conducted at the CERCA and Orphée facilities.

NOVEMBER

■ 8-9
IRSN and GRS organised the 6th Eurosafe Forum in Berlin (Germany) based on nuclear safety experience feedback.

■ 15
IRSN's Scientific Board held its first meeting.

■ 18
■ The Phebus FPT3 test was conducted. It was the fifth and last test in the PHEBUS FP programme.
■ The standing advisory group for nuclear reactors examined certain aspects related to the safety of the EPR (corium recuperator, safety injection system, boron dilution accidents, etc.).

■ 19
A round table was organised to discuss the role expert assessment organisations had to play regarding nuclear transparency. About 10 players from various fields took part (journalists, CLIs, associations, experts).

■ 25
The standing advisory group for nuclear reactors examined the experience feedback on the use of fuel during the period 1996-2002.

■ 30
■ The standing advisory group in charge of facilities intended for long-term storage of radioactive waste examined ANDRA's "Granite 2002" dossier.
■ Riskaudit signed a contract to provide Bulgaria with technical assistance to reinforce the control of radioactive sources.

■ 30/11-3/12
Participation in the Pollutec trade fair in Lyon.

DECEMBER

■ 2

■ The standing advisory group on nuclear reactors examined experience feedback on the use of French and foreign pressurised water reactors during the 2000-2002 period (1st session).

■ Contracts were signed with CEA to operate the CABRI and PHEBUS reactors, to conduct tests in these installations and to bring the CABRI installation up to standard.

3

The cooperation framework agreement with INRS was signed: it specifically concerns the transfer of knowledge from one organisation to the other, the pooling of scientific tools, joint research and expertise, professional training and expert assessment of workstation risks.

■ 6

A cooperation agreement was signed with ANVAR to promote technological transfer and make the most of IRSN's potential for innovation and development.

■ 12

Tripartite agreement between IRSN, EDF and CEA relating to the SOURCE TERM EVALUATIONS research programme, whose purpose is to reduce uncertainties on the evaluation of releases from radioactive products in the event of an accident involving core meltdown of a pressurised-water reactor.

■ 14

The Reactor Safety Commission examined an IRSN report on interactions between the weapon system of *Barracuda*, the future nuclear attack submarine, and the safety of the nuclear boiler room.

■ 14-22

Meetings between the federal atomic energy agency (Rosatom), NIKIMT, IBRAE and ERC of Saint Petersburg (Russia) and IRSN as part of the crisis management cooperation.

■ 15

The standing advisory group for basic nuclear installations other than nuclear reactors examined the conditions for dismantling Super-Phenix.

■16

The standing advisory group for nuclear reactors was presented with different subjects concerning measures taken or envisaged by EDF with regard to core meltdown accidents that could affect PWR power plants.

■ 21

■ As new website was launched where the analysis results of radioactivity in aquatic environments can be consulted.

■ The report specifying radon measurement protocols in spa facilities was sent to DGSNR and put on the Internet.

■ A study on the origin and future of radioactivity resulting from medical activities and found in Toulouse's waste-water system was presented to the Compagnie Générale des Eaux de Toulouse (water company), the Toulouse hospital, the local DRASS, DRIRE, DDASS and DSNR.

■ The DPPRA was sent a report on food chain contamination by fission products released during nuclear weapon testing.

■ 22

The standing advisory group for nuclear reactors examined the specifications on modifications envisaged by EDF on the clogging of sumps in safety injection and containment spray systems, in the event of an accidental break in the primary system of a PWR.

>Organisation

A short description of IRSN

Creation

IRSN was created by article 5 of the law of 9 May 2001 instituting the French health and environmental safety agency and by the implementing decree of 22 February 2002.

Status

IRSN is a public establishment of an industrial and commercial nature placed under the joint authority of the Ministries of Defence, the Environment and Sustainable Development, Industry, Research, Health and Social Affairs.

Directors

Jean-François LACRONIQUE, President of the Board of Directors.

Jacques REPUSSARD, Director General.

Michel BRIÈRE, Assistant Director General in charge of IRSN missions related to defence.

Philippe JAMET, Assistant General Director in charge of general matters.

Expertise and research

IRSN is the public expert in research and expertise related to nuclear and radiological risks.

Fields of activity

- Environment and response.
- Radiation protection of persons.
- Prevention of major accidents.
- Reactor safety.
- Safety of plants, laboratories, transport and waste.
- Defence nuclear expertise.

4 main lines of development

- Optimising support missions for public authorities.
- Reworking its research process in consultation with its main partners.
- Opening up its expertise to take the expectations of society into account.
- Developing the European and international dimension.

2004 budget

Receipts of 254 M€, expenditure of 276 M€, of which 16 M€ went into investments.

Staff

IRSN employs about 1,500 specialists – engineers, researchers, physicians, agronomists, veterinarians and technicians, experts competent in nuclear safety and radiation protection and in the control of sensitive nuclear materials.

IRSN sites

Head office: Clamart

Agen, Cadarache, Fontenay-aux-Roses, La Seyne-sur-Mer, Le Vésinet, Les Angles/Avignon, Mahina (Tahiti), Octeville/Cherbourg, Orsay, Pierrelatte, Saclay.

>Activity 2004

Key figures

RESEARCH

50%
of the IRSN budget
devoted to research activities

172
publications
in scientific journals, with review committees

TECHNICAL SUPPORT FOR PUBLIC AUTHORITIES

608
technical reports
to the public authorities (excluding defence-related activities)

272
notices
transmitted to safety authorities for defence-related activities

INTERNATIONAL ACTIVITIES

100
bilateral agreements
with research and expertise bodies from 30 countries

80
international projects
in progress

HUMAN RESOURCES

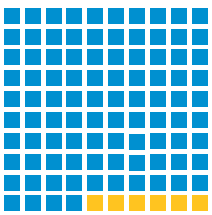
1,515
people
employed by IRSN or seconded to the Institute from CEA

IRSN'S INTELLECTUAL ASSETS

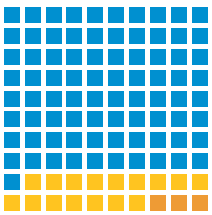
16
French patents
in force (one of which is co-owned by CEA) and 20 patents in force abroad

158
Software applications
and databases listed, 24 of which are co-owned by CEA

2004 budget

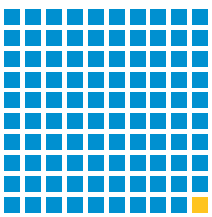


Expenditure:
- Operating **94%**
- Investment **6%**



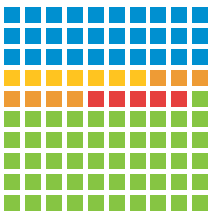
Origin of funding:
- State **81%**
- France **16%**
- Foreign **3%**

State



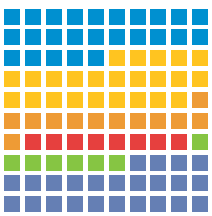
- MEDD **99%**
- Others **1%**

France



- EDF **30%**
- COGEMA **7%**
- DGSNR **7%**
- CEA **5%**
- Others **51%**

Foreign



- CCE **25%**
- RISKAUDIT **24%**
- GRS **12%**
- EPRI **8%**
- NRC **7%**
- Others **24%**

> The Board of **Directors**
on 31 December 2004

Through its deliberations, the Board of Directors decides upon the organisation and running of IRSN. It monitors the programmes of activities and when results of the work carried out are known, it decides upon the follow-up. From a financial point of view, it approves the annual statement of estimated revenue and expenditure, the amendments and the allocation of results.

It examines the general terms and conditions for formalising agreements and contracts. It approves acquisitions and sales of industrial property rights, acquisitions or sales of shareholding and large-scale real-estate projects. It checks on the general conditions of human resource management (recruitment, employment, remuneration).

The Board of Directors is made up of 24 members: 10 appointed representatives of the State, 6 qualified figures chosen for their competence, including either a member of parliament or a senator from the Parliamentary Office for evaluation of scientific and technological options, 8 elected representatives from the establishment's staff. The term of office for members of the Board of Directors is five years.

■ COMPOSITION

President: **Jean-François LACRONIQUE**

■ STATE REPRESENTATIVES

Patrick AUDEBERT
Manager of the national mission supporting the nuclear risk management, representing the Minister for Civil Security.

Jean-Denis COMBREXELLE
Director of Labour Relations, representing the Minister for Employment.

Marie-Claude DUPUIS
Director of the Industrial Environment Department, Department for the Prevention of Pollution and Hazards, representing the Minister for the Environment and Sustainable Development.

Florence FOUQUET
Branch manager of the nuclear industry, General Directorate for Energy and Raw Materials, representing the Minister for Industry.

Bernard FROIS
Director of the Power, Transport, Environment, Natural Resources Department from the Technologies Department, representing the Minister for Research.

Marcel JURIEN de la GRAVIÈRE
Delegate for nuclear safety and radiation protection for activities and installations related to defence.

André-Claude LACOSTE
General Director of nuclear safety and radiation protection.

Thierry MICHELON
Deputy Director of environmental risk management, General Directorate for Health, representing the Minister for Health and Social Affairs.

Marc PREVÔT
Engineer General, shipbuilding armaments Inspector, representing the Minister of Defence.

Nicolas VANNIEUWENHUYZE
Office Manager, Budget Department, representing the Minister for the Budget until 30 June when he is resigning – successor has not yet been appointed.

■ QUALIFIED FIGURES

Claude BIRRAUX
Vice-President of the Parliamentary Office for scientific and technological choices.

Dominique GOUTTE
Director of the major heavy ion accelerator, at the instigation of the Minister for Research.

Jean-François LACRONIQUE
Professor of Medicine, at the instigation of the Minister of Health and Social Affairs.

Maurice LAURENT
Former department head at the National Assembly, at the instigation of the Minister of Industry.

Jean RANNOU
Air Force General, at the instigation of the Minister of Defence.

Jacques VERNIER
Mayor of Douai, at the instigation of the Minister for the Environment and Sustainable Development until April 2004 when he is resigning – a successor has not yet been appointed.

■ FIGURES PRESENT BY RIGHT

Thierry TROUVÉ
Government Commissioner and Director for the prevention of pollution and risks.

Daniel RACINET
State Controller.

Jacques REPUSSARD
Director General.

Jean-Claude DALE
Accountant.

Marie-Catherine POIRIER
Secretary of the Works Committee.

■ SALARIED BOARD DIRECTORS

CFDT representatives
François ROLLINGER, Dominique MARTINEAU, Thierry FLEURY

CFE-CGC representatives
Hervé BOLL, Jean-Marc DORMANT

CGT representatives
Mireille ARNAUD, Xavier MOYA, Betty CATANIA

> The **Scientific** Board
on 31 December 2004

The Scientific Board examines the Institute's programmes of activities and gives its opinion. It checks upon the pertinence and follow-up of research programmes defined by IRSN. It assesses their results. It can make recommendations on the directions of the establishment's programmes.

The Scientific Board can be consulted by the President of the IRSN Board of Directors or by the supervising Ministers.

The IRSN Scientific Board was formed on 6 July 2004, by a joint order from the Minister of the Environment and Sustainable Development, the Minister of Health and Social Safety, the Minister of Defence, the Minister in charge of Industry and the Minister in charge of Research.

■ COMPOSITION

President: **Michel QUINTARD**
Director of Research at the Toulouse Institute of Fluid Mechanics, at the instigation of the Minister in charge of Research.

Bernard SEVESTRE
Engineer General, Assistant Director of the French Atomic Energy Commission, at the instigation of the Minister in charge of Defence.

Martin SCHLUMBERGER
Professor of Medicine and Clinical Director at the Gustave-Roussy Institut, at the instigation of the Minister in charge of Defence.

Ethel-Esther MOUSTACCHI
Scientific Director for the Atomic Energy High Commissioner, at the instigation of the Minister in charge of the Environment.

Victor TESCHENDORFF
Head of Department at the *Gesellschaft für Anlagen und Reaktorsicherheit* (GRS / Germany), at the instigation of the Minister in charge of the Environment.

André AURENGO
Professor of Medicine and Clinical Director at the Pitié-Salpêtrière Hospital, at the instigation of the Minister in charge of Health.

Jean-Marc COSSET
Professor of Medicine and Clinical Director at the Curie Institut, at the instigation of the Minister in charge of Health.

George YADIGAROGLU
Professor of nuclear engineering at the Swiss Federal Institute of Technology, at the instigation of the Minister in charge of Industry.

André PINEAU
Professor at the *École des Mines* in Paris, at the instigation of the Minister in charge of Industry.

Philippe LECONTE
Physicist and former Director of the research programme on management of radioactive waste at the CEA, at the instigation of the Minister in charge of Research.

René AMALBERTI
Professor of Medicine and Clinical Director at the Institute of Aerospace Medicine, at the instigation of the Minister in charge of Employment.

Lars-Erik HOLM
Professor of Medicine and Director General of the Swedish Radiation Protection Authority, at the instigation of the Minister in charge of Employment.

>Organisation chart

April 2005

BOARD OF DIRECTORS

Jean-François LACRONIQUE, President

GENERAL DIRECTORATE



Jacques REPUSSARD, Director General
Michel BRIÈRE, Assistant Director General in charge of IRSN missions related to defence
Philippe JAMET, Assistant General Director in charge of general matters

OPERATIONAL DEPARTMENTS

Department for Nuclear Defence Expertise

Jérôme JOLY, Director

- Application of international controls
- Technical support and studies
- Defence safety assessment
- Nuclear facility security

Department for the Environment and Response

Didier CHAMPION, Director

- Study of radionuclide behaviour in ecosystems
- Studying and monitoring radioactivity in the environment
- Analysis of geosphere-related risks
- Sample processing and metrology for the environment
- Radiation Protection response and assistance
- Emergency situations and crisis organisation

Department for the Prevention of Major Accidents

Michel SCHWARZ, Director

- Studies and experimental research on accidents
- Experimental engineering and instrumentation
- Fuel studies and modelling in accidents
- Fire, corium and confinement studies and modelling

Department for the Radiation Protection of Persons

Patrick GOURMELON, Director

- Radiation protection studies and expertise
- Radiobiology and epidemiology
- External dosimetry
- Internal dosimetry

Department for Reactor Safety

Martial JOREL, Director

- Pressurised-water reactors
- Gas-cooled, fast-neutron and experimental reactors
- Equipment and structures
- Systems and risks
- Thermohydraulics, cores and control of facilities
- Severe accidents and radiological consequences
- Human factors

Department for the Safety of Plants, Laboratories, Transport and Waste

Thierry CHARLES, Director

- Fuel cycle transportation and installation
- Laboratories, irradiators, accelerators and decommissioned reactors
- Radioactive waste
- Confinement, fire and industrial risks
- Criticality
- Aerodispersion of pollutants

FUNCTIONAL DEPARTMENTS

Department for Strategy, Development and External Relations

Jean-Christophe NIEL*, Director

- Strategic programmes
- Relations with institutional partners
- Management tools and follow-up of strategic objectives
- Study and research programmes
- International relations
- Policies and syntheses
- Promoting and supporting operations
- Relations with stakeholders
- Secretariat for standing advisory groups
- Risk management

Department for Scientific and Technical Evaluation and Quality

Joseph LEWI, Director

- Radiation Protection training
- Scientific evaluation and activities
- Quality Management
- Health, Safety and Environmental protection
- Scientific and technical knowledge engineering
- Scientific information resources

Communication Department

Marie-Pierre BIGOT, Director

- Internal communications
- Information and relations with the media
- Programmes and relations with the public

General secretariat

Jean-Baptiste PINTON, General secretary

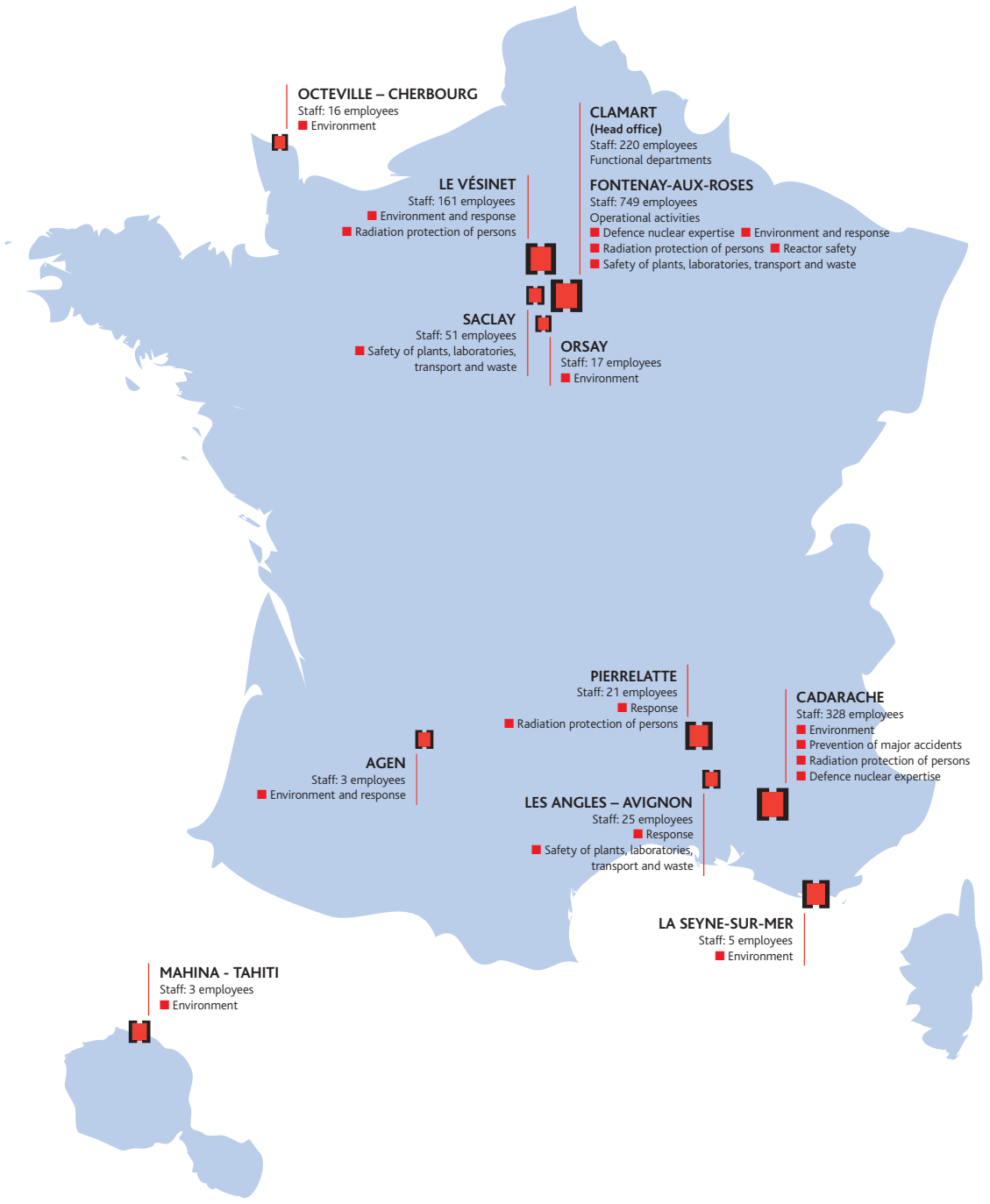
- Financial matters
- Human resources
- Commercial relations and legal support
- Managing real-estate holdings and corporate services
- Managing information systems

Accounting Office

Jean-Claude DALE, Accountant

* No longer working for IRSN at the time of publication of the report.

>IRSN sites:
Activities and staff



> **Details of IRSN sites can be found** on the flap at the back of the report.

Knowledge
for prediction

Description of programmes

To optimise the manner in which it carries out its assigned missions, IRSN organises its activities into a range of subject-related programmes. Some of these are termed strategic, as they are either cross-disciplinary, a response to the priority challenges of the Institute or mobilise resources and teams around a common objective. IRSN programmes are structured around six targets.

Civilian nuclear **expertise**

Human and organisational reliability

This programme covers all IRSN activities on the subjects of human reliability and organisational analysis in nuclear installations or other situations involving exposure to ionising radiation.
It also meets the growing demand from the safety and radiation protection authorities and takes account of the changes associated with the ageing of operating teams, changes in skill levels, etc.

Analysis of the safety of PWR and other operational reactors

IRSN carries out in-service monitoring in support of the authorities of EDF nuclear power plants and other reactors being operated for experimental purposes. It examines the information arising from the use of these reactors, identifies and prioritises safety problems and prepares reports based on the feedback. IRSN also analyses the safety dossiers submitted by users in accordance with the regulations.

Support for the safety assessment of operational reactors

IRSN carries out studies and research actions to optimise support for the public authorities in respect of safety for current and future installations. IRSN activities divide into three fields: the development of probabilistic safety studies, the carrying out of studies in support of analysis and the acquisition and/or development of software and calculation codes with the associated research.

PWR ageing

The ageing of nuclear power plants results in deterioration of components which needs to be prevented, monitored and counteracted to ensure that the installation can continue to operate under satisfactory safety conditions.
The research carried out by IRSN covers various aspects of the problem: ageing of components, study of the containment behaviour and non-destructive testing.

The fuel and its management during normal and accident operating conditions

For economic reasons, EDF is seeking to extend the useful life of fuel and is turning towards new materials. For these new operating conditions, IRSN activity involves:

- for expertise, the relevance of current safety criteria or the definition of new criteria and an assessment of the associated safety margins;
- for research, improvements in knowledge.



Future reactors and innovative projects

By around 2010, this programme should provide IRSN with an appropriate and considered position on the most credible projects being considered for the replacement of current generations of nuclear power plants. The programme is targeting Generation IV reactors, with a view to achieving improvements in safety, reductions in waste and resistance to proliferation and malicious acts.

Severe reactor accidents

IRSN studies and research carried out on core-meltdown accidents in a water reactor (severe accidents) aim to gain a sufficient understanding of the phenomena to be able to understand the risks associated with these accidents and the procedures adopted by the operator in response to them. The aim is to improve prevention of such accidents, to identify the resources needed to limit their consequences and to prepare IRSN for the management of the crisis should an accident occur.

Safety of plants, transport and dismantling

This programme is intended to contribute to safety of plants, transport and dismantling by identifying areas for safety improvements, where appropriate. It includes:

- assessment of safety in plants, other installations and transport;
- management of the national inventory of "civil" radiation sources;
- research and studies into the risk of criticality, especially during transport;
- expert assessment activity at an international level and for at-risk non-nuclear installations.

Defence nuclear **expertise**

Safety of installations, systems and transport

IRSN provides technical support to government authorities for the safety assessment of military nuclear systems, secret basic nuclear installations and defence-related transport systems. Activities concentrate on the expert assessment of safety documents, analysis of operating experience, assessment of internal emergency plans as well as preparations for the crisis organisation.

Material protection and monitoring

IRSN activities on this subject concern, on the one hand, the level of protection for nuclear material against the threat of theft or hijacking with malicious intent and, on the other hand, the respect for France's international commitments on the use of material that could serve in the manufacture of nuclear and chemical weapons.

In this context, the Institute provides direct technical support to the public authorities (national inspections, accompanying international inspections, missions of an operational nature) and also technical support to the administrative authorities (expert assessment of dossiers, contribution to the development of doctrines and regulations).

Protection of installations and transport against malicious acts

This programme aims to take account of malicious acts during the design and operation of nuclear



installations. It also addresses the assessment of potential consequences resulting from malicious acts against transport containers for nuclear or radioactive materials.

Protection of persons and the environment against **ionising radiation**

Environmental monitoring

The aim of this programme is to be able to determine, at any time, the radioactivity levels to which populations are being subjected, to determine its origin and to provide early warning of any abnormal rise in ambient radiation fields in the various environments.

Waste management safety

Activities under this field aim to understand the risks associated with radioactive waste and to identify, where necessary, the options available to improve its management from the point of view of safety and radiation protection. Activities under this programme relate to:

- an understanding of unused matter and material, waste and packages;
- the storage and disposal of radioactive waste regardless of its origin, activity levels or the radionuclides involved;
- the management of used sources;
- polluted sites.

These activities involve an assessment of operators' dossiers, the development of technical doctrines as well as studies and research to help understand those events that might affect the storage safety.

Chronic risks

This programme contributes to the assessment of the effects of chronic exposure to radioactive contaminants. Although risks are low for a given individual, they apply to vast human populations and immense ecosystems, which may give rise to significant consequences, especially at a collective level. Refining their assessment may therefore offer advantages when considering health or environmental management.

Radioecology

The research and studies carried out within IRSN are contributing to knowledge and understanding of the origin and future of radionuclides discharged or pre-existing in the environment. The aim is to assess their radiological impact under normal operating, incident or accident conditions. Operationally, this involves making contingency plans using aids-to-decision tools, the prediction of releases and their movement, reinstatement of the immediate and remote environment of an incident site, etc.

Radon

For more than twenty years, IRSN has been studying radon in all its aspects: formation and migration in the ground, exhalation then dispersion in the atmosphere, metrology, cartography, accumulation in buildings, health risks, reductions in concentrations, etc. The knowledge and experience acquired, which has no equivalent in France, enables IRSN to offer support to the public authorities engaged in a risk-management policy associated with radon and to those tasked with implementing it.



Radiation protection of workers

The ultimate aim of the programme is to identify the most critical situations and to analyse the means to reduce exposure. This programme combines IRSN activity relating to exposure (internal and external) of workers in nuclear installations, other installations and workstations that result in exposure to ionising radiation.

Radiation protection in the medical field

Medical exposures represent the main source of exposure of the population to ionising radiation of artificial origin. These exposures may present risks for practitioners exposed in a repeated manner and for patients also exposed repeatedly. This IRSN programme is divided into three areas:

- medical expert assessment;
- epidemiology of medical exposures;
- research into delayed complications in patients treated with radiotherapy.

Exposure assessment and protection equipment

This programme aims to improve understanding of people's exposure in normal situations and to carry out dosimetric expert assessments under complex situations, in several areas:

- radiation protection and epidemiological expert assessments of populations;
- dosimetry, routine measurement devices;
- dosimetry, measurement devices under development.

Radiation protection doctrine

Radiation protection doctrine is developed at an international level by a range of authorities that may be scientific, technical or regulatory in nature (ICRP, AEN, IAEA, Euratom, etc.).

This programme, based on the involvement of IRSN experts within these authorities, aims to develop the doctrine, introduce new subjects to study within these authorities and build a dialogue with all the French players concerned with radiation protection.

Hazards and crisis situations

Fire, explosion and dispersion

This programme covers IRSN activities in the field of control of risks associated with fire, explosion and aerodispersion of radioactive or toxic contaminants within the facilities or into the environment. The studies, research and expert assessments under this programme aim to improve installation safety levels and hence provide better protection for the public, workers and the environment.

Naturally-occurring hazards

Activities carried out by IRSN aim to assess the safety of installations against naturally-occurring hazards (earthquakes and floods), and to identify, where applicable, prospects for improvement. This programme addresses:

- expert assessments of the risks of flooding and severe drops in water level that could affect nuclear installations;
- an understanding of the phenomena that govern the morphological and geological changes at sites;
- the development, optimisation and validation of methods and tools enabling an assessment of the seismic hazard.



Management of emergency situations, risk management

IRSN ensures that its resources (Emergency Response Centre, mobile means) remain operational and are improved to be able to provide assistance to the public authorities following an accident or post-accident situation in France. IRSN prepares contingency plans and takes part in crisis exercises. This activity offers training to its teams in interaction with other players in the crisis, the coordination of exercises at national level and the preparation of both national and international contingency plans. Feedback, in this field, is a vital factor in achieving progress.

This programme has two parts:

- studies and development, crisis exercises;
- ensuring that the Emergency Response Centre and mobile means remain operational.

Management of post-accident situations

Post-accident management of a nuclear or radiological crisis may involve a large number of players required to undertake the long-term management of many interdependent facets: radiological protection and health monitoring of populations, reinstatement of territory, redeployment of industrial and agricultural activities, compensation for victims, etc. This programme aims to put in place an organisation, methods, and a range of technical tools, as well as a network of external contacts, to enable all the partners to carry out their missions effectively.

Radiation accidents

Following an accidental exposure to ionising radiation, medical teams must be able, in as short a time as possible, to assess the injuries suffered by the irradiated individual in order to be able to establish an appropriate treatment protocol. The aim of IRSN, as provider of technical support to the hospital structures, is to improve the diagnosis by taking full advantage of the interface between dosimetry, biological research and medical applications.

Radiation protection response and assistance

This programme covers:

- activities involving checks, tests and expert assessments of the effectiveness of ventilation and filtration systems in nuclear installations;
- assistance and response in operational radiation protection, to characterise the radiological state of the premises or sites, and contribute to the management of abnormal situations;
- monitoring activities in accordance with the decree relating to the protection of workers against hazards rising from ionising radiation.

These activities are carried out under conventions with the public authorities.

Education, distribution

Communication

As part of its missions, the Institute contributes to informing the public and public authorities about nuclear safety and protection of persons and the environment. It publishes the scientific results of its study and research programmes.

Training and education through research

Education activities enable the Institute's knowledge base to be formalised, enhanced and taught. This involves the setting up of external or internal courses, participation in external training and providing support for theses and courses. In addition, the IRSN's policy of scientific and technical excellence aims to achieve the highest possible level of scientific and technical merit across all its research and expert assessment activities and recognition of this excellence.

International assistance, support for programmes and agreements

The Institute's international activities involve:

- bilateral relations with foreign opposite numbers;
- relations with international organisations;
- special involvement in relations with European institutions;
- support activities for foreign safety authorities;
- contributions to the international activities of the French safety authorities.

Investments: updating of the CABRI reactor

The updating of the CABRI reactor involves improving the earthquake protection of the buildings and equipment, modernising the ventilation system and installing a pressurised water loop replacing the sodium loop. Once completed, this installation will be used to reproduce, under the CIP international programme, the thermohydraulic conditions of a PWR during a reactivity accident.

AMANDE

This new installation will generate metrology-standard monoenergetic neutron beams, needed for the study and characterisation of neutron detectors for radiation protection purposes. The AMANDE project will now provide support for the reference installations already operated by IRSN and will enable it to have primary references comparable to those in the major international metrology laboratories.

14%
share of external joint funding receipts for research programmes

6,200
source movements recorded in 2004

283
personnel attended IRSN radiation protection training

38,000
environmental samples taken annually

689,038
"hits" on the IRSN website

Research and public service missions

In order to be able to offer relevant expert appraisal, IRSN develops its own research programmes. For the Institute, this involves anticipating future questions on changes to and control over the risks of nuclear activities and developing new research topics on the accidents and crisis management where IRSN provides support to the public authorities. The Institute's public service missions also cover radiation protection monitoring, contributing to training on radiation protection matters as well as public information.

> 30	Defining and implementing national and international research programmes
> 78	Contributing to training in radiation protection
> 81	Permanent monitoring in matters of radiation protection
> 84	Public information

Assessment of programmed systems.

Defining and implementing national and international research programmes

The research activities carried out by IRSN have several objectives: applied research, not excluding basic research, research in support of expert assessment, a complementarity between experimentation, modelling and interpretation. Research programmes developed by the Institute give priority to national and international collaboration by welcoming PhD students, developing programmes in partnership and the creation of mixed research units.

Support for the safety assessment of operational reactors

IRSN carries out research and development activities into non-destructive testing methods and the assessment of research into programmed systems. These activities are in support of its expert assessment work.

Non-destructive testing

The equipment testing using ultrasound and eddy current techniques is mainly aimed at:

- developing new methods for demonstration purposes, such as the use of multi-element ultrasound sensors that can be adapted in real time to the complex forms of components. This work is aimed at showing the feasibility and advantages of these methods prior to their industrialisation;
- developing simulation software for these methods that will enable their performance to be predicted and hence achieve improvements in their industrial usability.

The year 2004 was dedicated to demonstrating the correct operation of flexible sensors on large-grain or cracked materials.

Assessment of programmed systems

The power of computers enables designers to produce increasingly complex software. It is therefore becoming increasingly difficult to validate its design. IRSN is constantly striving to improve its methods and tools for assessing programmed systems. On the subject of the analysis of coverage of validation tests, IRSN commissioned the development of the GATEL tool by CEA. The results of this activity have been used in particular to analyse the EPR-reactor protection system in 2004. The systems that EDF plans to use for this reactor are also multi-task and therefore introduce an additional complexity factor: in 2004, IRSN began the study of a tool to check the design rules and synchronisation properties for multi-task software that will facilitate the detection of unsafe behaviours during the analyses of such systems.

63 current theses

16 post-doctorates per year

37 holders of senior doctorates or authorised to supervise research

349 communications in congresses

26 ICPE under the Environmental Code

Power plant at Nogent-sur-Seine (Aube).

Reactor vessel head at the Civaux power plant (Vienne).

Research into the ageing of PWR

IRSN launched an experimental programme in 2003 to gain further knowledge on the subject of stress corrosion of alloys used for the welding of reactor vessel heads.

The stress cracking of nickel-based alloys in reactors led EDF to replace, in particular, some reactor vessel heads on French nuclear power plants. The recent discovery of cracks in Sweden (on reactor vessel nozzles), in Japan (dissimilar metal junctions on the pressuriser) and in the United States (reactor vessel penetrations) shows that inspections for cracking should be carried out on filler metals as well as on parent metals. It was in this context that IRSN began an experimental programme to assess cracking speeds on Inconel 82 in CEA's Venus loop in 2003. This programme, which is due to end in 2007, produced its first results in 2004. These results will be compared with those from other international experimental programmes. They will enable the Institute to use data acquired completely independently from operators and manufacturers when conducting its investigations.

14
nuclear activities authorised under the Public Health Code

8
current European projects on radiation protection and safety

Hosting of
38
foreign scientists

The fuel and its management during normal and accident operating conditions

The fuel behaviour has been the subject of major research work at IRSN, mainly concerned with the control rod ejection accident as well as the loss of primary coolant accidents and dewatering of spent fuel pits.

Control rod ejection accident

The study of the behaviour of fuel following the control rod ejection accident is primarily based on experimental programmes (CABRI programmes, analytical tests) and simulations (SCANAIR software for rod thermo-mechanical calculations).

Experimental programmes

In 2004, IRSN led the way in seeking to interpret the REP-Na tests carried out between 1992 and 2002 in the sodium loop of the CABRI installation and to define the tests of the CIP (CABRI International Project) which will be carried out using a new pressurised water loop currently under construction *(see text on p. 32)*.

For the REP-Na tests, the detailed interpretation of the REP Na-12 test (MOX rod irradiated at 65 GWj/t, Zircaloy-cladded) enabled confirmation of its representativity with respect to the case of a power reactor up to a maximum fuel enthalpy value of 80 cal/g.

This test, which did not cause a failure in the rod, also enabled the qualification of the SCANAIR software to be extended.

For the CABRI-CIP programme, the studies carried out enabled the conclusion to be drawn that the test loop was representative of power reactors. The first qualification test (CIP Q) of the test series, which should be completed by 2010, will aim to confirm the absence of artefacts associated with the new test facility and to study the physical

Environment of the CABRI experimental reactor.

phenomena arising after significant heating of the clad (that could not be simulated in the sodium loop). Development of the test matrix of the CIP programme was pursued and was the subject of detailed design studies. As a complement to this programme, IRSN is examining the possibility of using the Japanese NSRR-reactor for the study of the behaviour of fission gases present in the irradiated fuel during temperature transients.

Simulation

IRSN has continued to develop the SCANAIR calculation code, for use in preparing and interpreting the CABRI tests and their transposition to the scale of nuclear reactors. This software models the behaviour of a fuel rod subject to a power transient. The main development introduced into the SCANAIR software in 2004 was a model to assess the probability of fuel rod sheath failure during such a transient, calling on tools from elastoplastic failure mechanics. This model exploits a statistical analysis of mechanical test results on irradiated fuel clads in order to derive a (probabilistic) relationship between the size of defects and the rod burnup.

FOCUS

MODELLING OF IRRADIATED FUEL BEHAVIOUR IN A REACTIVITY INSERTION ACCIDENT (RIA)

The study into the behaviour of irradiated fuel rods following an RIA needs to cover:

- changes in the fuel microstructure (morphology, local heterogeneities in the fuel pellets and the cladding), resulting from the radiation effects;
- local effects (pellet-clad interaction, etc.).

One of the major difficulties of accident simulation lies here in the coexistence of very different scales: the micron for microstructures (hydrides in the clads, inter-granular bubbles of fission gases in the pellets) and the metre for rod height. To resolve these difficulties, it was clear that very advanced models had to be developed. By using scale change methods, these models determine the behaviour of a given microstructure, then introduce the result into a more general digital representation of the structures, such as that used in the SCANAIR calculation code.

It was mainly in the context of two theses, jointly funded with EDF, that these methods were the subject of major developments during 2004 with, for example, the development of an elastoplastic behaviour law for hydrided Zircaloy.

Thanks to their general character, the models developed can easily be applied to different situations (changes to fuel design, changes to operating conditions, other fuel types), demonstrating the advantages of this development for industrial applications.

SCANAIR software specialists.

Storage tank for CABRI installation test devices.

A model that is representative of heat exchanges between the clads and the coolant was also developed, validated and incorporated in the software. Its originality lies in the fact that it covers all heat exchange regimes for very rapid heating (of the order of 3,000 °C/s to 10,000 °C/s), including following a DNB.

Version 4 of the SCANAIR software, incorporating these latest developments, was transferred to EDF, which is partly funding these developments as part of the CEA-EDF-IRSN tripartite research agreement.

In addition, the detailed modelling work on irradiated fuel *(see Focus p. 32)* was continued. Models will be prepared on this basis to enhance future versions of SCANAIR.

In terms of applications, IRSN has used the SCANAIR software to define test conditions for the future CABRI water loop and has carried out studies supporting expert assessments into dossiers for fuel development programmes or for fuel management within the reactor, submitted by EDF. For example, this software is used by IRSN to assess the soundness of one of the criteria (clad temperature) proposed by EDF to ensure fuel containment during a reactivity insertion accident (RIA).

Loss of primary coolant accident and dewatering of spent fuel pits

The criteria associated with the loss of primary coolant accident, mainly aimed at ensuring that the reactor core would remain "coolable" during this transient, may be called into question by changes in fuel management (increases in burnup fraction) or new designs of fuel rods. Much work has been done on the phenomena that come into play (expansion/failure, oxidation, resistance to quenching, etc.). IRSN has, in particular, carried out a study into whether it would be useful to develop an advanced accident calculation tool with the associated R&D, in order to model these phenomena in detail. This feasibility study enabled the prioritisation of needs and will serve as a basis for the development of a specification for this tool.

IRSN has also undertaken the definition of a multi-year study programme concerning accidents involving dewatering of irradiated fuel assemblies during handling or in the storage pits (power reactors and spent fuel processing plants). Design of this programme has been mainly based on exploratory calculations, carried out using the ICARE-CATHARE calculation code, using the example of a dewatering in a spent fuel storage pit of a 900 MWe reactor.

Storage tank for CABRI installation test devices.

Modifications **to the CABRI installation**

In order to enable testing under thermohydraulic conditions that are representative of a water reactor, IRSN is jointly funding the fitting of a pressurised water loop in the installation to replace the sodium loop, previously used for the study of fuel in fast neutron reactors.

The research programmes carried out in the CABRI research reactor of CEA (Cadarache, Bouches-du-Rhône) on the behaviour of highly irradiated fuels enables experimental data to be gathered on the effects of an increase in burnup fraction for these fuels.

The work of installing the water loop is accompanied by an upgrade to the safety standard of the installation. There are also plans to refurbish certain equipment. In parallel, IRSN is developing an instrumented test device intended to be fitted with the sections of irradiated rod that are being tested. The international CABRI CIP programme currently being prepared in the future installation should include 12 tests starting between the end of 2008 and the beginning of 2009, at an average rate of three or four tests per year. The modifications to the installation have been submitted to public enquiry and have been the subject of a preliminary safety report that has been forwarded to DGNSR *(see Focus p. 96)*.

Team S2IE for CABRI and PHEBUS, from the experimental programmes support engineering department at Cadarache (Bouches-du-Rhône).

Progress made

The year 2004 has been set aside for the cleaning-up of the installation, the dismantlement of the old systems, and the packaging and removal of the equipment associated with the use of the sodium loop. The reactivity injection system has been dismantled with a view to optimising it, and the pit equipment of the CABRI reactor has been removed with the intention of reinforcing the pile block in 2005, to ensure its resistance to earthquakes. At the end of 2004, the installation was ready to receive the first components of the loop.

Progress in the studies

The geometry of the test device has been decided, and the corresponding instrumentation has been qualified.

In parallel, technical specifications for key components of the future installation have been written (reactivity injection system, equipment for monitoring fuel ejected during a test, device for coating the rod for post-test examination, etc.). The national and international partners on the planned experimental programme met twice during 2004 to define in detail the test matrix.

ASTEC software team.

The SARNET co-ordinator flanked by two collaborators.

Research work **into severe accidents** with core meltdown

The study and research programme carried out by the Institute in the field of core meltdown accidents is centred on the primary physical fields identified from accident scenarios and the options for limiting consequences.

The approach adopted in this programme is based on the establishment of accident scenarios, the identification of physico-chemical phenomena, the carrying out of experiments on discrete effects to determine the basic data and to develop elementary mathematical models, and writing calculation codes bringing together these models and data, as well as qualifying them using more general experiments.

2004, birth of the European SARNET network

The scale of the human, technical and financial resources to be used to examine in depth the questions relating to severe accidents and the advantages of sharing acquired knowledge encouraged the Institute to seek national and international partners. The European network of excellence SARNET, set up as part of the European Commission's 6th FPRD is an example of this. This network began its work on 2 April 2004. Coordinated by IRSN, it unites 49 organisations from 18 European nations involved in nuclear reactor safety research (safety institutes, universities, industry, etc.).

This network aims to:

- better coordinate European research capabilities on core meltdown accidents;
- contribute to reducing the lack of knowledge in this field by carrying out appropriate joint research programmes;
- incorporate the latest knowledge in advanced computer systems for the assessment of electro-nuclear reactor safety in Europe, especially in the field of probabilistic safety studies;
- disseminate information and train new experts in this field.

The following were achieved in 2004:

- the development and deployment of the communications platform via Internet ACT. This gives access to all information relating to the life of the network (documents, announcements of events, seminars or meetings, etc.); it enables the collection of opinions (discussion forums, questionnaires, etc.) and the creation of joint documents. It gives access to the ASTEC software and to the network's experimental database;
- the distribution in June 2004 of version V1.1 of the ASTEC software to 25 partner organisations on the occasion of the session organised by IRSN to provide training in its use. A qualification matrix and an assessment matrix for the software has been defined and the corresponding work has been initiated;

Intermezzo furnace for the BECARRE tests.

- the start of information exchanges between partners. Several circles of experts have been set up and more than a dozen working meetings have been organised with the aim of developing common positions on the phenomenology of severe accidents: their modelling, methods of assessing their consequences and priority requirements in research terms;
- the structuring of the DATANET experimental database configured according to the technical solution developed by the Joint research centre in ISPRA. This consists of a network of databases developed by certain European organisations at different sites to which access is available over the Internet.

FOCUS

SOURCE TERM PROGRAMME

In 2004, IRSN initiated a new programme, called SOURCE TERM, whose aim is to reduce uncertainties concerning the assessment of the release of radioactive products into the environment following a core meltdown accident in a water reactor.

Amongst these effluent releases called "Source Term", iodine and ruthenium are the radioactive products that present the greatest risk to exposed populations. The studies, carried out under "Source Term" over more than twenty years, along with an analysis of tests of the PHEBUS-FP programme, have shown that significant uncertainties remained (for example a factor of 10 on organic iodine concentrations in the containment, as this chemical form of iodine is virtually not retained, for example by the sand filter following a controlled depressurisation of the containment).
In 2004, in conjunction with its primary partners CEA and EDF, IRSN prepared a document describing the planned programme for the period 2005-2010 with estimates of its multi-year cost. The various IRSN experimental areas of the programme have made progress at a technical level: thus the EPICUR programme on the formation of organic iodine under gamma radiation continued with the completion of the experimental device, and the scientific and technical strategy of the CHIP programme on the chemistry of non-equilibrium iodine was determined.

The first item under the SOURCE TERM programme will concern the chemistry of iodine in the primary cooling system (CHIP) and in the containment (EPICUR). In the primary system, special attention will be paid to non-equilibrium chemistry (CHIP).
The second item will concern the sequence of a severe accident involving degradation of boron carbide (B_4C) control rods that equip the most recent French reactors as well as the boiling-water reactors in service in Europe (BECARRE tests).
The third item will address the consequences of a degradation of fuel elements in contact with air following penetration of the vessel after the meltdown of part of the reactor core or the dewatering of a spent fuel storage pit, especially the release and chemical behaviour of ruthenium (tests of release of fission products in the CEA's VERDON facility and tests under EPICUR). In addition, correct prediction of the sequence of a dewatering in a spent fuel storage pit requires a better knowledge of the oxidation of clads by air (MOZART tests).
The fourth item will address the release of fission products from the fuel. A microanalysis programme on irradiated fuel and on fuel that has been subjected to release tests (VERCORS) will enable a validation of the current interpretation of releases measured during tests already carried out. As a complement to this, it is planned to carry out three supplementary release tests in the CEA's VERDON facility using MOX and UO_2 fuel at high-burnup fractions.

Fitting the test section in the Intermezzo furnace.

IRSN is continuing the joint development of the ASTEC software with its German counterpart GRS, with the aim of making it the European reference software for severe accidents.
Public information relating to the network is available on website www.sar-net.org that opened at the beginning of 2005.

Studies and research into severe accidents carried out in 2004

Core degradation and behaviour of the corium in tank

This phase of the accident is studied using the ICARE/CATHARE software developed by IRSN. Version V1 was used as part of the PSA to examine breaches of the primary cooling system induced by core meltdown and was used to interpret the results of the German QUENCH tests carried out using boron carbide control rods.
Version V2 that enables the bi-dimensional calculation of core material thermohydraulics and motions was delivered in 2004.

The behaviour of fission products

Investigations on fission products have been dominated in recent years by the international PHEBUS-FP programme. The final test of the series, FPT-3, was carried out in 2004 *(see Focus p. 38)*. Discussions were held on the way forward for research into the behaviour of fission products in an accident situation with core meltdown. These resulted in IRSN creating a new programme, entitled SOURCE TERM, whose aim is to reduce uncertainties concerning the assessment of radioactive products released into the environment. The year 2004 was dedicated to identifying requirements, establishing the programme's priorities, defining its technical content and assessing the associated timescales and costs *(see Focus p. 36)*.

What is a severe accident?

A severe accident originates from a core water cooling failure that prevents the power generated by the reactor from being evacuated, even after the shutdown of the chain reaction (so-called "residual power").

Over a period of between one and several hours, a series of human or equipment failings can lead to deterioration of the fuel and its melting. Complex phenomena then occur, whose impact depends on the initial conditions of the accident and the actions of the operators. The accident may be described in four major phases:

- under the effect of residual power, the fuels present in the reactor core lose their integrity, releasing hydrogen following oxidation by water vapour of the clads surrounding the fuel and emitting fission products into the containment;
- if water is no longer injected into the vessel, the core melts and the mass of molten material thus formed (called corium) starts attacking the base of the vessel and then penetrating it. During this advanced stage of degradation, a vapour explosion may occur; the containment may also be affected by the effects of the hydrogen present (deflagration and/or detonation).
The reactor structures may also be subject to the effects of a vapour explosion resulting from a water/corium interaction before and after the penetration of the tank.
In the particular case of a penetration, ejection of corium may lead to direct heating of the atmosphere in the containment;
- under the effect of the heat released by the corium, the concrete basemat of the reactor pit under the vessel may suffer thermal degradation that could lead to the release of a range of gases that, when added to the water vapour already generated, would lead to a progressive rise in pressure within the containment;
- some of the fission products emitted during the first phase (mainly noble gases, iodine and caesium) may escape the containment either because of its leakage rate or as the result of deliberate actions of the operators.

Such an accident may thus lead to a major release of radioactive releases (1) into the environment.

(1) Such releases are still called "SOURCE TERMS".

PHEBUS reactor: dry storage area for test devices.

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FPT-3: FINAL TEST UNDER THE PHEBUS-FP PROGRAMME

The PHEBUS-FP programme involved a total of five reduced scale (1/5000) overall experiments, which have studied the release of fission products and of structural materials during the meltdown of an irradiated rod assembly, followed by the transport of these products into the primary cooling system, as well as their behaviour in the containment, under thermohydraulic and physico-chemical conditions that are representative of a severe accident. The results obtained are serving to qualify the ASTEC and ICARE-CATHARE software programs.

The fifth test in the programme was completed successfully on 18 November 2004. Its aim was to verify, within an overall test, that the calculation codes used for safety studies correctly simulated the degradation mechanisms of a water reactor core equipped with boron carbide control rods and the associated "source term".
The core was simulated by an assembly of 20 UO_2 rods (18 irradiated and 2 non-irradiated and instrumented) surrounding a boron carbide (B_4C) rod cooled by a weak flow of water vapour representative of that following a core meltdown accident. The increase in power in the assembly provokes a thermal runaway in the clad oxidation reaction, the failure of the B_4C rod and its oxidation.
This generates hydrogen, boric acid, as well as carbonated gases that could have a significant impact on the chemistry of fission products, especially on the chemical forms of iodine present in the containment. These gas emissions were detected on line.
The power was then increased until movement of the fuel was observed following its liquefaction leading to the shutdown of the test in accordance with predetermined criteria.
The fission products and structural material released into the system simulating the PWR primary cooling system and into the tank simulating the containment were measured. On line spectrometry measurements and sampling of the vapours and aerosols were carried out. In the containment, the experiment continued for four days, to examine the behaviour of fission products, and especially that of gaseous iodine.
A brief and rapid analysis of the measurements made during the FPT-3 test, as well as the initial non-destructive tests of the fuel assembly, suggested that the presence of a boron carbide control rod significantly affected the fuel degradation.

PHEBUS reactor control room during the test at Cadarache (Bouches-du-Rhône) on 18 November 2004.

It also suggested that the liquid mixtures resulting from the control rod degradation accelerated the dissolution of the fuel. High levels of oxidation of the boron carbide under severe accident conditions were also observed.
Of course, all this remains to be confirmed.
Several partners in the PHEBUS programme (IRSN, GRS, PSI) have also already carried out calculations to derive results from the test.

A PHEBUS test in figures

- About 60 people participated in the test.
- Duration of the test: five hours for the fuel degradation then four days monitoring the behaviour of the fission products.
- Between five and six years to analyse the data and interpret the test.

Analysis of containment strength.

The proposed programme will be jointly funded and executed under the IRSN-EDF-CEA tripartite framework. It already has support, internationally, from the European Commission and the USNRC.

Containment resistance

Concerning hydrogen explosions, IRSN has continued the development and qualification of its calculation tools, including the TONUS software. This has led to its participation in ISP 47 and the carrying-out of a highly instrumented combustion test programme, in collaboration with CNRS in Orléans.

TONUS was also qualified using the results of the TOSQAN programme for the distribution of hydrogen in the pressure vessel *(see Focus p. 39)*.

IRSN has also carried out RECI analytical experiments with a view to assessing the effect of catalytic hydrogen recombiners on the forms of iodine present in the containment. In 2004, these experiments enabled conversion rates for caesium and cadmium iodides into gaseous iodine to be determined.

The Institute also carried out a series of studies in support of the sizing analysis for recombiners in P'4 reactors (1,300 MWe).

Concerning the risks of vapour explosions, and as part of the SERENA operation of the OECD-NEA, IRSN carried out studies into corium/water interactions in the vessel and the vessel sump as well as a major programme of work comparing the models of the various software routines used by partners in this activity. Assessments were also

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TOSQAN PROGRAMME

The year 2004 has seen the completion of the "water vapour condensation" test phase of the TOSQAN programme and its interpretation.

A detailed analysis of all the results of these tests was also carried out. This examined in particular the influence of numerous parameters included in the condensation models in the thermohydraulic codes for the containment, with a view to identifying limits and sensitivity to the physical parameters measured. These models, generally developed from laboratory experiments, were thus validated at a more industrial scale. Additional investigations remain to be carried out in the case of stratified atmospheres.

Spray tests started during 2004 after initial calculations had been completed. A reference test was carried out whose results contributed to the development of an international comparative exercise. Specific spray tests were carried out in parallel to qualify an innovative non-intrusive optical measurement technique for the temperature of droplets entitled "overall rainbow refractometry", developed as part of a thesis. This technique was coupled to other optical methods such as spontaneous Raman diffusion spectrometry, PIV and an imaging technique enabling the measurement of vapour fractions and the speed and size of droplets. The results obtained enabled the carrying out of general and local analyses of the interactions between spray droplets and the air/vapour mix, illustrating the phenomena of condensation on droplets and of evaporation.

Apparatus for laser measurements using a new technique: rainbow refractometry.

Visual inspection of a fuel assembly at the Romans plant (Drôme).

carried out on the risk of loss of containment integrity for a 900 MWe reactor by the floor movements that could result in an explosion of vapour outside the tank. The experimental programme on direct heating of the atmosphere of the vessel of a P'4 reactor, carried out in collaboration with FZK in the DISCO installation, continued with the carrying out of a series of low temperature tests and the first high temperature tests.

Safety of plants, transport and dismantling

Research and studies carried out by IRSN relating to the safety of plants, transport and dismantling mainly concern the risks of criticality and the dispersion of radioactive material outside the containment buildings.

Studies and research into criticality

The risk of criticality, i.e., the unintentional initiation of a chain neutron reaction, exists at all stages of the fuel cycle, from uranium enrichment into uranium 235, fuel storage and transport, enhancement of material derived from spent fuel reprocessing through, to the storage of waste generated. The prevention of this risk involves determining the conditions that make it possible to ensure sub-criticality during these operations. It is also essential to know the consequences that may arise from a criticality accident. In these fields, the Institute carries out studies and research to develop advanced calculation tools with the highest possible level of qualification.

The studies that enable an assessment of the risk of criticality call on calculation codes that use nuclear data libraries (cross sections). These codes must be able to resolve neutron problems that differ widely one from another because of the diversity of fissile environments encountered and the geometry of the devices that contain them.

Under the CRISTAL project *(see Focus p. 41)*, the Institute developed a multi-group simulation program for three-dimensional neutron transport, entitled MORET 4. In 2004, this program was the subject of new developments to its algorithms for the physical, mathematical and statistical models. International publications and numerous organisations stressed the power of this software, particularly well adapted to the requirements of criticality studies.

The use of simulation software based on the Monte-Carlo method remains suspect for the calculation of specific situations within which non-grouped fissile materials interact. IRSN has contributed to improvements in these calculation methods by participating in the working group coordinated by the OECD-NEA; thesis studies were undertaken to reduce the uncertainties and bias of simulation calculations used to assess the risks of criticality by improving the statistical methods used. IRSN also continued, in 2004, to improve all its criticality calculation tools in terms of modelling capability for complex systems and the detailed analysis of calculation results, to gain a better understanding of safety margins.

The qualification of calculation codes is obtained by comparing data calculated using these codes with experimental data. Experimental criticality studies are therefore carried out under national

Illustration of modelling techniques for criticality studies.

or international partnerships. These involve the creation of full-scale configurations with known chemical, geometrical and neutron characteristics, very close to the critical state. These experiments are then reproduced by calculation. Comparisons between calculations and experiments enable any deviations or bias to be detected and quantified, and the security margins to be incorporated in criticality studies can then be determined. Thus in 2004, the Institute completed the development of the "Fission products" experimental programme under a PIC with COGEMA. This experimental programme was set up in 1995 and included more than 170 critical experiments, the last of which, carried out in April 2004, aimed at representing a realistic situation of the dissolution of irradiated uranium oxide PWR rods. At the end of 2004, IRSN carried out an experimental programme enabling the very accurate measurement of changes in the criticality properties of plutonium as a function of its ageing in the criticality laboratory of the CEA at Valduc (Côte-d'Or).

IRSN also considered the setting up of the following programmes:

- Pu TEMPERATURE EFFECT programme, intended to measure experimentally the effects of temperature on low concentration plutonium solutions where the overall effect of temperature could become positive;
- STRUCTURAL MATERIALS programme, designed for the qualification of neutron characteristics of the component elements of structural materials (steel, concrete, PVC, etc.);
- programme for the experimental qualification of configurations using low moderated MOX fissile environments.

The Institute has also continued its active participation in the ICSBEP international project. Under the aegis of OECD/NEA, this project enables the sharing of criticality experiments carried out throughout the world and the acquisition of high quality experimental data, for use in qualifying calculation tools.

A criticality accident results in the release of energy,

FOCUS

CRISTAL V1.0: NEW VERSION OF THE CRISTAL PACKAGE

The new version V1.0 of the CRISTAL package has been operational since November 2004.

This package, which is made up of a set of calculation codes, nuclear data libraries and calculation procedures, enables the execution of all types of calculations needed to analyse criticality risks in nuclear installations – excluding reactors – and the transport containers for radioactive materials. It was developed and validated under collaboration between IRSN, which manages the project, CEA and COGEMA.

This new version is a response to the need to calculate, without excessive conservatism, the criticality of transport containers, spent fuel storage and processing installations, while retaining an envelope approach to safety studies. To achieve this, the CRISTAL user has software, nuclear data and interfaces that enable the calculation of the abundance of the main radionuclides present in spent fuel. These calculations are carried out by the CESAR software developed by CEA and COGEMA, for different types of fuel taking account of the manner in which they were irradiated in the reactor and cooled in the spent fuel pit.

The CRISTAL package was validated by comparison between calculations and experiments. At the end of 2004, 1,300 critical experiments had been modelled and calculated using CRISTAL; these included 230 that were representative of spent fuel, some with fission products, which represents a unique step forward in the world.

STARMANIA test bench at Saclay (Essonne).

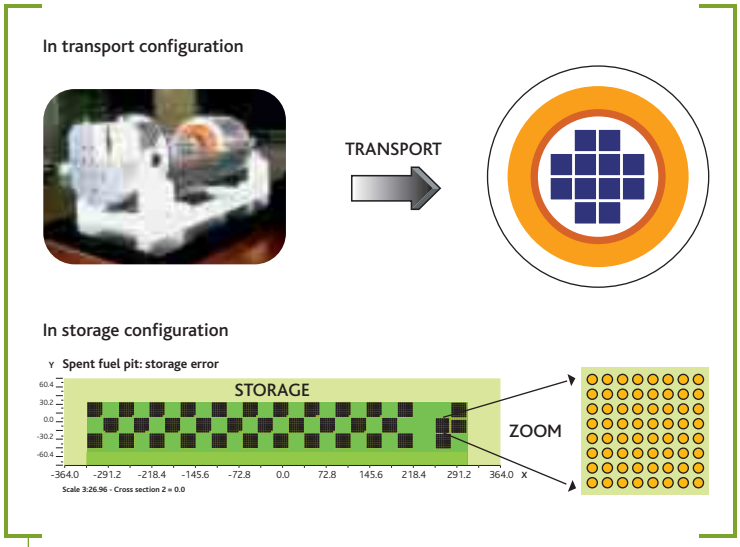

Illustration of modelling techniques for criticality studies.

essentially in the form of heat, accompanied by intense emissions of neutron and gamma radiation. In 2004, the Institute carried out studies into criticality accidents for transport containers to assess the consequences and options for response. Collaboration was initiated on these subjects with Imperial College, which provides technical support to the UK safety agency.

Radionuclide dispersion

In support of expert assessments of the risks of dispersion of radioactive or toxic material outside the containment buildings, IRSN carries out studies and experiments corresponding to a range of possible accident situations.

In order to be able to carry out more realistic assessments of radionuclide releases, work was undertaken to improve understanding of the transfers of gases and fine particles. The results obtained in the context of aeraulic tests in air on cracked concrete slabs (for example following an earthquake) enabled the development of a flow law through the cracks that is more appropriate than existing models. The work is continuing to address air/vapour mixtures and the retention of aerosols.

Full scale experiments in the STARMANIA installation enabled the gathering of data on the aeraulic and mechanical behaviour of equipment used to isolate for fire protection purposes (doors and firewall valves) when subject to pressure and temperature conditions that are representative of a fire in a confined area.

Modelling was carried out, aimed at determining the effectiveness of high-efficiency filters installed in series. The corresponding calculation models will be the subject of experimental validation. Work was also carried out on the effectiveness of zeolith trapping for certain gases.

In 2004, a programme was launched to enhance knowledge of the influence of wind effects on accidental releases, in the case of a partial or total failure of an installation's ventilation. This programme includes the carrying out of wind tunnel tests on models that are representative of nuclear installations.

Dry boring in a gallery of an experimental tunnel at Tournemire (Aveyron).

Waste-related research activity

In the field of waste, IRSN concentrated its efforts in 2004 on the management of high-level long-lived waste (HLLLW), in the light of the upcoming parliamentary meeting under the law of December 1991.

Storage in clay strata

The work was primarily concerned with the storage of HLLLW in a deep geological clay stratum. They included the development of digital models and their validation by laboratory or field tests.

To carry out these experiments on geological storage, IRSN has access to an old railway tunnel cut through a thick clay (shale) strata in Tournemire (Aveyron). The similarities between the shale at Tournemire and the rocks at the ANDRA laboratory in Bure (Meuse) enable IRSN to carry out both methodological and phenomenological studies. The study of the containment properties of shale was started by identifying and characterising fissures and an analysis of the interstitial solutions contained in the pores of the material. The chemical and isotopic analysis of fluids collected from these fissures enables their origin and their residence time within the massif to be identified. The very low water content of the shales made it necessary to develop a methodology intended to minimise any effect on the interstitial solutions during sampling. There was in fact evidence that extraction conditions did affect the isotopic composition of these fluids.

Characterisation of zones disrupted by excavation

Excavation usually disrupts the rocky massif leading to an increase in permeability in the area of the workings. This disrupted or damaged zone (termed EDZ: Excavation Disturbed Zone) may vary over time as the galleries are ventilated and the shales flow.

In 2004, under the DECOVALEX international project, IRSN began an exercise in modelling of the EDZ around the Tournemire tunnels. This project will continue to 2006 and will incorporate a comparison between modelling results and *in situ* characteristics. Changes over the longer term could be studied under this exercise as the Tournemire site has tunnels of very different ages (one year, eight years and a hundred and ten years).

A campaign of characterization of the EDZ by making radial drillings around the tunnels at Tournemire was set up to obtain the most complete set of data possible to form a basis for the modelling exercises. The data collected will enable better understanding of propagation in space and time in the disturbed zone. Drillings will enable measurement of the zone's permeability and changes in the propagation speed of ultrasonic waves. Measurements, especially of water content and porosity, carried out on the core samples taken during drillings, will complete the characterisation of the zone.

A test termed "mine-by-test" (tunnelling into instrumented rock to monitor the hydro-mechanical

Instrumentation used to monitor changes in the rock after drilling.

FOCUS

INNOVATIONS IN THE MELODIE SOFTWARE

The MELODIE software for modelling the transfer of radionuclides in geological formations benefited from two major advances in 2004:

- the first enables the simulation of radionuclide transport phenomena by convection and diffusion in heterogeneous geological environments, thanks to a calculation scheme using finite volumes;
- the second, taking advantage of a new, advanced, multi-processor architecture, concerns the parallelisation of the resolution of transport equations.

These changes offer major advantages for the overall modelling of a repository site and the assessment of dose impact in case a package is released.

IRSN is responsible for the development and updating of the MELODIE software.

reaction), undertaken as part of the European project NF-PRO (6th FPRD), enabled, in 2004, the obtaining of measurements of displacement, deformation and interstitial pressure. Programs for the interpretation and digital simulation of the reaction of rock to tunnelling have been developed.

Modelling of the behaviour of a storage site

Studies have been carried out with a view to describing the thermal, mechanical and chemical behaviour of a radioactive waste storage site, taking into account the disturbances caused by the implementation and the progressive deterioration of the various constituent materials.
These studies have mainly involved:

- modelling the geochemical interactions associated with the introduction of oxidising water into the Callovo-Oxfordian shales, as well as the presence of large quantities of concrete, to assess the degree and extent of the corresponding perturbations;
- developing hydro-mechanical models of the behaviour of shale/bentonite and shale/cement interfaces to be able to quantify the possible role of these interfaces in the performance of a seal;
- modelling the behaviour of an anchor keystone for a tunnel seal to assess the advantages and disadvantages of such a device in preventing flow across the fractured zone around the excavations;
- completing the development of a delayed failure model of the fracture zone around the excavations in the shales, to estimate the possible long-term behaviour of this zone;

Packaging and reference marking of clay core sample taken at Tournemire (Aveyron).

■ modelling the thermal changes in a chamber containing exothermic waste to identify the key parameters affecting the intensity and extent of heat flow in and around the packages.

The results of IRSN studies into the alkalisation of shales by cement and the long-term mechanical behaviour of damaged shales have been published in peer-reviewed publications.

IRSN also carried out studies in 2004 on:

■ the hydro-geological modelling of the Paris basin, and especially the Bure site, by incorporating into its model a new set of data and especially those relating to salt concentrations in deep aquifers;

■ the development of a modelling approach for storage structures in a geological environment, to identify the complementarity of storage barriers in order to confine released activity as close as possible to the packages. This study has been the subject of a European research project (BENIPA project) and is continuing under the Franco-German project REGIME (IRSN/GRS);

■ the development of a water transport program, including the possibility of change of phase (liquid/gas).

As for the development of the MELODIE software, which offers risk estimation for waste storage, 2004 marked a major development in the digital methods used, as well as in the strategy implemented to estimate the dose impact of a repository *(see Focus p. 44)*.

Ventilation system at the DIVA experimental installation at Cadarache (Bouches-du-Rhône).

Incorporation of **human factors in the design processes**

In 2004, the Institute continued the research started in 2003 on the incorporation of human factors in the design processes. This involved identifying the impact of the various decisions taken during the design on the future operators' work, and then studying the way in which this impact is taken into account in the development of the project team's decisions. Three modification processes for SEVESO classified installations were thus analysed.

The Institute also reviewed expert assessments carried out in the human factors and organisational fields over the last fifteen years. This involved primarily surveying the subjects analysed (supervisory interfaces, operating instructions, maintenance organisation, incident analysis), as well as the approaches adopted (ergonomics, sociology, management, etc.).

Research activity **in the fire and aerodispersion fields**

IRSN research into fire encompasses the sequence and consequences of fire, its propagation and the circulation of smoke to other premises via openings or the ventilation system.

The purpose of the research into the aerodispersion of pollutants is to develop the ability to contain radioactive or toxic materials and to reduce uncertainties in the assessment of the normal or accidental releases of pollutants and of their dispersion, especially with a view to understanding the consequences for man and the environment.

Research programmes

The experimental approach offers, among other things, the opportunity to extend knowledge about the specific physico-chemical phenomena of fires and to supplement the database needed to develop and then validate models related to the various phenomena resulting from fires in a confined-ventilated area. These models are then introduced into the calculation codes used for studies in support of the assessments of the effectiveness of fire precautions. Some programmes are carried out in collaboration with industrial partners (EDF, COGEMA, etc.) and are the subject of exchanges with other national and international organisations (INERIS, universities, US-NRC, etc.).

Two research programmes were completed in 2004: the first addressed fires in electrical cabinets (CARMELA/CARMELO programme), and the other was about changes in gas pressure when a fire occurs in an installation consisting

Full-scale blowing device to test the strength of VHE filters and fire dampers under pressure (STARMANIA).

of several spaces (DIVA 0 programme).
Two other experimental programmes, started in 2003, firmed up in 2004 with the preparation and completion of the first test campaigns. The PRISME programme is concerned with heat and smoke propagation from a fire source to adjacent spaces *(see Focus p. 48)*. The PICSEL programme aims to better assess the consequences of fires with slow kinetics of the "electrical cabinet type" in a nuclear installation *(see Focus p. 49)*.
In parallel with these programmes, in 2004 IRSN continued with the acquisition of data and information on the behaviour of compartmentation equipment (doors and firewall valves) in the STARMANIA installation. These tests are intended to ascertain changes in aeraulic and mechanical strengths of these compartmentation devices as a function of the temperatures and pressures to which they might be subjected during a fire in a confined space.

Simulation of a fire

Two approaches have been developed to simulate a fire in a nuclear installation: a simplified approach, currently using the FLAMME_S/SIMEVENT software, and, from 2006, the SYLVIA software, and a detailed approach being run under the ISIS code. For the simplified approach, the coupled FLAMME_S/SIMEVENT software has been operational since 1999. It was used in 2004 to carry out studies prior to the PRISME programme tests (accurate definition of test conditions and integrity check for the DIVA installation during these tests). Development of the SYLVIA software continued in 2004 *(see Focus p. 50)*.
For the ISIS code, which will enable the development

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BEHAVIOUR OF URANIUM HEXAFLUORIDE (UF_6)

Under the PIC set up by IRSN with operators of the upstream cycle of nuclear fuel (COGEMA, EURODIF, FBFC) addressing the behaviour of uranium hexafluoride (UF_6), the work undertaken by IRSN in 2004 covered:

- tests and simulations to assess the UF_6 behaviour in a room under different configurations (building ventilation configuration, leak rate, etc.). Because of the difficulties of operating with UF_6, the tests undertaken in IRSN facility in Saclay (Essonne) were carried out using SF_6, a good simulator of UF_6 for the phenomena studied;
- the development of a modelling tool for the sublimation of solid UF_6.

The aim of this work was to enable a more realistic assessment of the chemical and radiological consequences of an accidental uranium hexafluoride release.
All the tests and models will be used in support of the design for a new method to quantify releases.
The programme is planned for completion in 2006.

Experimental device simulating the behaviour of heavy gases at Saclay (Essonne).

Device for PICSEL tests under the SATURNE hood.

FOCUS

PRISME EXPERIMENTAL PROGRAMME

In 2004, IRSN continued its work under the PRISME experimental programme.

The aim of this is to study propagation mechanisms for smoke and heat from a fire in a given room towards adjacent premises.
It will provide unique large-scale information on these phenomena that are important for the understanding of the risks associated with fire.
It will enable the validation or modification of the corresponding IRSN calculation codes, and hence offer better estimates of the time periods after which there might be failure in essential safety equipment following a fire.

Three smoke propagation modes were taken into account: propagation via an open door, propagation via a ventilation duct transiting the room where the fire started and ventilating an adjacent room, and propagation via a ventilation duct involving reversal of flow in the latter.

The programme includes both an analytical and a global approach.
The analytical approach involves separate studies of the source, the three propagation modes described above and the flows into the adjacent room.
The global approach studies the interactions between the three propagation modes for actual fire scenarios, with and without the effect of ventilation.
The study of the fire source, carried out in 2004, enabled the description of the behaviour of a sheet of hydrogenated tetrapropylene in an open area and in a closed room ventilated mechanically. This reference fire will be used for the study of the three propagation modes and of flows into the adjacent room.

of a fire to be studied in detail by calculating in particular the temperatures and concentrations of the various gases in the different elemental volumes of a room, 2004 saw the development of version 2 that enables the simulation of fires in confined spaces with mechanical ventilation. A series of calculation cases (test cases), of increasing complexity, enabled the validation of the models used to be consolidated, in particular for the simplified ventilation model that was coupled to the basic version in 2003. The calculation of a full-scale fire test in the FLIP test series, carried out in the PLUTON installation, began at the end of 2004 and marked the start of the qualification phase.
In conjunction with the PRISME and PICSEL experimental programmes, a preliminary study, conducted with specialist universities in the field, led to a proposal and initiation of work on a thesis on the generic development of the power of a fire with a view to creating improved models for combustion rate in solid materials.

Research into aerodispersion

In order to assess the measures needed to understand the containment of radioactive material and to reduce uncertainties in the estimation of releases into the environment, the work undertaken by IRSN aims to determine the physico-chemical phenomena relating to the suspension of contaminants and their transfer under normal and accident situations in an installation. In 2004, under this topic, IRSN undertook the enhancement of the BADIMIS database, used in the Institute's expert assessments and studies, exploiting newly obtained test results about the suspension of radioactive materials when powders and contaminated objects are dropped. New programmes on the suspension of contaminants were

Control room of the DIVA experimental installation.

launched. They concern contaminated liquids and contaminated solid materials affected by a fire. The work about changes in physical characteristics of aerosols generated during a fire and the clogging of high-efficiency filters by these aerosols has enabled new basic data to be acquired that has been incorporated into the calculation tools.

As far as atmospheric dispersion is concerned, IRSN has continued to upgrade its calculation tools for dispersion and the estimation of the consequences of an accidental release of radioactive products to replace certain models now considered obsolete. The aim is to have available a set of tools incorporating the latest knowledge acquired on the topic of dispersion in the near field of the installations, but also at a regional or continental level, that could be used in a crisis situation and for study and expert assessment purposes.

In 2004, the architecture of the various tools was completed and the development of calculation models was continued with collaboration from university partners. A first version of the pX software intended for crisis situations was developed.

FOCUS

PICSEL EXPERIMENTAL PROGRAMME

The PICSEL programme is being undertaken by IRSN under a PIC with COGEMA.

It concerns the study of fires in electrical cabinets that could affect an installation including several ventilated premises (clogging of high-efficiency filters by smoke, disturbance of pressure levels in premises, etc.), as well as equipment containing radioactive material (glove boxes, bins, etc.).

The aim of this programme is to enhance knowledge about the phenomena relating to the propagation of fires in solid materials in confined and ventilated spaces, and to qualify the calculation codes for these phenomena. The PICSEL programme started in 2003 and will continue to 2008.

2004 was set aside for the carrying out of PICSEL_A tests: these were intended to characterise an electrical cabinet fire in a free atmosphere under the extraction hood of the SATURNE device, by measuring the concentration of soot produced, the heat flux from the source to nearby equipment and the source power. In parallel, the PICSEL_C tests, relating to the characterisation of components of the glove box (glove ports) and waste bins, were prepared for execution at the beginning of 2005. The PICSEL_A and PICSEL_C tests represented the two stages prior to the tests that will be carried out in the DIVA installation (in multi-premises configuration) in the second half of 2005. For these tests, the configuration of the premises and the ventilation network will be decided based on initial calculations carried out using the FLAMME_S software.

Test aimed at ascertaining electrical cabinet combustion modes.
1- Ignition phase. 2- Fully developed fire. 3- Post-experimental phase.

Team developing the SCANAIR software.

FOCUS

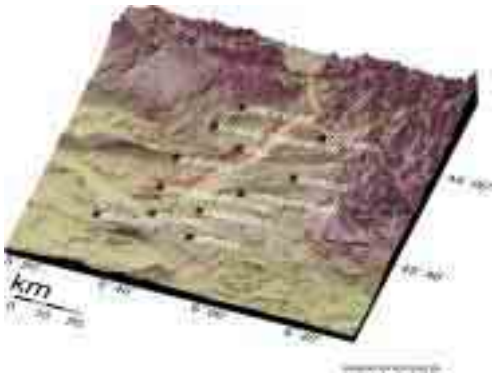
SYLVIA SOFTWARE PLATFORM

If the risks associated with fire are to be better understood, it is vital to be able to predict the development of a fire within an industrial complex consisting of premises that may or may not contain radioactive material, linked one to another by a ventilation system or other openings.

To this end, IRSN is developing SYLVIA, that simulates the propagation of a fire in such an installation and calculates in particular the transport of smoke, hot gases and, where applicable, any suspended contaminants. Delivery of the first version is planned for 2006. A preliminary version was produced in 2004. This simulates the flows of a gaseous mixture and is coupled to a graphical tool that enables the construction of a ventilation network and the entering of software input data. The physical models correspond, for the fire, to a simplified approach, as in the FLAMME_S/SIMEVENT software, but with significantly improved digital processing of the equations, especially for the description of the interaction between the fire and the ventilation. Subsequently, changes in the compartmentation and containment elements resulting from the fire will be modelled (filter clogging, changes to the aeraulic behaviour of doors and firewall valves, etc.).
Over the longer term, SYLVIA will incorporate a detailed calculation module of the fire (ISIS software) and will be coupled to SUNSET to carry out uncertainty analyses.

Research on **earthquakes**

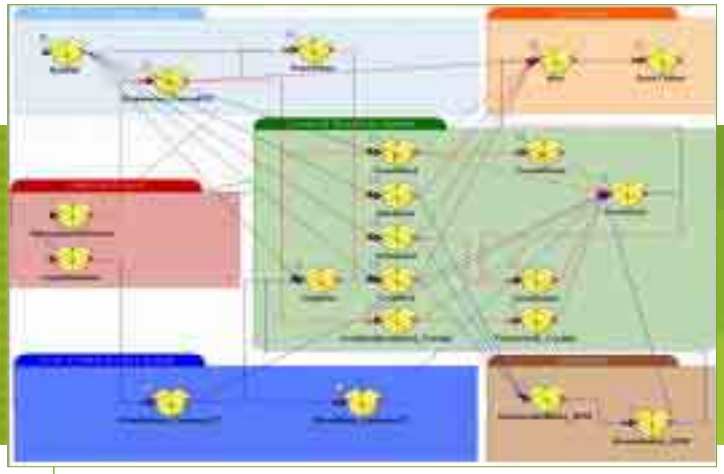
IRSN's seismological work aims at a better understanding of earthquakes as an external source of potential hazard to at-risk installations.



Location of stations of the IRSN seismic network for the Middle Durance fault, against a topological background. The red lines show the fault segments.

Seismological and geodesic instrument arrays enable source activity to be measured, and speeds and deformations to be estimated.
In 2004, data from the array installed around the Middle Durance fault and determination of the source mechanism for around thirty earthquakes enabled confirmation of the primarily strike-slip faulting nature of the fault, which must be known in order to be able to carry out digital simulations of motion prediction.
The study of site effects (effects of superficial soil layers on motions resulting from earthquakes) also focussed on the two instrumented sites: the Grenoble intermount basin and the Aigion region in Greece. In 2004, the response of superficial layers to seismic stresses, termed the "transfer function", was calculated from recordings of weak motions at both sites. Finally, a major effort addressed the probabilistic estimation of the seismic hazard for which a study was carried out at the Tricastin site (Drôme).

Electronic slate for the referencing of samples taken from the environment.



The SYMBIOSE platform is used to model transfers of radionuclides in the environment.

Radioecology research

In 2004, the Institute carried out research into two aspects of radioecology: on the one hand, the behaviour of radionuclides on ecosystems in relation to controlled or accidental releases resulting from nuclear activities and on the other hand, work intended to achieve a better understanding of the spatial and temporal development of radioactivity in the environment.

Development of models, tools and expert assessment techniques

In order to be able to assess the impact of nuclear activities on the environment, IRSN has been over many years developing and maintaining the models and tools needed to predict the behaviour of radionuclides. In 2004, a new version of the ASTRAL software, jointly funded by EDF, was installed at the Institute's Emergency Response Centre (CTC). This software enables an assessment of the concentrations of radionuclides in various sectors of the food chain, following an accidental atmospheric release. The main innovation is the ability to carry out calculations for uranium. In addition, a version of the CASTEAUR software, dedicated to the estimation of the radiological impact of radionuclide releases into watercourses, has been developed to enable longer-term calculations. For the marine environment, the DISPRO software, whose aim is to predict the atmospheric dispersion of radionuclides in the near field of the La Hague plant (Manche) has been validated by campaigns involving sea plotting. In the field of new tools, a prototype of the SYMBIOSE integrated modelling platform has been completed. Unlike software that only works in a single environment (agricultural, aquatic or airborne), SYMBIOSE addresses all the media using the same software, enabling the modelling of transfers both within and between the different media. As part of the work undertaken in collaboration with EDF, specific models have been

FOCUS

LAUNCH OF THE ERICA EUROPEAN PROGRAMME

Adopted under the 6th FPRD EURATOM, the ERICA European programme was launched in March 2004.

Its aim is to develop a method to measure (from scientific, decision-making and societal points of view) the effects of radioactive contaminants on the environment, with an emphasis on the protection of fauna, flora and ecosystems. ERICA is based on lessons learned from the European FASSET programme (5th FPRD), in which IRSN participated, that formalised a conceptual framework for assessing the impact of radionuclides on the environment. Coordinated by the Swedish radioprotection authority (SSI), ERICA brings together 15 partners from seven European nations.

Five working groups have been set up:

- development of assessment tools;
- development of methods to characterise and estimate the risk to the environment;
- preparation of recommendations concerning the demonstration of the protection of the environment against radioactive contaminants, including managerial aspects and communication with interested parties;
- applications for the assessment methods developed to a range of *in situ* study cases;
- general project management.

IRSN participates in all these groups and is coordinator for the second. The ERICA programme, which will end in February 2007, will provide an approach that offers logical links between methods and software tools enabling assessment and management of the environmental risk associated with radionuclides.

Sampling of sediment in the Rhône river at Arles following a flood occurrence.

developed and incorporated into SYMBIOSE that enable the prediction of carbon 14 and tritium transfer in the environment.

Development of applied knowledge

Experimental activity, aimed at understanding the mechanisms that control the behaviour of radionuclides in the environment, are being undertaken in support of model development. 2004 thus saw the completion of the European BORIS programme, coordinated by IRSN, that, using experiments and modelling, enabled the role of biological elements to be better explained, firstly in the properties of sorption/absorption of radionuclides in soils and secondly in the soil/plant transfers.

In the study area concerned with the resuspension of marine sediment, work under a thesis presented in 2004 enabled the demonstration of possible remobilisation of plutonium in sediments deposited in the Channel and the Irish Sea.

In the atmospheric dispersion field, IRSN participated in several experimental measurement campaigns that aimed either at a better understanding of atmospheric dispersion phenomena in an urban environment (collaboration with Météo-France), or at characterising aerosols released by the La Hague plant (collaboration with COGEMA).

The activities planned under the IRSN/CEA/EDF tripartite collaboration continued in 2004. In this context, IRSN worked mainly on the development of a method for the assessment of the risk to the environment resulting from radionuclides and carried out several studies into the behaviour of radionuclides in the non-saturated zone of the soil.

At an international level, IRSN teams were heavily involved in the IAEA's EMRAS programme. In particular, the Institute was tasked with coordinating the activities of the group assigned to revising the IAEA guide TRS-364 that is a compilation of basic radioecological data.

Finally, in the context of the many calls for tender emanating from public organisations (ANDRA, Seine-Normandie Water Agency, Basse-Normandie Region , PACA Region , Ministry for Research, Ministry for Environment), around 10 projects proposed by the Institute were adopted concerning the evolution and effects of radioactive pollutants in the environment.

FOCUS

LAUNCH OF THE EXTREME PROJECT

In 2004, IRSN launched a project concerned with the impact of extreme events on the transfers of materials in coastal regions.

This project, entitles EXTREME, was in part born out of the results of the CAROL project, that enabled, on the scale of the lower Rhône valley, the determination of what had become of the various artificial radioactive element contributions that this region has been subjected to over the past forty years. The aim of EXTREME is to assess the impact of "extraordinary" natural processes on the flow and distribution of radioactivity stocks, whether they are artificial or natural in nature. The main aim will be to understand the scale of the transfers of materials and contaminants associated with these exceptional climatic episodes. Studies will also be carried out into the transfers between the atmosphere and the ground during high precipitation rates, fog or deposits of particles of Saharan origin. Similarly, the river flow towards the sea or the land, in the case of flooding, will be monitored. Finally, the resuspension of sediments in coastal regions, in stormy conditions, will also be studied. Preliminary results show that such exceptional events lead to significant flows of radioactivity and to activities that are temporarily superior to those corresponding to the mean transfer processes. Some extreme events may thus lead to transfers equivalent to several months, even several years, of accumulated mean transfers, as well as the creation of new storage areas.

Sediment press used to extract interstitial water for analysis.

Understanding spatial and temporal changes to radioactivity in the environment

The Rhône is the primary source of artificial radioactivity in the western Mediterranean. The flow of pollutants, whether radioactive or not, travel down the Rhône to the sea, and hence the accumulations of radionuclides that have formed, especially at its delta, are of interest to the national and international scientific community. They are the subject of a range of projects (ORME, RESYST, MEDICIS and EUROSTRATAFORM): IRSN participates in some of these.

For the ORME project, the collaboration takes the form of the supply of data from the IRSN's OPERA station in Arles (Bouches-du-Rhône) that possesses a device unique in France for the automatic measurement of pollutants flow. The Institute's know-how is also of interest to the Rhône and Mediterranean Water Agency that participated in the funding of this station, as well as the Oceanographic Centre of Marseilles, that will soon be using this infrastructure to analyse chemical pollutants. Studies based on the results from this station have also shown the significance of peaks in the flow arriving at the sea. The first results of a thesis started in 2002 show that more than 80% of the 115 GBq of caesium 137 carried by the Rhône during 2002 were carried during only about twenty days of flood flow. The primary source of the flow of caesium and plutonium into the Mediterranean is no longer discharges from nuclear installations but the drainage of the radioactivity present in the soils of the drainage basin and the remobilisation of radionuclides present in ancient sediments stored in the riverbed. At sea, various phenomena result in the rapid deposit of radioactive pollutants in a fairly limited 30km^2 zone

FOCUS

THE ECORAD CONGRESS

In September 2004, IRSN organised the second ECORAD, an international congress on radioecology; this was held in Aix-en-Provence (Bouches-du-Rhône).

Under the patronage of the International Union of Radioecology (IUR) and the International Commission on Radiological Protection (ICRP), ECORAD brought together more than 320 scientists from 36 different countries.

The aim of the congress, entitled "The scientific basis for environment protection against radioactivity" was to carry out a survey of the knowledge available to the international scientific community and hence to assess the impact of radioactivity on the environment.

The congress was particularly interested in newly acquired data on the effects of chronic exposure on organisms and ecosystems, with a view to enabling the development of relevant international recommendations.

Five technical meetings were held in the margins of the congress, including the general assembly of the IUR.

150 papers were submitted to the congress secretariat, for publication in the report of the congress. The year 2005 will see the issue of these papers in the SFRP's review *Radioprotection*. The guest lectures will themselves be featured in an IRSN publication.

The Institute intends to make ECORAD a regular international meeting place for radiological scientists. The third is planned for September 2007.

Programme of the ECORAD international congress (September 2004).

Since April 2004, the CEA's carbon 14 measurement laboratory at Gif-sur-Yvette has been equipped with an accelerator mass spectrometer (AMS). IRSN is entitled to use it to study 400 samples a year as it made an 8.5% contribution to its financing.

corresponding to the river's prodelta. However, the results obtained in 2004 in respect of one of the sampling series under the REMOTRANS (5th FPRD) programme, carried out in 2001 and involving many institutes under the supervision of IRSN, showed that this zone did not represent an ultimate resting place for radionuclides. Levels had in fact dropped significantly since the inventory carried out in 1998 using samples taken in 1991. The future for the deposits and the dispersion of radionuclides on the continental shelf concerns the international community under the European programme EUROSTRATAFORM in which CNRS, IFREMER and IRSN are participating for France along with around 10 European institutes.

Research into **the metrology of radionuclides in the environment**

Radioecological studies on land involve the search for radionuclides under a range of conditions, sometimes in very small quantities, in order to be able to understand and quantify the spatial and temporal movements of radionuclides discharged during nuclear activities. There is therefore an ongoing requirement for improvements and changes to metrology techniques in support of such studies.

In 2004, IRSN therefore pursued several developments in radionuclide metrology:

- development of an analysis method for gamma radiation spectra by digital simulation of different measurement configurations; this method is currently being adapted to the *in situ* characterisation of radionuclides present in the soil;
- improvements in understanding of background noise in germanium diode spectrometers used by IRSN in the Modane (Savoie) underground laboratory, enabling the measurement of very low activities (of the order of a few mBq) of radionuclides in very small quantities of material (less than a gram). As an illustration, development of this instrumentation has allowed us to offer instrumentation support to a radiotoxicological study carried out in 2004 within IRSN on the ingestion of sand particles with high levels of natural radiation;
- development, in collaboration with the *École des Mines* in Nantes (Loire-Atlantique), of the coupling of a mass spectrometer and a capillary electrophoresis system intended to characterise the chemical form (speciation) in which radionuclides are found in the environment, information essential to an understanding of their behaviour.

Sorting female zebra fish (Dario Rerio) to study their fecundity after chronic exposure to uranium.

Influence of **exposure chronicity** on the behaviour and toxicity of radionuclides: **the ENVIRHOM programme**

Amongst the environmental disruptions that are often evoked as a possible cause of the development of certain pathologies, the case of radioactivity merits detailed study. It is for this reason that IRSN launched, in 2001, the ENVIRHOM research programme. Its aim is to enable a better assessment of the risks associated with chronic exposure to ionising radiation.

Within the ranges of exposures that lead to deferred risks (cancers, genetic mutations, etc.) rather than immediate effects, the current system to protect the human from ionising radiation is based on the assumption of a linear relation without a threshold between a "dose" indicator and the risk run. This indicator has been adjusted primarily thanks to the monitoring of Hiroshima and Nagasaki survivors, who were exposed to high levels of exposure consisting of gamma and neutron radiation.
In practice, this exposure mode rarely affects major populations or the environment, which are more often exposed to chronic moderate radiation resulting from internal contamination and for which there is very little relevant experimental data. This is one of the main conclusions of the European programme ERICA, in which IRSN participates. The aim of the ENVIRHOM programme is therefore to contribute to correcting these shortcomings so that the extrapolations used to assess risk can be made more reliable. The initial results, while still not suitable for transfer to an operational impact assessment tool, already confirm that moderate internal contamination are indeed a specific situation.

Human exposure

The first task undertaken involved verifying, using several specific examples, whether the accumulation rates, excretion rates and toxicity of radionuclides after chronic contamination could be predicted based on what can be observed in the case of acute exposures. The first element studied was uranium, as this can be present in high concentrations in the subterranean waters of certain regions (Finland, New Mexico, Canada). The corresponding studies were carried out using rodents that had been contaminated experimentally by uranium added to their drinking water. The first results were obtained in 2004.

Accumulation of uranium in tissues and comparison with ICRP models

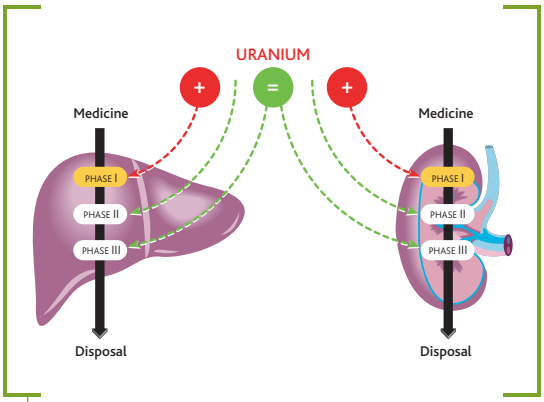
The experiments show that uranium accumulates in most organs of the rat, and that the process is complex. The uranium concentrations in the colon seem to increase gradually over time. This agrees with the ICRP models predicting that, in chronic exposure cases, the uranium concentration in a given organ rises to reach a plateau, and the rate varies according to the organ studied. In contrast, the results obtained for other tissues show that uranium accumulation does not follow this pattern. The kidneys, the skeleton, small intestine, the brain, muscles, liver and the body overall, show very specific contamination profiles that result in physiological changes linked to the contamination

Laboratory specialised in the study of daphnia at Cadarache (Bouches-du-Rhône).

duration. In addition, one can see a significant deposit of uranium in certain structures, such as the brain or the teeth, which were not covered specifically in conventional models. The data obtained is not yet such as to support an opinion that these phenomena, observed on rodents with uranium, can be generalised to other radioelements and the human race. However, they show that the consequences of chronic exposure cannot be systematically extrapolated from those arising from acute exposures. These results have been submitted for publication.

Effects on the central nervous system

The studies on the central nervous system were carried out by measuring any disruptions to sleep or behaviour. Enriched uranium and depleted uranium were used to distinguish the effect due to chemical toxicity from the overall toxicity of the element. The results show that an exposure of forty-five days to enriched uranium is sufficient to disrupt the sleep/waking cycle in animals, affect their short-term memory and increase anxiety levels. These effects are not seen with depleted uranium and can be explained, at least in part, by the uranium accumulation in certain brain structures. When the contamination is continued for nine months, the depleted uranium seems to affect the cellular organisation in certain brain structures. An article has been accepted for publication.



Schematic representation of the effects of uranium.

All these effects are observed when the uranium concentration measured in the kidneys, usually considered to be reference target organ, is less that the known toxicity threshold. This seems to indicate that the brain is more sensitive to uranium than are the kidneys and that it could be used instead of the kidneys as reference organ. However, it remains to be explained why depleted uranium does not accumulate on the same way in the brain and why, apparently, it does not induce the same neurobiological effects.

The detoxification function of xenobiotics

The experiments carried out after chronic contamination by depleted uranium over nine months show that the latter can modify the detoxification function of xenobiotics, such as medicines. The three medication metabolism phases that exploit the enzymes and transporters that enable the elimination of foreign substances were analysed especially in the liver and kidneys. This study shows that chronic contamination by depleted uranium induces over-expression of first-phase enzymes (P450 cytochromes) in these organs while the phase-II enzymes and the phase-III transporters are not affected.

The increase in the expression of P450 cytochromes and the absence of changes to phase-II enzymes and phase-III transporters could result in changes to a major defence mechanism of the organism, detoxification by xenobiotics. Effectively, in the case of a medicinal treatment, the medication metabolism may produce a metabolite that could become toxic if it accumulates following a rise

Chironomid larvae in uranium contaminated environment.

in its synthesis rate (phase I) without an increase in its elimination (phases II and III). Conversely, if the medication retains its initial active form, its rapid degradation in phase I could lead to therapeutic ineffectiveness.

If these hypotheses are confirmed, medicinal dosages will have to be changed when treating individuals with chronic exposure to uranium. The results obtained in 2004 are presented in articles that will be submitted for publication in 2005.

Exposure of the environment

The limited amount of data available prior to the launch of ENVIRHOM would appear to substantiate the hypothesis that relatively high dose rates are needed before definitive effects emerge. The order of magnitude is around 10 mGy per day (or about 1,000 times the natural exposure rate). Nevertheless, the data is too fragmentary to draw reliable conclusions.

It is in fact entirely possible that this order of magnitude will vary depending on the nature of the radiation source.

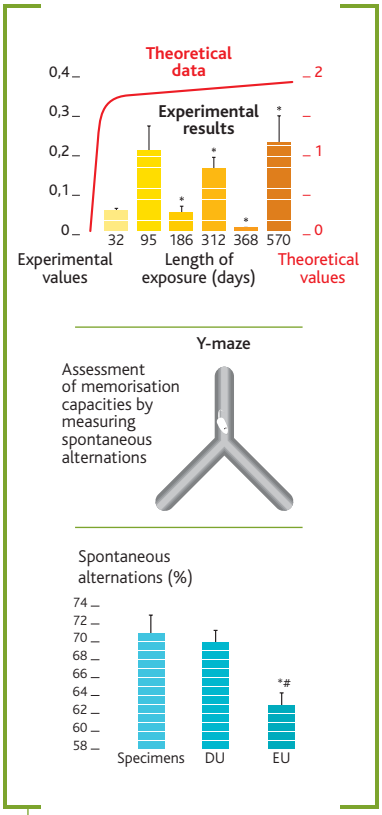
Furthermore, interpreting observations in the natural environment is particularly difficult because of its lack of homogeneity. A large-scale environment showing little contamination could in fact be a mosaic of accumulations and of zones with virtually no contamination.

The case of uranium

Indisputable effects are seen even for quantities that are lower than those used in the experiments on the rats. For example, concentrations as low as 150 nanomoles per litre are sufficient to prevent growth in seaweed populations. The same results are obtained using depleted uranium or with uranium enriched with uranium 233 (which is highly radioactive); this would appear to prove that the effect of the radioactivity is, in this case, negligible when compared with the chemical toxicity. At this level of concentration, the dose estimations are however of the order of 10 mGy per day, which seems to confirm that, for the low dose rates that are characteristic of environmental contamination, quite large doses of radioactivity are needed to produce discernable effects.

Other radionuclides

This example naturally poses the question of improvements to conventional dose indicators to make them more representative of real effects. The dose rate is clearly an important parameter, as is the type of radiation. To clarify this point, tests are under way on a range of test organisms (daphnia, fish, worms) using depleted uranium, uranium 233, americium 241, polonium 210 and selenium 79.



Uranium concentration in the rat after chronic ingestion of depleted uranium (DU) via its drinking water.

Prospects

The first results confirm the validity of the initial assumptions: chronic exposure is a specific problem, the different test organisms and the range of techniques applied demonstrated that they were well suited to the task of demonstrating definite effects or microscopic effects that could be precursors.

Granite house in Kersaint (Bretagne) where the Institute conducts experiments to further understanding of the circulation of radon in the home.

Research **activity on radon**

IRSN undertakes research to improve knowledge of the effects on health resulting from radon in housing. Research also addresses the measurement of radon under particular conditions, its behaviour in buildings and the deposit of its daughter products.

Risks of lung cancer associated with domestic radon.

The risks of lung cancer associated with domestic exposure to radon and to tobacco smoking have been the subject of numerous epidemiological studies. Most of these have failed to show a significant risk but lacked statistical power. The joint analysis of 13 case studies undertaken in Europe, that included the French study carried out by IRSN, enabled some conclusions to be drawn. The French study, published in 2004 in the review *Epidemiology* covered 486 cases of lung cancer and 984 subjects. Radon concentrations were measured or recreated for each of the houses over the thirty years preceding the diagnosis of lung cancer and the tobacco smoking history of each subject established by questionnaire. The study showed an

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UNDERSTANDING THE RADON CONCENTRATION MECHANISMS IN BUILDINGS

As part of a research programme concerned with understanding the mechanisms affecting the radon concentration in buildings, IRSN is using an uninhabited detached house, located in Kersaint (Finistère), on a well-characterised uranium-bearing geological formation.

Instrumentation of the various rooms and of the garden has enabled monitoring since 2002 of radon penetration through the basement slab, its accumulation in the building and its distribution via air circulation between the floors and exchanges with the outside. In 2004, changes to the instrumentation enabled the detection of the disturbance caused by the building on the surrounding ground and the characterisation of two additional radon sources in the building: the semi-buried walls in the basement and the building materials.

In parallel, the multiplicity of parameters involved led IRSN to develop the calculation code RADON2 that enables the study of radon concentrations in the internal atmosphere of the building. The aim is to develop a tool for the prediction of radon activity per unit volume in houses located in regions with a high potential for exhalation or on polluted sites.

As a preliminary, the validity of the phenomenological model on which RADON2 is based must be confirmed using data acquired by instrumentation during the experimental phase that continues into 2005.

Scientific collaborations have been developed with the University of Bretagne-Occidentale and the laboratory for the study of transfer phenomena as applied to buildings in La Rochelle (Charente-Maritime) for the characterisation of the permeability of the overall envelope of the building.

Probe measuring radon concentration in the ground.

increased risk of lung cancer as radon concentration rose, with results at the limit of statistical significance. The joint European analysis, published in 2004 in the *British Medical Journal*, covered 7,148 cases of lung cancer and 14,208 subjects. It shows a significant relation, of the linear type with no threshold, between exposure and effect once allowance has been made for age, sex, the region lived in and smoking habits. For an increase of 100 Bq/m^3 of radon, the risk of lung cancer over a lifetime increased by 8.4%. Thanks to its significant statistical power, the study confirmed the existence of an increased lung cancer risk following domestic exposure to radon. This result is coherent with values published in the literature and with those extrapolated from results of studies on uranium miners.

Radon metrology

IRSN has undertaken work on the presence and behaviour of radon in thermal spa establishments to improve understanding of the exposure of those taking the waters and the staff to natural radiation. This work has shown that exposure routes and levels differ according to the category of personnel considered (doctors, kinesitherapists, maintenance and laundry personnel, etc.) and as a function of duration of stay and of contact with the thermal water, which is responsible for the presence of radon in the buildings. In 2004, IRSN developed a protocol that defined two methods for measuring natural radiation in thermal establishments.
Following work on the metrology of the activity per unit volume of radon in a particularly humid atmosphere, IRSN carried out radon measurements in prehistoric decorated caverns that come under

FOCUS

USE OF RADON AS A GEOLOGICAL PROBE

Ever since the launch of the *Viking* spacecraft in 1976, the search for life on Mars has been a major concern of scientists studying the planets.

A vital aspect of this research is the unambiguous determination of the presence or absence of water in the first few metres of soil at equatorial latitudes. A "simple" measurement of radon concentration in the lower Martian atmosphere could provide proof of the presence of water, which up to now the *Spirit and Opportunity* robots and the satellites *Mars Odyssey* and *Mars Express* could not provide.
The planned use of radon as a geological probe on the planet Mars results from the well-established fact on Earth that the exhalation of radon from a porous soil is highly dependent on the water content of that soil: a quantity of water, even very small, increases spectacularly the ability of radon to collect in the pores of the soil and migrate into the atmosphere.
A thesis jointly funded as part of the partnership with the CNES is under way to transpose this observation to the environmental conditions on the Martian surface and to define the characteristics of a radon detector that could be embarked on a future Mars exploration platform. A PhD student arrived in December 2004 in IRSN's laboratory for the physics and metrology of aerosols.

Baccara, the radon calibration bench at Saclay.

Map of the gamma dose rate in real time with respect to geographic location.

the Ministry of Culture. Because of the very specific nature of the atmosphere of these caverns (confined and humid), an experimental protocol to characterise radon concentrations is being validated in five prehistoric decorated caves selected by the Ministry: Chauvet in Vallon-Pont-d'Arc (Ardèche), Niaux (Ariège), Lascaux, Font-de-Gaume and Combarelles (Dordogne).

Epidemiology of nuclear workers

IRSN is developing epidemiological activity with a view to estimating the risks of cancer associated with chronic exposure to low doses of ionising radiation.

Radon dosimeter at Kodalpha.

Current radiation protection standards are primarily based on the results of the follow-up of survivors from the Hiroshima and Nagasaki bombs, who were exposed to high dose rates over very short time scales. Current concerns in radiation protection are more directed towards individuals exposed to low doses over a prolonged period in the course of their work. Models are used to extrapolate the knowledge from the Hiroshima and Nagasaki survivors to groups of individuals chronically exposed. In order to verify the validity of these extrapolations, epidemiological studies on populations exposed to low doses over time have been set up since the 1970s. Workers in the nuclear industry represent an appropriate group for these studies as they form an abundant population whose employment is stable and where there are high-quality records of doses received.

In this context, IRSN has set up monitoring for a cohort of employees from the CEA-COGEMA group, with a view to estimating the risks of cancer associated with occupational exposure to ionising radiation, exposures that are low but chronic. This monitoring requires the retrieval of the individual doses received by the workers throughout their career, search for vital statistics (whether deceased or not) and, where relevant, the cause of death. In total, more than 50,000 workers employed by the CEA-COGEMA group since the 1950s are involved. An initial descriptive analysis of the mortality of CEA workers was published in 2004 in the *American Journal of Industrial Medicine*. This showed evidence of under-mortality of this population in comparison with the general French population for both all

Archive room of the source expertise unit at Fontenay-aux-Roses (Hauts-de-Seine).

causes of death and for all cancers, but a significant excess of deaths from malignant melanoma. An analysis of the dose-effect relationship for part of the cohort (29,000 individuals) was carried out. Analysis of the whole cohort will be possible once all dosimetry has been validated.
Part of this data was forwarded to the ICRC, that is coordinating the international study relating to about 50,000 nuclear workers in 15 countries and that in particular addresses the effects on health of external X- and gamma radiation. An analysis of mortality was carried out and an article was submitted in 2004 for publication in a review. The cohort of CEA-COGEMA workers will also be incorporated into the European research project, coordinated by IRSN, into the risks of internal exposure to ionising radiation.
Finally, under a PIC between IRSN and COGEMA, a study was launched in 2004 into the morbidity of current workers, in collaboration with COGEMA's work medicine department.

FOCUS

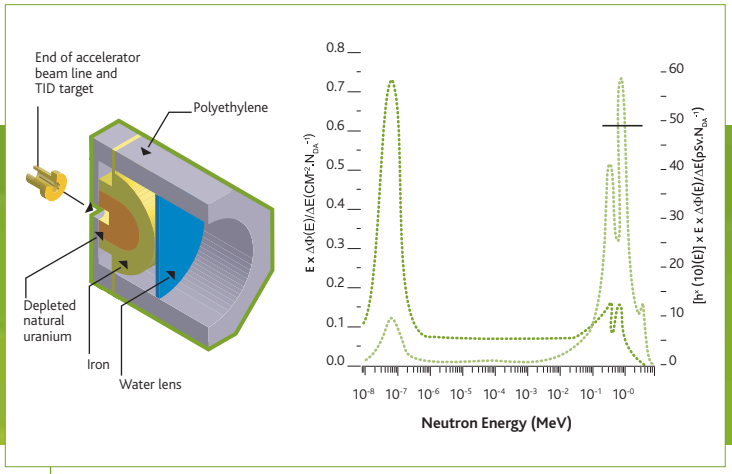
COORDINATION OF EUROPEAN PROJECTS ON THE EPIDEMIOLOGY OF IONISING RADIATION

IRSN's epidemiology laboratory has already coordinated several European research projects, especially under the 4th (1996-1999) and 5th (2000-2003) FPRD.

This work concerned the quantification of the risk of cancer associated with cumulative exposure to radon, and in particular based on studies of uranium miners.
In 2004, a new research project was developed in response to the call for tenders from the 6th FPRD.

This research, more ambitious than earlier programmes, will involve 18 partners from nine countries, under the coordination of IRSN. Its aim is to improve understanding of the health implications – cancers and other pathologies – of chronic exposures to ionising radiation.
In particular, it aims to introduce new factors into the quantification of the risks associated with internal exposures, by incorporating the majority of European studies on the subject: cohorts of uranium miners (more than 20,000 miners), study into domestic radon (joint study by 13 European countries), and studies into the risks for nuclear workers who have received internal exposures, etc. This research implies collaboration between research teams across three disciplines: epidemiology, dosimetry and bio-mathematical modelling.

The project is due to start in 2005 and will last three years.



Development of reference neutron fields with the CANEL T400 device producing realistic mixed fields.

Improvements in radiation protection

To improve radiation protection for workers, patients and the public, IRSN makes regular improvements to the methods and tools it uses to assess the exposure of persons to ionising radiation. In nuclear installations where radioactive material is handled, the workers are exposed to a risk of internal contamination. Their protection is provided by equipment, whose performance following an accident has been studied by IRSN. Effectiveness has also been improved.

In 2004, IRSN mainly worked on the development of tools for the simulation of internal contamination, by developing reference neutron fields, the lowering of detection limits, for example for the measurement of wounds contaminated by actinides or for the passive dosimetry of neutrons, and finally the assessment of exposure on board aircraft during solar maximum.

Effectiveness of protection equipment

In the area of protection equipment effectiveness, IRSN studied in 2004 the situation created by the accidental failure of static containment provided by the gloves and sacks fitted to glove boxes used for the handling of radioactive material. The results enabled a quantification of the amplitude of aerosol transfer phenomena following the tearing of such equipment under a range of configurations. The effectiveness of a safety device offering dynamic containment by means of an additional extraction flow was demonstrated, regardless of the nature of the contaminant (gas, aerosol). The benefits of such a device on the reduction of aerosol transfers towards the outside of a containment are greater for the larger particles (5 µm).

Dispersion of pollutants

In the field of pollutant dispersion, thesis work completed at the end of 2004 enabled the development of correlations describing the spatiotemporal evolution of the concentration of a gaseous pollutant in the immediate vicinity of an accidental leak as a function of the various parameters concerning the leak (speed and duration of the emission, dimensions of the aperture), the pollutant (initial density and concentration) and ventilation of the room (transverse flow rate). These correlations were incorporated into a simplified calculation tool that can be used to estimate the concentrations of pollutants in a room after an accidental rupture in the containment provided by a containment. Complementary work is being undertaken to study the case of a specific contaminant, as well as the influence of partitions and obstacles in a room.

Sampling

In the field of aerosol sampling, the work undertaken by IRSN aims to provide the means to evaluate the sampling strategies to be introduced to estimate the exposure of workers, and especially the choice between individual and fixed-station sampling. In 2004, comparative tests of various types of sampler were carried out *in situ* in a workshop. Two main points were identified: responses differed between fixed-station samplers and individual samplers and depended primarily on their individual performance as a function of the granulometry of the sampled

Physical phantom used for the calibration of whole-body radiation measurement installations.

aerosols. In addition, the comparison between individual sampling and ambient sampling showed that the activities measured by individual sampling might be significantly higher, in certain contexts, than those determined from ambient sampling.

Improvements to *in vivo* measurement of actinides

Mathematical phantoms for the realistic *in vivo* measurement of actinides in the lungs and contaminated wounds

One of the methods used to estimate the internal contamination of an individual relies on the direct measurement of X- and gamma radiation emitted by his/her organism. This *in vivo* method, termed "anthroporadiametry", offers the advantage of being quick and easy to implement for X- and gamma radiation emitters at energies exceeding 100 keV. Where actinides have been incorporated, its use is more problematical as the emitted radiation is low and highly absorbed in tissues. Although major efforts have been made to improve physical phantoms (mannequins) used to calibrate anthroporadiametry installations, such models can only offer an approximate representation of the human body. Consequently, corrections have to be applied to the calibrations obtained using these physical phantoms in order to extrapolate them to a given individual. These corrections are critical, but particularly significant for the *in vivo* measurement of low energy radiation, as absorption in tissue is high.

So, to improve the calibration, three-dimensional mathematical phantoms built up from scanned images or IRM (voxelised phantoms) were linked to MCNP Monte-Carlo calculation codes. An interface, called ŒDIPE, enabled, firstly, the generation of voxelised phantoms and, secondly, the simulation of whole-body measurement under conditions similar to reality.

In 2004, an initial validation of this approach involved introducing into ŒDIPE the geometric characteristics of the multi-detector counting system belonging to the biological and medical analysis laboratory at COGEMA Marcoule (Gard)

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ANTHRO-Si project

In 2004, IRSN completed development of a prototype of ANTHRO-Si, the whole-body counting measurement system.

This was the result of a project started in 1995, to lower the detection limits of current measurement systems, that use germanium detectors cooled using liquid nitrogen.

This project involves the design of a system based on the use of "pixelated" PIPS silicon detectors operating at ambient temperature.

Whole-body measurements can rapidly determine the radiation of radionuclides incorporated by a person. It is used for medical monitoring of workers at risk of internal contamination. However, for transuranic elements, the sensitivity of the measurement is limited by the fact that low energy X- and gamma lines (< 100 keV) associated with alpha disintegrations are absorbed. This absorption and the heterogeneous distribution of activity in the tissues contribute to the difficulty in interpreting the results of the measurement.

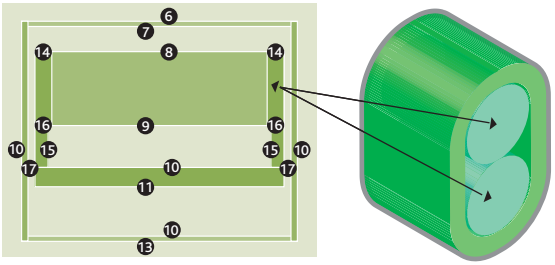
The metrological performance of ANTHRO-Si will be studied in 2005 for wounds contaminated by actinides, before considering whether it can be industrialised.

The major advantage of ANTHRO-Si is its ability to locate contaminations more accurately thanks to the "pixilated" detectors with minimal mechanical size, while offering, at first sight, a better compromise between resolution of the measurements and the surface of the detector than the germanium detectors. This system, if industrialised, would be a simple *in vivo* measurement system for internal contamination resulting from accident situations.

Development of 3D digital phantoms.

based on drawings provided by the manufacturer. Activity measurements were then made using point sources; these enabled the validation of the geometric description of the system by comparison with measurements "simulated" by the MCNP code. Other measurements, made using the Livermore physical phantom (at the Lawrence Livermore Laboratory – USA), enabled the validation of the ŒDIPE tool for the installation, demonstrating the possibility of deriving graphs of virtual effectiveness, as they were obtained by simulation, with a view to calibrating the installation.

Application of voxelised mathematical phantoms associated with the MCNP Monte-Carlo code for the realistic *in vivo* measurement of actinides in the lungs and in contaminated wounds.



Sectional view of the modelling of a germanium detector.

Based on these results, research has been targeted on determining the uncertainties in the measurement. The first stage involved studying the variation of incorporated activity within an individual (represented by a voxelised phantom), when the measurement system was calibrated using a range of thoracic thicknesses for the Livermore physical phantom. The results obtained revealed two points: the advantages of carrying out calibrations of whole-body installations using voxelised phantoms with morphology close to that of the persons being measured; the need to determine bio-parametric equations specific to European morphology, as current equations are in general determined by the morphology of North Americans.

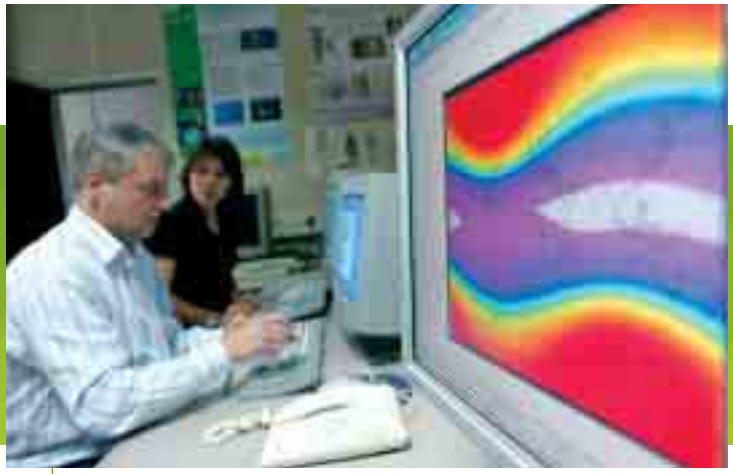
The second stage involved the simulation of non-homogenous contaminations, to improve understanding of the influence of heterogeneity in the contamination on the calibration. Two simplified cases of lung contamination were used; their results were compared with those obtained for a uniform contamination of the lungs. The results seem to show no significant difference between a non-homogenous contamination and a uniform contamination for energies in excess of 26 keV; but, a slight difference is reported at 17 keV. Consequently, heterogeneity in contamination does not call into question existing calibrations.

Dosimetry of neutrons by track detection

In 2003, the IRSN's dosimetric monitoring laboratory undertook a study with the aim of improving the passive neutron dosimetry system based on the track detection technique. The objectives are a reduction of the detection threshold, better treatment of background noise as well as an extension of the response of the dosimeter to low energy levels.

The physical principle of the detector used (a polycarbonate commercialised under reference PN3) depends on the interaction of neutrons in the volume of the material. The resultant breaks in the polymer chains create damaged areas that react in contact with a strong alkaline medium before the rest of the polymer. The result is the appearance of microscopic tracks on the detector

Positioning of the neutron dosimetric apparatus in front of CANEL.



Dosimetric assessment during a solar flare.

surface after several hours of immersion in an alkaline solution.

The determination of optimum parameters for chemical treatment concluded in 2004 with the development of a new protocol for the measurement of doses resulting from neutrons. Thanks to a chemical treatment, the detector becomes sensitive to external charged particles, which improves its performance, with a response multiplied by two; there is an indicator that shows if the dosimeter has been irradiated; the addition of converters in contact with the dosimeter enables the entire energy spectrum to be covered.

Development of reference resources

The IRSN's neutron metrology and dosimetry laboratory holds the status of laboratory associated with the National metrology and test laboratory (LNE). It therefore operates within its facilities all the tools required to better define the major standard quantities such as fluence and ambient dose equivalent. These quantities are obtained after experimental confirmation of energy distributions for radiation fields calculated using the MCNP code. In 2004, the final results of the international spectrometry campaign on the CANEL T400 installation were published. These resulted in improvements to the characteristics of one of the CANEL screens; they also gave access to the energy distribution of the neutron field of the SIGMA stack. In addition, liquid scintillation spectrometry of the neutron reference sources called into question the universality of the spectrum of the AmBe source indicated in standard ISO 8529-1.

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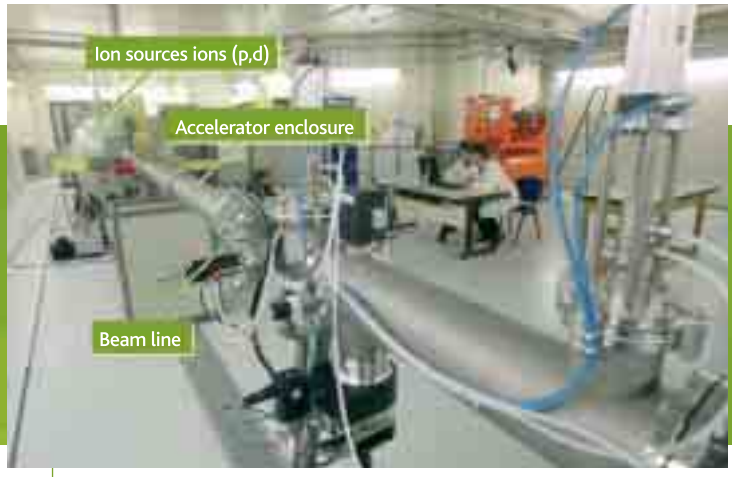
COSMIC RADIATION: THE DOSMAX PROJECT

Because of cosmic radiation, aircrew receive individual annual doses that, in certain cases, can attain several millisieverts.

In this context, the DOSMAX project, funded by the European Commission, linked more than 10 European laboratories between 2000 and 2004, with the aim of assessing exposure on board aircraft during solar maximum periods. Numerous measurements were carried out in flight by the various laboratories, in collaboration with the airlines. The Institute organised an airborne intercomparison of dosimetric systems from the various laboratories on an Air France cargo aircraft during a Paris-Fairbanks-Tokyo flight. This intercomparison was a unique opportunity to compare the responses of several dosimetric techniques in an actual situation and to show if there was good coherence between the various experimental systems and the models used to carry out the routine monitoring of the doses received by aircrew. The effective dose measured for a return flight was 120 µSv ± 10 µSv (for comparison, the individual annual effective dose due to cosmic radiation in France is of the order of 300 µSv).

Measurements taken by IRSN with the NAUSICAA apparatus on board Air France long-haul aircraft between 1996 and 1998 show the reality of exposure of flight personnel.



AMANDE accelerator.

The **AMANDE** installation

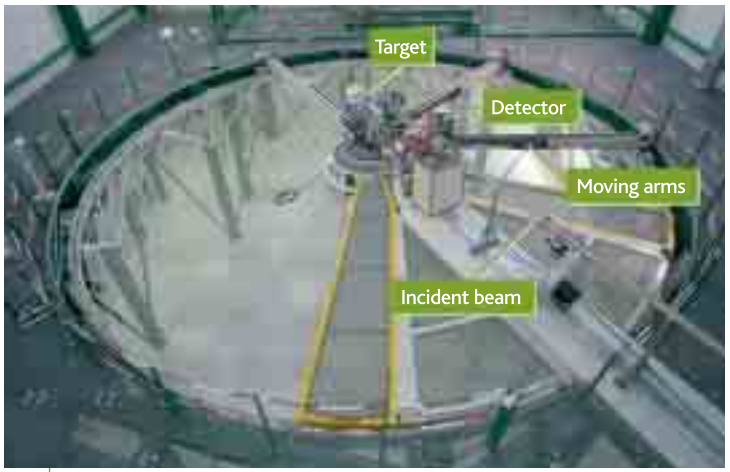
In 2000, IRSN decided to build a new installation, called AMANDE, which could generate mono-energetic neutron radiation fields, whose energy could be varied between 2 keV and 20 MeV. The primary aim of this installation is to determine the response of measurement equipment as a function of neutron energy, as recommended by the international standard ISO 8529-1.

The AMANDE installation will be at the heart of the French neutron reference system, ensuring that the IRSN's neutron metrology and dosimetry laboratory (LMDN) becomes a reference laboratory for this field at national, European and international levels. This laboratory is associated with the national metrology and test laboratory (LNE) for both dosimetry and neutron metrology matters. The AMANDE installation could also generate a reference 7 MeV photonic field (recommended by the international standard ISO 4037-1) that currently does not exist in France. It will enable an extension to the IRSN's calibration capabilities in the high-energy photon field.

2004 saw the completion of build and installation as well as the setting up of the accelerator itself with its associated equipment. The performance of this accelerator will enable an accurate determination of the energy and fluence of the neutron field with a resolution of less than a few percent. Neutron emission could reach 5.10^8 s^{-1} and will generate continuous or pulsed radiation fields with a pulse width of less than two nanoseconds. As the experiment hall has metal walls, background noise resulting from diffused neutrons is significantly reduced compared with equivalent installations with concrete walls. Finally, an automated system with moving arms enables accurate location of the detectors to be irradiated at a given angle and distance (up to 6 m) from the target, the neutron source.

The AMANDE installation completes the installations already in use at IRSN:

- two neutron generators, associated with the CANEL device, that generate neutron fields similar to those observed at certain work stations in reactors;
- an irradiator that employs two radioactive sources (one of americium-beryllium and the other of californium);
- SIGMA that generates a field with a high proportion of "thermal" neutrons.



Test hall for the AMANDE installation.

"Rando" whole-body phantom for dosimetry of patients.

The radioprotection of patients: **consequences of radiotherapy on healthy tissue** present in the radiation field

The IGR and IRSN have formed a mixed unit, under the framework of the Higher Education's Own Research Unit (UPRES) 27-10 for the study of the physio-pathological mechanisms that control the development of radiation-induced fibrosis and the definition of new therapeutic strategies for their treatment.

The doses of radiation required to control cancerous tumours in the abdominal-pelvic region cause acute and delayed intestinal toxicity phenomena. The delayed complications of the radiation-induced fibrosis type may have very significant consequences both from their chronic and progressive nature and from the associated morbidity and mortality. Currently no treatment is available.

Recent studies have shown that the fibroses were evolutionary pathologies comparable to a chronic scar-formation process. Two models have been proposed to explain the delayed effects developed by healthy tissue following radiotherapy. The first describes the delayed effects as the consequence of severe and persistent acute effects. The second describes the delayed effects and the radiation-induced fibrosis as the result of the irradiation of connective tissue and the reduction of parenchymatous and stromal cells. These two hypotheses are being examined within the mixed team. Preclinical tests have been carried out with a specific intestinal growth factor: the Glucagon-like Peptide 2 (GLP-2). This therapeutic approach aims to produce epithelial cells and the re-colonisation of the intestinal mucus after irradiation. The study is being undertaken under a research contract with the Novo Nordisk laboratories

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EUROPEAN MOVES IN MEDICAL RADIATION PROTECTION

The research carried out by the mixed IGR/IRSN team on radiation-induced enteritis forms part of the European-wide effort to encourage the transfer of research results to radiotherapy.

The Translational Research Group (TRG), formed in 2001 within the Radiotherapy group of EORTC, had as its aim the development and coordination of relations between clinicians with the aim of ensuring the early clinical application of advances in research into radiobiology and radiopathology. The activities of the group are directed along three lines: predictive agents, diagnostic agents and therapeutic agents, into which the work of IRSN fits perfectly. Two clinical studies, plus a predictive test resulting from IRSN work, will be set up in collaboration with the IGR.

The involvement of IRSN in the TRG/EORTC and ESTRO group puts the Institute at a European level in the medical radiation protection field.

Preparation of the colouring of histological cross section slides.

(Denmark), suppliers of the growth factor. One beneficial effect has been shown in the acute and delayed damage to the irradiated small intestine of the rat. This work was the subject of two publications in 2004. Complementary studies are now needed to confirm the therapeutic effect and to understand the modes of action of GLP-2.

A second therapeutic line of enquiry has been developed in parallel. This is based on the results obtained by IRSN on physiopathological mechanisms leading to radiation-induced enteritis in man. These results mean that it may be possible to consider using the inhibition provided by Connective Tissue Growth Factor (CTGF/CCN2) as a means of effective and specific action against fibroses. This discovery opens up genuine therapeutic possibilities as pharmacological inhibitors of the Rho/ROCK channel exist that control the production of CTGF: the statins and fasudil. Therapeutic experiments using statins have been started using the rat: the first results show a resorption of radiation-induced enteritis in the rat.

These promising preliminary results, published in 2004, and the close collaboration with the IGR, lead one to hope that an early clinical application of the new anti-fibrosis strategies will be possible.

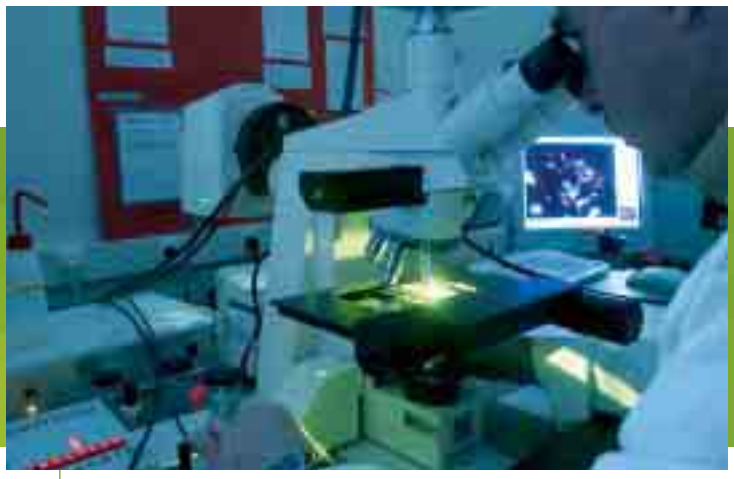
Irradiation and contamination **accidents**

The research programme carried out by IRSN on the effects of medium and high doses of radiation is divided along two lines: research for bio-indicators for diagnostics, or even prognostics, enabling an understanding of the extent of the radiation-induced damage; research into new targets for therapeutic action.

In parallel, the development of operational measurement systems at different points of the organism completes the diagnostic resources. The risk of terrorist actions has increased interest in this research programme that associates physiopathologists with physicians.

Cutaneous radiation syndrome

Two hospital organisations, the Burns Treatment Centre (CTB) at the Defence teaching hospital in Percy (Hauts-de-Seine) and the oncology-radiotherapy department at the Curie Institute (Paris), to whom IRSN often provides technical support, have acquired an internationally renowned ability in the field of medical treatment of cutaneous radiation-induced syndrome, resulting from their experience in the treatment of victims of accidents in Georgia, Peru and Poland. Their experience shows that, while the pathogenics of the cutaneous effects of ionising radiation are well described, the medical treatment remains extremely complex and problematic; the only therapeutic issue is the removal of irradiated tissue and skin grafting where tissues are tending towards necrosis. This finding has led IRSN, in cooperation with the CTB clinicians, to develop a research programme supported by the DGA, aimed at improving diagnosis and treatment of localised irradiation *(see Focus p. 69)*.



Observation with a fluorescence microscope (FISH technique: fluorescence in situ hybridisation).

Improving diagnostics

An accurate and early dosimetric assessment of the degree to which the exposed tissue is affected is useful but does not suffice to confirm a diagnosis. It must be supplemented by an assessment of tissue damage and the volume of tissue likely to suffer necrosis. An overall approach to the improvement in diagnostics of localised irradiation, including the intercomparison of various biophysical (Doppler laser, thermography, RMN), clinical and biological techniques, was initiated in 2004 under a contract with the DGA *(see Focus p. 69)*. Here, IRSN is developing a new approach to biological dosimetry of localised irradiation, based on the application of cytogenetic techniques on the cells present in the skin tissue. This approach, tested during the last localised irradiation accident (Georgia) treated in France, is being validated on an experimental animal model. Its results will then be compared with those obtained by the biophysical techniques regularly used in clinic.

Identification of new therapeutic targets

From a physiopathology point of view, the response of skin tissue to acute high-dosage radiation can be compared to a pathological tissue repair process, with the epidermal, vascular and mesenchymatous components all contributing to the failure to heal.

Histological studies, carried out during different cases of localised irradiation accidents, provided accurate information about the various stages of the process. Molecular studies using biochip have enabled the identification of the principle genes involved in the cutaneous vascular response in man, during the latent phase of the cutaneous radiation syndrome. The expression of some of these genes

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IMPROVEMENTS IN THE DIAGNOSIS OF CUTANEOUS RADIATION SYNDROME

In 2004, IRSN responded to a call for tenders from the DGA for improvements in the diagnosis of cutaneous radiation syndrome.

The bid by the Institute was accepted. This research programme combines clinicians from the Percy Hospital, radiobiologists from IRSN and the Defence medical service research centre (CRSSA) and physicians from the instrumentation, signals and systems research and study laboratory (LERISS) in the Paris 12 University.

The programme is organised around two major themes:

- the development of dosimetry tools for localised radiation, a thesis jointly funded by the DGA and IRSN started in September 2004;
- the study of the physico-pathological consequences of localised radiation of cutaneous tissue. The transformation of the irradiated tissue towards necrosis is one of the possible consequences of localised high-dose radiation that remains without a satisfactory medical response. This transformation occurs through successive eruptions that are difficult to predict. The aim of the study is to examine the pathological tissue repair process after radiation with a view to defining new therapeutic strategies. This research consolidates the links that IRSN has forged with hospital organisations that can take responsibility for radiation victims, and in particular the Percy Hospital, with the Institute providing technical support to the medical treatment of victims of accidental radiation.

Preparing samples after a histological analysis.

has been confirmed using molecular biology techniques, and their functional involvement has been verified in the animal.
The significance of the initiation and maintenance of vascular endothelium activation after irradiation of the cutaneous tissue has thus been demonstrated experimentally. Strategies aimed at controlling this structural and functional degradation of the vascular compartment could therefore be explored in the short term.
An article summarising this was submitted for publication in 2004.

A therapeutic approach to accidental irradiation

A study of radiological accidents that have occurred over recent years shows that, in most cases, the outcome was fatal primarily through lack of a therapeutic strategy adapted to the whole range of radiation-induced damage. It is difficult to treat an acute radiation syndrome because of the simultaneous attack against several physiological functions, and in particular the haematopoietic, gastro-intestinal and cerebrovascular systems. A generalised inflammatory syndrome may also appear, sometimes accompanied by secondary pathologies affecting the liver, the kidneys or the lungs. This array of pathologies can be grouped under the term "radiation-induced Multiple Organ Failure Syndrome" (MOFS).

Irradiation and contamination accidents - Placing a sample for measurement by EPR spectrometry.

Cellular therapy

The reduction or disappearance of normal stem cells, capable of regenerating tissue after a trauma, would appear to be the possible cause of radiation-induced MOFS. In the future, cellular therapy, which consists of bringing in cells capable of repairing damaged tissue, could be a promising approach. The work undertaken by IRSN within the mixed team installed at the Saint-Antoine Hospital (UPRES 16-38, Paris) is investigating the possibility of adapting the principles of cellular therapy to the case of victims of accidental irradiation in order to correct cellular deficits in each of the damaged tissues.
This approach was first developed for bone marrow. The results obtained show that the technique of *ex vivo* expansion of haematopoietic cells is particularly effective in treating medullar aplasia. Adaptation of this technique to the case of accidental irradiation has been tested on an experimental model of heterogeneous high-dosage irradiation of a non-human primate. Medullary cells were sampled after irradiation, expanded and reinjected into the animal, seven days after irradiation; the results obtained showed a real but

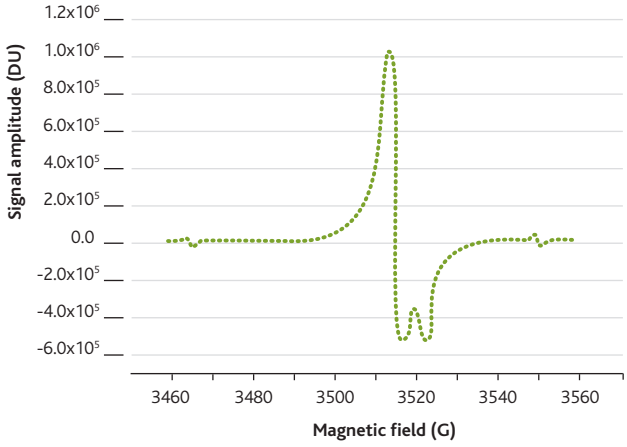
Filling of tubes with fixing mixture in order to fix chromosomes.

minimal effect on medullary aplasia. However, the irradiated animals developed a MOFS, suggesting the need to use other types of cell to correct the functional deficits observed. In the light of this, studies were undertaken in 2004 aimed at demonstrating the possibility of transplanting human mesenchymatous stem cells (MSC) into irradiated immunodeficient mice (NOD-SCID), in which it is possible to assess the implantation, proliferation and differentiation of the grafted human MSC. These studies show that the MSC are capable of implantation in numerous organs following a whole-body irradiation and that they migrate in preference towards the damaged zones following an abdominal irradiation. The results obtained also show that once implanted, the MSC proliferate and differentiate by acquiring the characteristics corresponding to the receiver tissue, in particular for the vascular system, the kidneys and brain. These results have led to the current study of molecular addressing mechanisms for the MSC towards damaged tissue and their involvement in the functional regeneration of the damaged tissue.

Molecular therapy

A European contract called NAIMORI brought together between 2001 and 2004 a number of European teams (CIEMAT, Madrid (Spain); Erasmus University of Rotterdam (The Netherlands); ILM/University, Ulm (Germany); CEA/Évry; IRSN) to evaluate the response of haematopoietic tissues and human epidermis to radiation and to seek new therapeutic approaches to medullar aplasia, inflammation of the tissues and the cutaneous radiation syndrome. IRSN was responsible for the work to characterise the generalised inflammatory response and its limitation by cytokines. The experimental model adopted was whole-body or abdominal irradiation of mice, some treated by therapeutic agents.

The animal survival rate and the recording of numerous biological parameters were supplemented by a histological analysis of sampled tissues. The association of thrombopoietin (TPO) with interleukins (IL) 4 or 11 was shown to be more effective for animal survival than TPO alone. This improved animal survival rate cannot be explained solely by the restart of blood-cell production; the results suggest that the combined TPO and interleukin treatment reduces radiation-induced inflammation and acts on vascular permeability. In addition, in the case of abdominal radiation alone, a remote effect on the lungs that were not included in the radiation field was observed. This effect on the lungs could result from the action of



Irradiation and contamination accidents – EPR signal of hydroxyapatite in tooth enamel showing a high dose (60 Gy).

Change of culture medium for human adult stem cells.

circulating inflammatory mediators arising from the gastro-intestinal response to radiation.
All the results obtained in this European programme were incorporated in nine IRSN scientific publications. They tend to show that the three major types of tissue that determine the outcome for victims of radiation are the haematopoietic, epithelial and vascular tissues. The regenerative capability of the stem cells responsible for the repopulation of haematopoietic and epidermal tissues determines the response of these two types of tissue. Simultaneously, the inflammatory response developed by the irradiated endothelial cells interferes with tissue repair.

Dose measurement by electronic paramagnetic resonance

IRSN is studying spectrometry using electronic paramagnetic resonance (EPR) with a view to developing a technique for the determination of doses received in different parts of the organism to establish the best possible diagnosis and propose the most appropriate therapeutic strategy. This technique involves an assessment of doses received by biological specimens that retain the free radicals created by the ionising radiation; the quantity of free radicals is directly proportional to the dose absorbed; the number of free radicals is determined by placing specimens in a magnetic field and quantifying the absorption of microwave radiation under resonance conditions.
This technique has been in use at IRSN for several years for small *ex vivo* specimens requiring invasive sampling (bone, tooth enamel, dentine) for material arising from the victims' environment (sugars, etc.), or for exposures to photons or electrons. It was successfully applied to the victims of accidental exposures in Georgia and Poland. In 2004, this technique was extended to the case of an exposure to a mixed field (photons + neutrons) typical of a criticality accident. In particular, a study showed and quantified the difference in sensitivity of dentine and tooth enamel to photons and neutrons. These dosimetric properties enabled the experimental determination of the photonic and neutron components of a mixed field using EPR spectrometry measurements on enamel and dentine. The measurement protocols introduced at IRSN were validated during the third international dosimetry intercomparison using EPR spectrometry on tooth enamel.

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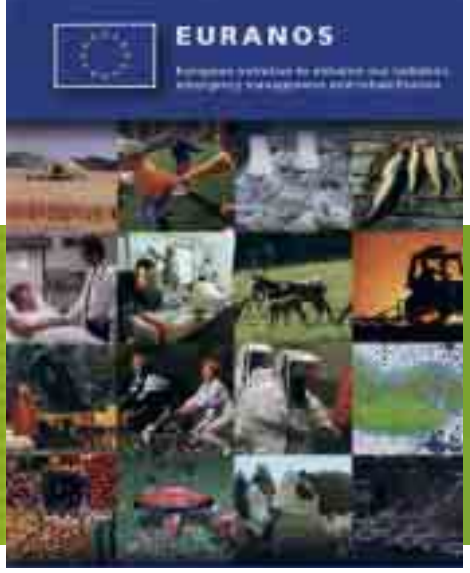
EUROPEAN FIRST PROJECT

During therapeutic radiation for the treatment of cancer, the healthy tissue surrounding the tumour may be damaged.

These lesions may have serious consequences, such as tissular aplasia or fibrosis. Their existence limits the effectiveness of treatment by radiation, forcing a reduction in doses received by the patients.
In 2004, the FIRST project was accepted under the 6th FPRD.
IRSN is responsible for studying the gastro-intestinal system.
The Institute is also involved in the study of the effects on the skin, as well as in a study into the preparation of mesenchymatous stem cells for grafting purposes.



Management of **post-accident situations**

In 2004, the major part of IRSN's research into the management of post-accident situations came under the international projects EURANOS and CORE.

EURANOS is a project coordinated by the German organisation FzK, which brings together nearly 50 teams and 20 countries. Adopted by the European Commission under the 6th FPRD, its main aim is to define possible actions for the rehabilitation of agricultural and built-up areas following an accident resulting in long-term radiological contamination. The work began in 2004 with the setting-up in France of groups of relevant parties (agricultural technical institutes, local government services, elected representatives, experts), who will be tasked with proposing appropriate rehabilitation strategies for the various post-accident situations: transition between the emergency phase and the start of post-accident phase, the first weeks following the accident and the later years.

The CORE programme aims to achieve long-term rehabilitation of living conditions for the populations of the four districts of Byelorussia contaminated by the Chernobyl (Ukraine) accident, by means of a range of actions in the fields of agricultural development, health, radiological protection and education. IRSN is contributing to this in the health and education fields.

International cooperation to **improve control over radiological and nuclear risks**

Collaboration between nations enables resources to be shared, knowledge to be enriched and skills reinforced. In the fields of research into radiation protection and nuclear safety and reliability, the international aspect of the IRSN's work develops year on year. Its major aim is to deepen scientific and technical understanding and to develop tools for the modelling of phenomena.

By enabling an increase in knowledge and providing additional tools, especially calculation codes, and optimising methods, the international cooperation developed by IRSN contributes to a better understanding of radiological and nuclear risks and to improvements in their control. The exchanges and activity are carried out within the framework of bilateral or multilateral agreements, programmes launched by community or international authorities: European framework programmes for research and development (FPRD), and projects carried out under the auspices of the OECD Nuclear Energy Agency (NEA). They also come under the working groups and committees of the IAEA, NEA, UNSCEAR and the European Commission, etc. These exchanges and activities lead to conclusions that may have

French-German Initiative for Chernobyl (FGI): steering committee meeting on 6 October 2004 in Kiev (Ukraine).

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INTERNATIONAL CONFERENCE ON THE FGI RESULTS

On 5 and 6 October 2004, IRSN, GRS and the Chernobyl centre organised an international conference in Kiev on the results of the French-German Initiative (FGI) for Chernobyl, launched in 1996 by the French and German Ministers of the Environment to mark the 10th anniversary of the accident.

This conference was attended by about 200 people from Ukraine, Byelorussia, Russia, the European Union and international organisations (EBRD, EC and IAEA).

In fact, while many studies have been carried out in the past, mainly in Ukraine, Russia and Byelorussia, on the consequences of the Chernobyl accident from safety, environmental and health viewpoints, the results were scattered, sometimes ignored and often heterogeneous.

The FGI mobilised numerous teams of scientists around 35 projects. It facilitated the gathering of data, their validation and organisation into coherent databases that were accessible to public authorities, scientists and the public. The aim was to make available to the international community a unique tool for the collation and diffusion of scientific information that could be used to model phenomena and the management of crisis situations and in the development of systems to monitor the consequences of an accident on the health of populations. The data set thus created on the consequences of the accident is accessible on the website www.fgi.icc.gov.ua.

Rostrum at the international conference on 5 and 6 October 2004 in Kiev (Ukraine).

the advantage of an international consensus. In 2004, the activities of IRSN in this field were concerned with the continuation of the projects in the 5th FPRD, preparation and initiation of new 6th FPRD projects, completion of the programme under the Franco-German initiative for Chernobyl and increasing bilateral collaboration, especially with the United States and Russia.

Cooperation between IRSN and the CPHR on the study of the Chernobyl accident consequences on the health of children

In 2004, IRSN and the Cuban CPHR took a first step towards cooperation on the protection of man and the environment against nuclear radiation. This project is based on the experience of the CPHR with the treatment of Ukrainian children irradiated following the Chernobyl accident. About 8,000 children have been received in Cuba since 1986 for treatment under an inter-government agreement between the two countries.

In association with the relevant Ukrainian organisations, the activity was concerned with the study and extension of the dosimetric and medical databases for the period 1990-2004. To complete the activity, the medical teams in the Cuban centre of Tarara, where the children were treated, were contacted. Finally, the current cooperation between IRSN and the CPHR in the radiobiology field continues, with in particular the hosting of two Cuban students in IRSN's laboratories.

Participation by IRSN at the IAEA conference in Beijing

IRSN was involved in the international conference organised by the IAEA between 18 and 22 October

IRSN has signed cooperation agreements with radiation protection and nuclear safety organisations in 27 countries:

Germany, Argentina, Belgium, Byelorussia, Bulgaria, Canada, China, South Korea, Cuba, Egypt, Spain, United States, Finland, Hungary, India, Italy, Japan, Morocco, Czech Republic, Slovak Republic, United Kingdom, Russia, Slovenia, Sweden, Switzerland, Tunisia, Ukraine.

1st meeting of the SARNET steering committee on 2 April 2004, during the 6th FPRD.

2004 in Beijing on the theme "Continuous Improvement of Nuclear Safety in a Changing World". The main aim of this conference was to contribute to the definition of the Agency's 2007-2011 programme on the subject of nuclear safety by promoting exchanges of view in this field.
In addition to the presence of nuclear safety experts, this conference brought together numerous managers of organisations who came to debate the major questions associated with nuclear safety. Thus, the IRSN's Director General spoke on the following subject: "The challenge of sustainable development in the nuclear field: Research is more than ever a vital component of nuclear safety and radiation protection policies." He stressed in particular the importance of developing and harmonising risk assessment methods to meet society's expectations in the field of radiological and nuclear risk management.
More generally, this conference aimed at providing answers to the questions raised by the deregulation of the electricity markets, the diversification of technologies and the globalisation of economies, especially in the fields of quality assurance, knowledge management, the harmonisation of standards and safety practices.

Participation by IRSN in the 6th FPRD

The 6th FPRD (2002-2006) is directed towards greater integration of teams by sharing resources, skills and knowledge, mainly through the creation of long-term networks of laboratories.

In 2004, IRSN continued its work under projects adopted following the first call for proposals:
- the SARNET network of excellence, relating to severe accidents, headed by IRSN, that coordinates the efforts of around 250 scientists in 49 different organisations;
- the ERICA project, dedicated to the protection of the environment against radiation, in which IRSN is participating in the assessment of the radionuclide transfers into the environment and the resultant risks;
- the EURANOS project, concerning the conduct of the post-accident phase, under which IRSN is working on the definition of appropriate countermeasures;
- the NF-PRO project for the behavioural modelling of fission products in the geosphere, with a view

FOCUS

DEVELOPMENT OF COOPERATION BETWEEN IRSN AND THE NRC

In 2004, IRSN and the NRC (United States) increased their bilateral cooperation through numerous exchanges on the subject of the experimentation and modelling of severe accidents.

Amongst other things, the NRC decided to participate in the fire programme (PRISME) undertaken in the DIVA installation in Cadarache (Bouches-du-Rhône). Similarly, IRSN and the NRC are cooperating actively in the field of physical protection for nuclear material and installations, especially the transport of nuclear materials. In addition, discussions were initiated in October 2004 with the NRC on new experimental programmes, and especially the SOURCE TERM programme that, amongst other things, will address subjects associated with the releases of iodine or fission products. Finally, IRSN and the NRC are continuing their cooperation under the CABRI-water loop programme on reactivity accidents that can affect pressurised water reactors.

to determining the performance of their containment during storage;

- the COWAM 2 project on the governance of risks associated with waste storage.

During 2004, IRSN also participated in the preparations for two projects in the radiation protection field, which were adopted under the call for proposals in 2004. These are CHRONIC RAD EPID, a project led by IRSN which addresses the epidemiology of cancers associated with ionising radiation, and CONRAD, a project dedicated to dosimetry.

Development of cooperation between IRSN and Russian institutes

In 2004, IRSN increased its cooperation with the Russian institutes, that began in the 1990s, under the agreement between CEA and the Russian Minister for Atomic energy (Minatom now Rosatom).

This cooperation now covers a wide field: human protection, criticality, design and safety of liquid metal reactors, fuel and severe accidents in water reactors.

As far as human protection is concerned, the subjects cover the study of the tissue banks of irradiated victims as well as an assessment of the pathologies that could result from chronic contamination by caesium.

2004 was also notable for an increase in cooperation in the crisis management field between IRSN and Rosatom. Activities will include the comparison of crisis management procedures, including tools, the organisation of international crisis exercises concerning the transport of nuclear material, participation in exercises in France and Russia and the response strategy in an emergency situation or during the post-accident phase.

FOCUS

END OF THE EUROPEAN ASTRID PROJECT

The ASTRID project, set up by the European Commission under the 5th FPRD and coordinated by IRSN, was completed at the end of 2004.

Eight partners participated in this, including the safety authorities from Finland (STUK), Hungary (HAEA) and Sweden (SKI), and technical institutes such as FzK, GRS (Germany) and VUJE (Slovakia).

The first objective of the project was to define an assessment method for the state of the installation in case of an accident affecting a European light water reactor (PWR, WER, BWR), in order to structure and harmonise the technical expert assessment at a European level: this objective was achieved through the definition of an expert assessment method.

The second objective was to develop a computerised crisis tool to support the expert assessment method, to diagnose the status of the affected installation and rapidly assess the releases (real or potential) based on pre-calculated discharges. It should also be able to assess in more detail the possible developments of an accident, by simulating the thermohydraulic behaviour of the reactor, and the emission and transfers of fission products in the installation. The tool is currently in a pre-operational state: collaboration with GRS will contribute to rendering it operational.

Full meeting of the International Commission for Radiological Protection (ICRP) in Beijing (China) in October 2004.

New recommendations concerning radiation protection

2004 was marked by the consultation process initiated by the ICRP with professionals in the radiation protection field, national authorities, international organisations and more broadly the general public, to listen to their opinions on the draft for new general recommendations concerning radiation protection. The radiation protection doctrine is developed at international level within a range of scientific, technical and regulatory bodies. According to the terms of reference of the relevant international agencies, IRSN specialists participate in this work either as experts or as part of their public service role or in support of the authorities. It must be remembered in this context that ICRP publications serve as a basis for the drafting of international regulations, especially the European directives and the core standards of the IAEA. The international bodies involved are: UNSCEAR, ICRP, IAEA (RASSC), Euratom (groups of experts under articles 31 and 37), NEA (CRPPH), IUR and organisation for radiation protection standardisation (ISO, IEC). In this context, IRSN has increased and structured its internal and external consultation process. Within the Institute, a network was installed in 2004, linking the IRSN specialists involved with international authorities, as well as the representatives of the directorates concerned. Amongst the seminars organised, the first, for which preparations were made in 2004, was held on 27 January 2005 and involved a presentation of the draft for future recommendations by the IRSN's representatives participating in the work of the ICRP. Externally, the Institute has set up a pluralist working group whose aim is discussion with the players involved (authorities, industry, associates, institutions). This group met twice in 2004 and was able to distribute information on the work of the ICRP and other major international agencies concerned with radiation protection. Finally, to parallel the changes in radiation protection doctrine, IRSN wanted to examine in more depth certain much-discussed subjects, such as the effects of low doses (especially following the publication by non-institutional experts of a report calling into question the method used by the ICRP to estimate the risks associated with internal contamination) and the concept of environmental protection, with the aim of updating the Institute's position. Concerning environmental protection, it must be emphasised that, up to now, the approach has been characterised by the ICRP's hypothesis that man was the creature that was the most radiation-sensitive, and that the measures taken to protect humanity should guarantee protection for the environment. Over the decade, the lack of scientific demonstration of this statement and the rise in influence of environmental preoccupations, as demonstrated by numerous international conferences, has led to a re-examination of this hypothesis. It thus became important for the Institute, which is one of the few organisations in the world to undertake research into radioecology, to prepare a doctrinal statement in this field. Furthermore, IRSN has undertaken the translation into French of the first publication of the ICRP dedicated to this subject (publication 91 issued in 2003 and entitled "A framework for assessing the impact of ionising radiation on non-human species").

A radon metrology training session in Le Vésinet (Yvelines).

Contributing to training in radiation protection

One of the missions assigned to IRSN when it was formed was to contribute to the radiation protection training of health professionals and those who are exposed in the course of their work. This activity is based on a recent regulation aimed at ensuring that greater account is taken of the risks to which professionals are exposed.

An activity to help **prevent risks** and their **possible consequences**

As a research and expert assessment establishment, IRSN has a duty to provide training and to contribute to teaching in the areas in which it has competence: nuclear safety and radiation protection.

The ultimate aim of this training and education is not only to provide theoretical knowledge, but also to promote tools and methods aimed at minimising nuclear and radiological risks in all the activity areas under consideration. Training and education must contribute to promoting prevention and they therefore demonstrate the social worth of the Institute to those economic, industrial or institutional players involved in these risk-bearing activities.

It is for this reason that, apart from the participation of IRSN agents in teaching during the university year – long recognised as effective –, the decree relating to the missions of the Institute focuses on the professional radiation protection training. It targets specifically medical or paramedical staff involved with medical imaging or therapy using ionising radiation. This explicit mention of the medical sector echoes the preoccupations of the public authorities and the recent development of legislation and regulations aimed at providing greater protection for personnel and patients. In this context, IRSN must:

- continue, or increase, its presence on university or school courses by giving priority to a specific training project concerning nuclear safety and radiation protection;
- create the conditions for the development of a sector for professional training aimed at the various professional categories concerned and demonstrating the Institute's involvement in "hands on" prevention.

Following the creation within IRSN of a pole for professional training, 2004 was set aside for consideration of a strategy to be implemented

20
training sessions
organised and completed

on this subject and for the setting-up of a range of training activities for specific categories of professionals.
In strategic terms, the aim was to set development targets taking into account the IRSN's reference role in nuclear safety and radiation protection, identify partners, classify the categories of priority professionals and finally reconcile the training quality with the economic balance of an activity that relates to a competitive sector.
The first training modules completed in 2004 were selected on the basis of expressed requirements and their feasibility. The priority categories were workers exposed to ionising radiation: IRSN employees, approved organisations tasked with measuring radon in establishments open to the public, company doctors and persons tasked with monitoring workers' dosimeters, as well as the factory inspectorate.
At the request of the local information commission in Saclay (Essonne), a course on "radiation protection, citizenship and governance" was arranged for its members, local elected representatives, representatives of associations and teachers. Finally, several specific activities to raise awareness were arranged in the hospital sector, forerunners of more sustained activity during 2005.
In 2004, all the sessions were organised by IRSN management. Several other offers were made of training in radiation protection in the medical field. These offers may be supplemented by sessions arranged at a client's request. Several dossiers of this type investigated in 2004 should come to fruition in 2005.

FOCUS

TRAINING ON RADON

Since 2004, IRSN has been organising training courses on the radon metrology for any organisation wanting to participate in an approval scheme for radon measurement in locations open to the public. This training has been made necessary by recent changes in legislation in this area.

The new French regulations relating to the management of risks associated with radon, following on from the directive 96/29/Euratom, introduce an obligation for owners of locations open to the public to "implement measures to monitor exposure to natural radiation where these are likely to affect health". These measures must be implemented by IRSN or by an approved organisation (decree dated 15 July 2003). Obtaining approval issued by the Minister for Health in the light of a recommendation from the national approval commission is subordinate, amongst other things, to the provision of proof that the organisation has achieved competence either through practical experience or by attending specialist training in the radon metrology.
The aim of the training is to familiarise students with the various techniques for detecting radon as well as the investigations required when the presence of this gas has been demonstrated.
In 2004, more than fifty requests for approval were submitted to the commission and IRSN trained around 20 students.
Four training sessions are planned for 2005.

Trainees receive a combination of theoretical and practical training.

Each training session is attended by about 15 external participants.

Training sessions carried out in 2004

Subject of sessions or professional training activity	Session duration	Number	Target audience of sessions in 2004	Number of students trained
Radon metrology	3 days	2	Approved organisations, housing experts	21
Dosimetry management at work	2 days	2	Industrial medical officers, radiation protection officers	12
Training in the radiation protection of exposed workers	1 day	7	Exposed personnel	110
Radiation protection inspection in a work environment	3 days	2	Factory inspectors, medical inspectors	40
Raising awareness in a medical environment	1 day	6	Hospital doctors and personnel, industrial medical officers	80
Radiation protection, citizenship and governance	1 day	1	Elected representatives, CLI members, teachers	25
TOTAL		**20**		**288**

Real-time radiological monitoring of French territory in the warning systems remote monitoring room in Le Vésinet (Yvelines).

Permanent monitoring in matters of radiation protection

The public service missions assigned to IRSN relating to radiation protection concern the radiological monitoring of the environment in France, assessment of human exposure and management of radiation sources.

Radiological monitoring of the environment

Radiological monitoring of the environment is provided by IRSN, using telemetry devices and laboratory analysis of environmental samples. It operates throughout the territory using stations that may or may not be located close to facilities that could discharge radionuclides into the environment.

The remote monitoring networks

These provide real-time radiological monitoring of the environment by means of self-contained beacons that continuously measure the radioactivity of the area where they are located. In more detail, two networks provide air monitoring (Téléray for the ambient gamma dose rate and DARA for atmospheric dust). Two other networks monitor the water (Hydrotéléray for rivers and Téléhydro for wastewater in towns).

Once an increase in radioactivity is detected, a warning is sent to IRSN and an initial investigation is mounted. There were a dozen trips of Téléray beacons in 2004: most were of meteorological origin or resulted from the near proximity of the beacons to a transport of radioactive containers. In addition, the year 2004 saw the setting up of a "supervisor" enabling all the data from the remote sensing network to be centralised on a server independent from the establishment server. In parallel, most of the equipment was modernised with a view to improving data acquisition and processing.

The sampling networks

These supplement the environmental monitoring by taking measurements on samples from various environmental locations. In 2004, 32,727 samples were analysed. The samples are taken by IRSN or technical associates (DDASS, French Navy, Météo-France, EDF, COGEMA, etc.). They enable changes in activity level to be monitored in the various environments to which the public is exposed. Sometimes, these networks may reveal abnormal situations and they enable the consequences to be estimated. This was the case in 2004 for a special study relating to the consequences of the flood conditions on the Rhône in 2003.

500
sampling points
across the country

1,000
dosimetric
measurement points

213
beacons making up
the territorial remote
monitoring network

Nearly
100,000
radiological analyses
carried out

Environmental monitoring by radiation monitors is completed by a network of manual sampling operations.

Towards an optimisation of monitoring and greater visibility

In order to improve the management of the mass of data acquired by these networks, IRSN has initiated work aimed at developing a unique computer management tool. Discussions began in 2004 to identify the exact role of this monitoring. This will lead to a redeployment of resources in the years to come.

Finally, a new website (http://eau.irsn.org/) went on line at the end of 2004. There, the general public can find the data relating to the radiological monitoring of the various aquatic mediums (seawater, rain, rivers, subterranean waters, etc.).

The permanent monitoring mission requires from the laboratories a rigour in sample analysis that the Institute wants to inculcate by means of accreditation to its instrumentation laboratories *(see Quality chapter, part 3)*.

Inside a SARA monitor (automated aerosol radioactivity monitoring device).

Environmental monitoring in French Polynesia

In 1962, France set up a radiological monitoring network in Polynesia. Since 1976, the Institute has itself been managing a network spread over seven islands (Tahiti, Maupiti, Hao, Rangiroa, Hiva Oa, Mangareva and Tubuai). The total area covered by this monitoring is equivalent to that of Europe. The sampling strategy adopted makes it possible to determine the exposure of individuals either externally, by inhalation or ingestion. The primary effort addresses the latter component, for which a sampling plan was established based on a nutritional study updated in 1991. The radioactivity analyses cover gamma, strontium and plutonium emitters. Caesium 137, detected at very low activity levels in virtually all the 400 samples taken, is the predominant radionuclide. The last dosimetric analysis carried out by IRSN concerned 2003. The total "added" dose attributable to fallout from atmospheric testing is less than 5 µSv per year. IRSN prepares an annual report that is available on the Institute's website.

Team from the source expertise unit.

Monitoring ionising radiation sources

Concerning the monitoring of ionising radiation sources, IRSN carried out the following principle operations in 2004:

■ technical examination of 18 initial or renewal requests for authority to hold or distribute sources, in response to tasking from the competent authorities (DGSNR, AFSSAPS, DSND, prefectures);
■ technical examination of three requests for dispensation from CAMARI (certificate attesting the ability to handle radioscopy and industrial radiography equipment) at the request of the departmental labour directorates;
■ provision of advice on four technical or regulatory subjects associated with the use of ionising radiation sources:
- exemption criteria for industrial electrical generators;
- draft decree on the monitoring of the movement of sources;
- European equivalences of the radiation protection officer;
- categorisation of sealed sources in accordance with the IAEA and in accordance with European Directive 2003/122; application to the case of France.

In addition, the following statistics for 2004 illustrate the magnitude of the task that has been assigned to IRSN of managing the national inventory of ionising radiation sources:

■ 2,400 authorisations issued, renewed or transferred between authorities;
■ 4,700 requests for the supply of sealed sources;
■ 1,500 requests for the supply of unsealed sources;
■ 3,300 recovery certificates;
■ 460 requests for the export of sources;
■ 300 requests for the import of sources.

The large number of authorisation requests that were subject to modifications in 2004 can be explained by transfers of skills between authorities. Such changes have to be transferred by IRSN to the national inventory.

Travelling exhibition at La Rochelle in June and July 2004.

Public information

One of the IRSN's missions is to provide information to the public about radiation protection and nuclear safety. To achieve this, the Institute has developed a range of activities to enable it to provide answers to society's concerns about the technical and health risks associated with nuclear matters. There is also a need to respond to the public's desire for involvement in the subject. This policy shows that the Institute is ready to listen to the concerns of society.

Information and communication activities

Information activities undertaken by IRSN in the field of radiation protection and nuclear safety have to contribute to the education of the public on risks and their prevention. They also enable the Institute's scientific output and activity to be promoted.

Information for the general public

Intended primarily for the general public and for students, the road show entitled "Nuclear under close surveillance" was conceived in partnership with DGSNR. This interactive and educational exhibition addresses by means of panels, models, computer games and videos, the numerous subjects associated with nuclear matters: radioactivity and health, nuclear reactors, the Chernobyl accident, the fuel cycle. Each year, it visits any locality that submits a request. In 2004, the exhibition visited Saint-Dié (Vosges), Metz (Moselle), La Rochelle (Charente-Maritime), Martigues (Bouches-du-Rhône): a total of 6,500 visitors including 1,120 students, during 25 weeks of operation. In parallel to the exhibition, series of scientific lectures were organised on subjects of general interest: the Chernobyl accident, radioactive waste, nuclear installations and earthquakes, nuclear power stations under extreme climatic conditions, ionising radiation and health.

IRSN participated in a range of events aimed at raising public awareness of the challenges faced by science. Thus, on 25 May, on the occasion of the open day at Croissy-sur-Seine (Yvelines), the Institute welcomed a large number of visitors to its laboratories in Le Vésinet. Workshops were available on the measurement and monitoring of

Open day on the Le Vésinet site in May 2004.

Road show "Nuclear under close surveillance"
6,500 visitors including 1,120 students; 4 towns visited

15 conferences organised

778 requests for information processed via the contact box on the website

12,000 copies of the annual report issued

Travelling exhibition for junior high school pupils.

radioactivity in the environment, intervention and assistance in radiation protection.
Similarly, IRSN participated in the "Science Fair" (15-17 October). This event aimed to familiarise visitors with science and technology and to help improve their understanding of the challenges of research. The Institute had a stand in the Science Village installed by the Ministry in the Luxembourg garden. 16,000 people visited the Village. IRSN also took part in the events organised by the local council in Clamart (Hauts-de-Seine) during a conference on 15 October on nuclear matters and the health applications of ionising radiation.

Information for professionals

IRSN participates in exhibitions and conferences to provide information for professionals in the environmental, health and nuclear safety fields. In 2004, the Institute exhibited its radiation protection expert assessment activities at specific conferences and exhibitions: doctors (MEDEC, 16-19 March), radiologists (open days of the French radiological society, 1-2 October), radiation protection officers (congress of the SFRP, December). At the MEDEC, the Institute jointly organised on 17 March a conference on "health effects resulting from radiation of the foetus and the infant". IRSN also participated in the 11th Congress of the IRPA (23-28 May), held in Madrid (Spain). At this congress, that every two years brings together the experts in the field, IRSN scientists presented their recent work and the Institute had a stand.
In addition, the Institute participated in Pollutec (30 November-3 December), a trade fair for environmental professionals, where its stand provided details about the services, nuclear-related and otherwise, that it can offer to industry and local authorities.

Finally, the 6th EUROSAFE forum that was held in Berlin on 8 and 9 November 2004: this was organised by IRSN and GRS and brought together experts in nuclear installation safety, waste management, radiation protection and nuclear material safety *(see Focus p. 86)*.

Internet

The Internet is a major vehicle for information and cannot fail to develop further. The Institute's website was created in 2002 and saw its usage rise significantly in 2004, with more than 690,000 hits, or an average of 25,000 single visitors per month, mainly professionals. The main activity on the site in 2004 involved a programme of information publication and update and improvements in the graphical identity of the Institute's thematic sites. In addition to the information provided on the institutional site, IRSN administers specific sites, mainly linked to databases or projects being monitored by the Institute: scientific site, SISERI, CRISTAL, portal on environmental monitoring, etc. Work has also begun on the contact box, to improve it and to ensure that visitors' requests are answered as well as possible. Finally, consideration is now being given to a rebuild of the site to make it a portal site, structured by the public.

IRSN's stand at the Pollutec exhibition in Lyon in December 2004.

Participation in
5
professional exhibitions
and public events

30,000
information booklets
and 4,500 training
pamphlets distributed

55,548
visits in 2004,
to the IRSN's
scientific site,
or about 2,000 single
visitors per month

Nucléon guides members to help them discover IRSN.

FOCUS

EUROSAFE 2004 FORUM

On 8 and 9 November 2004, IRSN and GRS jointly organised in Berlin the 6th EUROSAFE forum on the subject: "Learning from experience – a cornerstone of nuclear safety."

EUROSAFE is the fruit of a European initiative in 1999 by IRSN and its German opposite number GRS; its aim is to promote convergence in the technical practice of nuclear safety across Europe. It is based on an annual forum, a half-yearly scientific and technical magazine and a website.

The forum was attended by about 450 experts from technical safety organisations, research institutes, regulatory authorities, electricity companies, industry, public authorities and non-governmental organisations from the European Union, Switzerland and Eastern Europe. Intended to foster closer collaboration between technical safety organisations, these scientific and technical days offer the chance each year to debate matters relating to experience gained in nuclear safety.

The latest work by IRSN, GRS and their partners in the European Union and Eastern Europe was described.

All information on the forum, the texts of the presentations and issues of the EUROSAFE tribune are available at www.eurosafe-forum.org.

The next forum, organised jointly by AVN, IRSN and GRS, will be held in Brussels on 7 and 8 November 2005.

The Eurosafe forum in November 2004 in Berlin.

For scientific communication, the rebuilding of IRSN's scientific website (http://net-science.irsn.fr/) has been initiated to improve its ergonomics and readability.

The aim of this site is to ensure that the Institute's teams and work are known. The new version is expected to be on line at the end of the first half of 2005. Action has also been taken to ensure that the site is listed by Internet search engines.

Publications

In 2004, IRSN continued to publish information documents intended for the general public, professionals and scientists. In this way, IRSN provides the public with a collection of pamphlets on radioecology, the transport of radioactive materials, radon, radioactive waste, etc. In 2004, this collection was supplemented by a new document on caesium.

A collection entitled "The professionals collection" has also been created and six pamphlets updated and distributed at the exhibitions and conferences attended by the Institute. These address the following subjects:

- aiding medical teams following radiological accidents;
- medical exposure to ionising radiation;
- ionising radiation and health;
- services provided in non-nuclear fields;
- operational radiation protection, services and expert assessments;
- response to a nuclear accident.

Similarly, the collection of IRSN scientific booklets has been updated and developed, and three sub-collections created. *Lignes directrices* consists of guides or booklets of recommendations, such as the completely new publication *Vos patients et les*

Information is provided for the general public by the IRSN travelling exhibition.

rayons, un guide pour les médecins praticiens, a translation of the ICRP publication *Radiation and your patient: a guide for medical practitioners*; IRSN is here fulfilling its public service role by the free distribution of this guide to the medical world. *Colloques* contains contributions to the symposia or conferences organised or jointly organised by IRSN (in 2004 for example ECORAD). *Sciences et Techniques* brings together the sum total of knowledge of radiation protection or nuclear safety. These publications are coordinated and for the most part written by IRSN scientists, with participation from one or several external authors. The quality of these works is guaranteed by an editorial committee.

Finally, each year IRSN publishes its annual report distributed to higher authorities, opinion formers and to points of contact in the press and associations, both in France and internationally. In 2004, 9,000 copies of the French version of the 2003 annual report were produced, and 3,000 of the English version.

9
national nuclear crisis exercises (civilian sector)

2
actual mobilisations of IRSN's Emergency Response Centre

24
meetings held by standing advisory groups

Technical support and assistance for public authorities

IRSN carries out its work in a spirit of partnership with the public authorities, whether acting on behalf of the authorities (technical assistance) or providing technical support.

For IRSN, the key to progress in the fields of expert assessment and technical support lies in the pursuit of technical dialogue with manufacturers and the formalisation of the Institute's technical approach by publishing policy documents.

> 90	Technical support with regard to nuclear and radiological risk
> 128	Operational support in the event of a crisis or radiological emergency

IRSN analyses technical dossiers supplied by EDF.

Technical support with regard to nuclear and radiological risk

At the request of the authorities, IRSN assesses technical dossiers submitted by operators. These dossiers concern the safety of reactors, plants, transport and dismantling as well as waste management and preventive measures with regard to earthquakes. They also concern radiation protection of persons and the environment. The Institute analyses all the risks and draws up reports on the provisions proposed to control them. Those reports are then transmitted to the authorities or standing expert groups.

608
technical reports to the public authorities (excluding defence-related activities)

Participations in nearly
600
BNI inspections

107
test reports issued on cross-comparison studies of environmental radioactivity measurements

150,000
workers monitored by external dosimetry

21,089
radiotoxicological analyses

125
anthropogammametric analyses

Reactor **safety analysis**

IRSN provided support for DGSNR in assessing the operating safety and radiation protection of the 58 reactors on French nuclear power plants. In particular, the Institute examined the risks of clogging of sump filters and the protection of those reactors from external hazards. It also assessed the safety of the EPR nuclear reactor project and followed up experimental reactors.

Assessment of pressurised water reactors (PWR)

IRSN provides support, in particular, for the examination of work and inspection programmes conducted during refuelling shutdowns, the examination of general operating rules, participation in monitoring inspections and the analysis of feedback. IRSN also contributes to the areas covered by reactor safety reviews. It examines data submitted by EDF on those topics, jointly with EDF, and reactor safety reviews requested by DGSNR in the context of 10-yearly outage programmes.

Examination of work and inspection programmes conducted during refuelling and reactor maintenance shutdowns

In the course of 2004, IRSN conducted examinations during some 40 shutdowns lasting between three and eight weeks. In each case, the Institute studied the work and inspection programmes planned by the operator, followed-up the performance of those operations and examined the results of start-up tests.

Examination of general operating rules

The operator modifies the technical operating specifications (STE) and periodic test regulations according to the modifications implemented on reactors and feedback received. IRSN gives its opinion on the acceptability of these documents from the safety point of view. Moreover, in 2004, IRSN issued about 100 reports on acceptability of EDF requests for concessions with regard to technical operating specifications (STE) for various reasons (operating contingencies, equipment unavailability, etc.). In this context, after the heat

The Fessenheim nuclear power plant (Haut-Rhin).

wave in summer 2003, IRSN analysed an STE amendment dossier aimed at relaxing some operating requirements concerning the maximum tempera-ture inside the reactor building and the annual scheduled outage time authorised for the cleaning of some heat exchangers. In the case of the latter, IRSN was unable to approve the DGSNR proposal in view of the supporting evidence provided.

Reactor safety reviews and corresponding safety reports

During 2004, IRSN continued safety reviews on 900-MWe and 1,300-MWe reactors with a view to conducting third and second 10-yearly outage programmes, respectively. Every reactor undergoes a safety review every 10 years. This review entails verifying that power plants are maintained in compliance with baseline requirements on design and operation, and the study of possible changes in those baselines and corresponding modifications. The purpose of these modifications is to improve reactor safety. They are based on feedback received, new knowledge obtained and new safety provisions adopted for the most recent reactors whenever that is technically feasible and there is a significant gain in terms of safety.

Analysis of reactor operation feedback

IRSN examines feedback on reactor operation from various points of view including, in particular, events and anomalies.

■ The 681 significant events reported by EDF in 2004 were examined and are described in a computer database. The incidents that were most characteristic of safety failings were, or will be, submitted to thorough analysis and, in some cases considered to be precursors, probabilistic studies will be conducted in order to assess their severity in terms of risks of damage to the reactor core *(see Focus p. 99)*. Furthermore, IRSN sends reports on the most significant incidents to the IAEA in accordance with the terms of the international "Incident Reporting System".

■ A quarterly meeting is held between EDF, DGSNR and IRSN to identify events of a generic nature concerning power plants and to give advice on how

15
dose assessments
by biological dosimetry

134
assessments of human
radiation protection

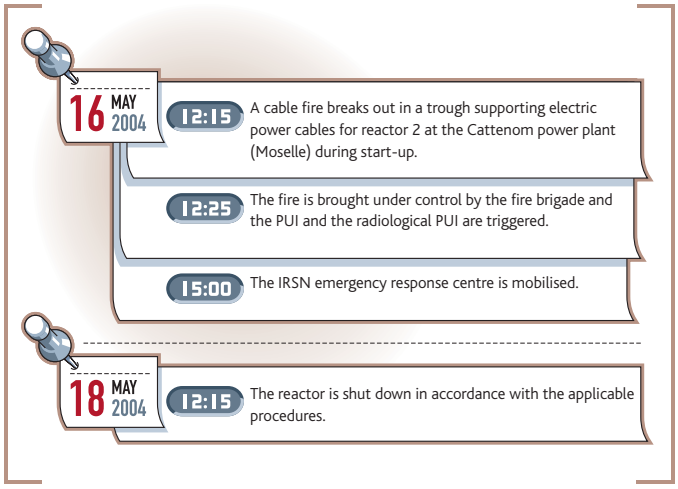
FOCUS

INCIDENT AT FESSENHEIM

An error in the configuration of a pipe system on 4 January 2004, due to inadequate preparation of a servicing operation led to the entry of resins into the primary cooling system of reactor 1 at the Fessenheim power plant (Haut-Rhin).

Although the system was quickly returned to compliance, the resins caused clogging of the sampling lines resulting in the loss of automatic monitoring of the concentration of boron in the water in the primary cooling system and several filters on the injection line at primary coolant pump joints which led to loss of the injection function. The numerous filter replacement operations required to recover the injection function led to the contamination of seven persons. IRSN examined the methods proposed by EDF to shut down the reactor and, more particularly, the risks posed by the presence of the resins in the systems with regard to cooling (blocking up pipes) and availability of the reactor's shutdown rod cluster control assembly (jamming during drop). IRSN then examined the results of inspections on the equipment concerned (pumps, measuring sensors, reactor control rods) and the monitoring programme proposed by EDF to follow up the changes in various parameters during the next operating cycle. IRSN recommended that EDF should pay special attention to the rod drop time and the fouling of some filters which could be due to the presence of resin residues. A thorough analysis of this event was started by IRSN and will form the subject of a report in 2005.

Management of significant events.



to deal with them. In this context, EDF and IRSN draw on lessons learned from events that have occurred in foreign power plants.

- Every three years, an assessment of reactor operation feedback for power plants in service is presented to the standing advisory group for nuclear reactors *(see Focus p. 94)*.
- In 2004, IRSN developed statistical event analysis tools which can be used to generate indicators in order to obtain an overview of changes in safety at power plants in operation.

Monitoring inspections

In 2004, IRSN supported basic nuclear installation inspectors in the preparation of nearly 300 moni-

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INCIDENT AT CATTENOM

A cable fire broke out in a trough supporting electric power cables for reactor 2 at the Cattenom power plant (Moselle) during start-up on 16 May 2004. The fire was brought into control by the fire brigade and the internal emergency plan (PUI) was triggered. The IRSN Emergency Response Centre was mobilised (see Focus p. 129) and the reactor was shut down in accordance with the applicable procedures.

Owing to the potential safety consequences of such an incident, IRSN conducted in 2004, a detailed analysis focusing on the following aspects:

- design: the incident was caused by the heating of 6.6 kV cables from the coolant pumps to the condenser. The pump motors for the Cattenom plant units required a power of 9 MW, instead of 5 MW as in the case of other 1,300-MWe reactors. The cables were not correctly dimensioned, however, and the trough concerned had recently been closed following modification work: as a result, the heat generated could no longer escape satisfactorily. The damaged cables were replaced before restarting the reactor and the troughs were re-opened on a temporary basis. It is planned to install cables with a larger cross section on the site's other plant units in order to prevent them overheating;
- management of the fire alert: the rapidity and effectiveness of external emergency actions were evaluated;
- human factors: the control of the reactor in these circumstances was examined;

This analysis will form the subject of an IRSN report scheduled for release in 2005. This event was reported to the IAEA.
In addition, IRSN assessed the steps taken by EDF for the restarting of the reactor and recommended that a cable and trough temperature monitoring programme should be implemented by EDF.

Power plant at Belleville-sur-Loire (Cher).

toring inspections on EDF reactors. IRSN accompanied the inspectors for some of those inspections.

Risk of clogging of containment sump filters

Clogging of sumps by debris originating, in particular, from heat-insulating materials following a break on the primary cooling system can jeopardise core cooling in the long term. For this reason, EDF conducted a study on design modifications to prevent this risk. Early in 2004, EDF put forward a dossier of assumptions it had adopted in order to define modifications to be made to all French power plants: the implementation of those modifications is scheduled to start in 2005. After examining this dossier, IRSN presented its conclusions to the standing advisory group for nuclear reactors on 22 December 2004. In drawing up this report, IRSN took into account the first results of an experimental pro-gramme it launched to evaluate the risk of chemical compounds being formed during the recirculation phase in the long term. The advisory group decided that some assumptions required further confirmation by EDF but that the solutions it had adopted should be implemented as quickly as possible on power plants.

Protection of reactors against external hazards

In this field, the year 2004 was mainly dedicated to pursuing safety assessments regarding the protection of reactors against floods of external origin. In this context, the maximum design flood levels and the dossiers of the plants at Belleville (Cher) and Le Bugey (Ain) were examined. These were considered to be priority sites owing to the considerable reinforcement of existing protection systems planned by EDF. This provided IRSN with the opportunity to express its opinion on the

FOCUS

INSULATION DEFECT ON VALVE ACTUATORS

An insulation defect was revealed, in September 2003, by accidental spraying of two valve electrical splice boxes on reactor 2 at the Penly power plant (Seine-Maritime).

The valves concerned, located inside the reactor building, must be able to operate in degraded ambient conditions including, in particular, when they are exposed to spraying. In the course of inspections conducted during the subsequent shutdown of the reactor, in early 2004, the operator detected cuts in the insulating material on the electric wires supplying power for the valves. The inspection of other actuators subject to the same qualification requirements revealed a large number of similar defects.

These defects were liable to jeopardise the operation of the actuators in an accident situation, i.e., emergency shutdown in safe condition. Furthermore, these defects may have concerned reactors at other power plants. For this reason, IRSN sent DGSNR a report, in 2004, recommending the inspection of all existing reactors during shutdowns. EDF subsequently confirmed the generic aspect of the defects, this being due to incorrect utilisation of the insulation removal tool before making connections.

Owing to the extent of the corrective work to be performed on reactors, IRSN recommended focusing on the minimum number of actuators at a first stage. The Institute took into account the respective weights in the probability of core meltdown and of the risk of a defect on a single actuator leading to failure of an entire electric switchboard and, thus, all the actuators depending upon it.

An insulation problem occurred on reactor 2 at the Penly nuclear power plant (Seine-Maritime) in September 2003.

Experts in flooding hazards.

FOCUS

EXAMINATION OF FEEDBACK FROM 2000-2002

On 2 December 2004, IRSN presented the standing advisory group for nuclear reactors with its conclusions on the examination of feedback from the operation of PWRs over the period 2000 to 2002.
This examination, conducted every three years, provides the opportunity to conduct a transverse investigation on safety-related matters highlighted during the relevant period.

The following topics were dealt with in 2004: processing of significant safety-related events, analysis of the application of technical operating specifications, analysis of start-up tests and periodic tests, analysis of electrical switchboard failures, measurement deviations from flow and temperature sensors, reliability of diesel generators and feedback from instrumentation and control equipment for 900 MWe and 1,300 MWe plant units.

The conclusions of the report submitted to the standing advisory group for nuclear reactors (GPR) indicate that EDF must carry out a number of actions in order to improve safety with regard to the topics examined, especially measurement deviations on flow and temperature sensors.

IRSN examines feedback on PWR operation.

planned reinforcement measures and on the temporary measures proposed by EDF to cover the period pending the completion of modifications on the plants. The improvement of operating documents was also examined in 2004.

Internal emergency plans (PUI)

A new standard was defined in 2003 for internal emergency plans at EDF power plants. Work on examining the corresponding dossiers was vigorously pursued in 2004: Cruas (Ardèche), Chinon, Le Bugey, Nogent (Aube), Penly (Seine-Maritime), Gravelines (Nord) and Saint-Alban (Isère). During the year, work was completed on the examination of the EDF dossier recommending the setting up of a specific internal emergency plan organisation to deal with floods liable to affect all the reactors on a single site.

Assessment of the safety of the EPR nuclear reactor project

Following the drawing up of "Technical Guidelines for the Design and Construction" (in October 2000) and pending a request for authorisation to proceed, IRSN is continuing to examine the safety of the EPR project on the basis of technical dossiers:

- connected with the compliance with general safety objectives;
- concerning innovative technical solutions (corium recovery, computerised instrumentation and control, etc.);
- which have changed since the technical directives (containment with metal liner, etc.);
- describing changes concerning power plants in operation (with regard to floods, heat waves, etc.), for the EPR project.

During 2004, a set of EDF technical dossiers concerning the EPR project were examined by IRSN and

Aerial view of the future EPR site at Flamanville (Manche).

were presented and discussed during meetings of the standing advisory group for nuclear reactors. These dossiers concern:

- the Teleperm XS computer platform which will be used to develop the reactor protection system;
- the new containment design comprising a prestressed concrete internal containment with a metal liner and a concrete external containment;
- improvement of worker radiation protection;
- computerised control principles;
- design of the corium recovery system *(see Focus p. 105)*, to maintain the reactor's containment integrity in accident situations involving core meltdown;
- accident situations involving heterogeneous dilution of the boron in the primary cooling system;
- the design of the safety injection system;
- the processing of non-qualified multiple equipment failures in case of earthquake;
- foreseeable combinations of internal and external hazards and internal events to be taken into account for reactor design.

EDF's technical dossiers concerning allowance for the risk of impact by a commercial aircraft were examined and discussed at a meeting of the restricted group responsible for nuclear reactors.

FOCUS

EPR REACTOR: COLLABORATION WITH FINLAND

In December 2003, following the decision by the Finnish council of state to build a fifth nuclear reactor in Finland, the operator, TVO, decided to construct an EPR-type reactor and applied to the Finnish Government for permission to build.

The dossier was submitted to technical examination by the Finnish safety authority (STUK) in 2004.
STUK held technical discussions with DGSNR and IRSN during 2004 to consider modifications to the EPR project which could be requested by STUK on the basis of Finland's current regulations regarding the safety of nuclear reactors.

The EPR project in progress on the Olkiluoto site in Finland.

These discussions focused, in particular, on the prevention of failures for main pipes of the primary and secondary systems, the limiting of the consequences of accidents involving failure of steam generator tubes, the design of the corium recovery system, and digital instrumentation and control. Efforts were made to harmonise the positions on these various topics.
The Finnish Government granted permission to build in February 2005. In-depth discussions will be continued with STUK during subsequent EPR project development and implementation phases in Finland and in France.

Discussions and explanations on the CABRI installation with an IRSN reactor safety team.

FOCUS

SAFETY OF THE CABRI EXPERIMENTAL REACTOR

In 2004, IRSN examined the preliminary safety report submitted by CEA to support its request for modification of the CABRI installation.

This examination covered the following points in particular:

- the design and dimensioning of the pressurised water loop which will be placed at the centre of the reactor core;
- the utilisation of zircaloy for the manufacturing of the in-pile section of that loop;
- the seismic reassessment of the installation;
- the list of operating conditions adopted for the safety demonstration;
- the radiological consequences of envelope accidents retained.

IRSN's analysis took the specific features of the CABRI reactor into account:

- it is not constantly in operation (a few days a year only);
- the first barrier of the loop is the vessel containing the pressurised fluid (the experimental rod clad may burst during the test);
- fuel-water interaction could cause a pressure peak in the loop's primary system and this must be allowed for when dimensioning it;
- the zircaloy used to manufacture the in-pile section of the loop is a fragile material;
- very high level effluents may be produced by the experiments.

This analysis was presented to three meetings of the standing advisory group for nuclear reactors.

A report was drawn up by IRSN on the procedure and the qualification of equipment that EDF intends to use for the EPR reactor.

In October 2004, EDF selected the site at Flamanville (Manche) to build a first reactor and submitted a dossier with the national commission for public debate. Following this stage, EDF is expected to apply for authorisation to build the reactor. It will supply the preliminary safety report which will then be examined by IRSN.

Follow-up of experimental reactors

In 2004, IRSN's appraisal work on research reactors and fast-neutron reactors mainly concerned CABRI, PHEBUS, the high-flux reactor of the Laüe-Langevin Institute (RHF) and PHENIX.

The analysis of the preliminary safety report on the CABRI reactor, modified by the installation of a pressurised water loop, was presented during two meetings of the standing advisory group for nuclear reactors. In general, the work done involved the detailed examination of every aspect of that reactor's safety by means of an approach similar to that adopted for power reactors while allowing for specific features of the installation's operation *(see Focus p. 96)*.

Assessing the safety of the PHENIX reactor.

Furthermore, IRSN examined supplementary items requested from the operator of the PHEBUS reactor, regarding shutdown criteria in particular, prior to the conducting of the PHEBUS-FPT3 test in November 2004.

In 2004, the Institute also studied the proposal from the high-flux reactor operator concerning the seismic classification of equipment and associated functional requirements. This proposal is intended to respond to a recommendation made by the standing advisory group in May 2002 during the HFR safety review.

In January 2003, the restarting of the PHENIX reactor was authorised for a period limited to the equivalent of 720 days operation at full power. Its decommissioning is scheduled for 2008. In 2004, IRSN assessed the safety of irradiation experiments conducted in this reactor, some of which fall into the category of research operations conducted in the context of the 1991 law on the management of high-level long-lived waste. IRSN also examined the operator's demonstrations illustrating the consequences for the safety of steam generators of some "malfunctions" noted on two modules of a steam generator (especially the deformation of water tube spacer grids) and the proposal for more thorough inspections on steam generator modules. In addition, IRSN studied dossiers concerning, in particular, the failure of a steam generator chest in the event of simultaneous failure of a sodium module and a water tube. Furthermore, IRSN evaluated CEA studies conducted to show that the melting of a fuel assembly could not be propagated beyond the six nearest assemblies.

PHEBUS reactor: test device storage pit.

IRSN conducts civil engineering survey.

Support for the **safety assessment of operational reactors**

In 2004, IRSN's activities in support of the safety analysis of reactors in operation were mainly focused on work in the fields of civil engineering, thermal-hydraulics and PSA.

Civil engineering

In preparation for the third 10-yearly outage programmes for 900-MWe power plants, IRSN conducted a review of the design and dimensioning of civil engineering works. It assessed the behaviour of some works, such as electrical buildings, in case of earthquake or explosion of external original. IRSN continued its action on the analysis of the behaviour of containments allowing for the effects of ageing of structures and accident situations which could affect their tightness. To optimise its capabilities in digital simulation, IRSN took part in an international exercise for the cross-comparison of designs and tests, organised by the OECD-NEA which considered containment mockups tested in the USA.

In the context of feedback on the floods of 1999, lRSN examined the stability of the protective dykes on the sites at Belleville (Cher), Fessenheim (Haut-Rhin) and Le Bugey (Ain) in 2004.

In general, IRSN checks on the in-service follow-up of civil engineering works and EDF's manner of dealing with cases of non-compliance identified: equipment or tank anchoring defects, etc.

For the follow-up of containments, IRSN examined the tests carried out in 2004 on the sites at Golfech (Tarn-et-Garonne) and Cattenom (Moselle). In the context of the EPR project, IRSN continued its examination of the design of civil engineering works. The installation's containment and its ability to withstand an intentional impact by a commercial aircraft were covered in reports presented to groups of experts.

Furthermore, regarding the modification of regulations in line with new scientific knowledge, IRSN continued its work with a view to revising basic safety rules concerning the aseismic design of BNIs.

Level-1 probabilistic safety studies

Probabilistic safety studies (PSA) assist in assessing the measures adopted by operators by the systematic investigation of accident scenarios. In particular, they make it easier to weight the importance for safety of problems identified during design or operation so that high-priority improvements can be put forward, where applicable. A level-1 PSA covers scenarios leading to core meltdown and determines their frequencies.

The year 2004 saw the completion of the level-1 PSA for 900-MWe power plants using "event-related" control. The corresponding summary report was circulated in September 2004. This study is regularly used for safety assessments including, in particular, to appraise precursor incidents and requests for concessions with regard to technical operating specifications.

A revision of the level-1 PSA was begun in 2004 to allow for control of the "state-oriented approach" type, using the PANAME method developed by

Thermal-hydraulic studies with the CATHARE code.

IRSN to quantify the reliability of control actions. The information obtained in this study was used in the safety revision for the third 10-yearly outage programmes for 900-MWe power plants. The IRSN study thus identified topics for which the advantages of design or operating modifications should be examined by EDF.

Thermal-hydraulics

IRSN uses the CATHARE code to conduct thermal-hydraulic studies in support of safety analyses in order to understand physical phenomena that are not fully mastered or to obtain new tools.

In 2004, calculations regarding accidents involving complete loss of steam generator feedwater were conducted for the future EPR reactor. In the context of the examination of the in-service strength of tanks for the 900 MWe reactors – a topic that will be presented to the standing nuclear section in 2005 – supplementary calculations were performed in order to assess the envelope characteristic of thermal-hydraulic studies conducted by EDF.
IRSN performed calculations for about 30 level-2 PSA front-end phases using SIPA/SCAR simulators in 2004. The Institute also pursued its study of the "inherent" dilution phenomenon. This type of barium

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COMPARATIVE STUDY OF PSAs APPLIED TO SAFETY-RELATED EVENTS

IRSN conducted probabilistic assessments on safety-related events with the most severe potential consequences.

About 10 events, occurring in French or foreign power plants, are selected every year. The aim of these studies is to assess the increase in probability of core meltdown resulting from those events.
They help to define measures which could reduce the consequences for safety. These preventive measures may entail organisation or equipment. As a result of these studies, it can be determined which scenarios out of all those resulting in core meltdown are significantly affected by the event studied and, thus, those requiring priority action in order to reduce possible consequences.
In 2004, IRSN completed a comparison of probabilistic analysis methods applied to events, in cooperation with the German and Japanese safety operations (GRS and NUPEC, respectively). This exercise, based on three actual significant events, showed that the three authorities had similar approaches but that the probabilistic models should preferably be harmonised.

Event quantification meeting at the pressurised water reactor assessment department.

SIPA simulator development room.

dilution may occur in the event of a primary system break due to the stopping of the feed – to the core – of "clear" water (without barium) which has accumulated in the water boxes and steam generator tubes when natural circulation is resumed (without primary coolant pumps). The study included detailed thermal-hydraulic calculations and CATHARE calculations simulating the PKL installation used to study "inherent" dilution phenomena in the context of OECD projects. Furthermore, to obtain a tool to assess future EDF studies, IRSN began studies on steam pipe failure accidents.

SIPA 2 simulator

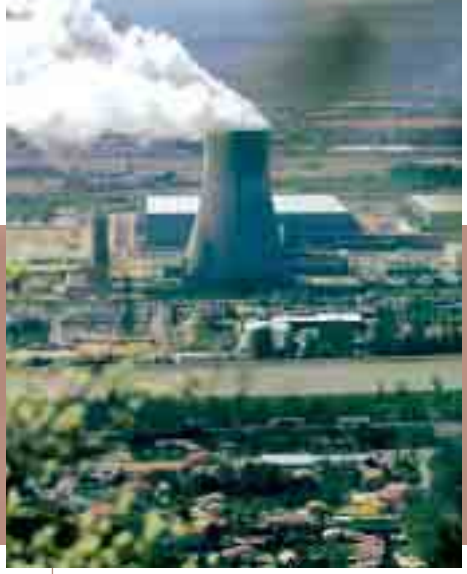
The SIPA 2 simulator is used at IRSN to prepare scenarios for crisis exercises, provide training in reactor physics and control and conduct studies on the thermal-hydraulic behaviour of power plants and their operation in accident conditions.

Two simulator configurations are currently being used. In one, the boiler (primary and secondary systems) is simulated by the CATHARE-SIMU code for 900-MWe and 1,300-MWe reactors and, since early 2004, the other features the simulation of the boiler and cooling system in shutdown state by the CATHARE 2 V2.5 (SCAR) code.

The first version is used for training purposes (nine one-week sessions a year on normal operation, design basis accidents and non-design basis accidents) in the preparation of crisis exercises under IRSN responsibility: power plants at Gravelines (Nord), Nogent (Aube) and Le Blayais (Gironde) in 2004 and for studies concerning 1,300-MWe power plants.

The second version is used for studies regarding 900-MWe power plants with, in 2004, the calculation of accident front-end phases in power operation and shutdown conditions for the 900-MWe level-2 PSA, and the study of operation in case of failure of a steam generator tube, in the context of the examination of the MOX Parity dossier transmitted by EDF *(see Focus p. 102)*.

In parallel to these activities, the renovation of the SIPA 2 simulator, to begin in 2005, was thoroughly examined in 2004.



The Tricastin power plant at Pierrelatte (Drôme).

Ageing of pressurised water **reactors**

In the context of its work on PWR ageing, IRSN conducted studies on the ageing of electrical equipment in 2004. These studies covered the following three areas:

■ assessment of the impact of ageing on the "steady-state" lead batteries, currently used in PWRs, on their operability during and after seismic stresses. Indeed, the conservative sizing of some batteries could lead EDF to seek to use them in conditions adversely affecting their availability in case of seismic stresses. Despite a visible deterioration in their condition following an accelerated ageing sequence, the batteries tested demonstrated good electrical and mechanical behaviour both during and after seismic tests;

■ an analysis of changes over time in the reliability of certain safety-critical electrical components, based on a statistical analysis of data relating to defects that have occurred during use of these components;

■ an enquiry into the obsolescence and ageing of electrical equipment at 15 companies with a range of activities. This provided feedback on their practices and strategies for managing electrical equipment during utilisation and long-term storage. The difficulties and problems encountered and the associated ageing phenomena were surveyed. This information will contribute to the assessments conducted by IRSN in this field.

IRSN conducts studies on the ageing of lead batteries.

IRSN experts who took part in the study of the "MOX parity" dossier.

Fuel in normal and accident operating conditions

IRSN is providing DGSNR with technical support for the study of fuel management provisions proposed by EDF and, in particular, management changes planned by the operator by 2007.

EDF plans to implement new fuel management methods:

- MOX parity for 900-MWe CPY power plants (increase in the burnup fraction of MOX fuel to 52 GWj/t, fuel assembly mean maximum value);
- GALICE for 1,300-MWe power plants (increase in burnup fraction of UO_2 fuel to 60 GWj/t);
- ALCADE for 1,450-MWe power plants (increase in UO_2 fuel burnup rate to 52 GWj/t).

Definition: the burnup fraction (expressed as GWj/t) characterises the quantity of energy produced per tonne of fuel.

Each new fuel management method is subject to an approval process conducted by DGSNR which entails three examination phases by IRSN:

- feasibility of the proposed management;
- updating of the safety dossier (revision of safety report studies, general refuelling safety assessment dossier);
- updating of the operation dossier (revision of general operating rules).

In 2004, the safety dossier on MOX Parity management *(see Focus p. 102)* and the feasibility dossier for GALICE management were prepared.

The boosting of fuel performances entails a reduction in safety margins. Therefore, demonstrating the acceptability of a new fuel management

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IRSN'S OPINION ON THE "MOX PARITY" DOSSIER

EDF plans to modify the management of MOX fuels used in combination with UO_2 fuels in 20 reactors in France by implementing a new management dubbed "MOX Parity".

The reactors concerned are currently operated on the basis of a "hybrid" fuel management: UO_2 fuel assemblies are used for four cycles in the reactor compared with three cycles for MOX assemblies.

The objective of MOX Parity management is to increase the number of irradiation cycles for MOX fuel assemblies to 4. This new management will require an increase in the enrichment of the MOX fuels and will therefore lead to an increase in the maximum burnup fraction of MOX assemblies.

The acceptability of EDF's proposals were examined between mid-2001 and mid-2004. Following this examination, IRSN's decision in 2004 went against the implementation of the new management as proposed by EDF. The Institute's reservations mainly concerned inadequacies in the substantiations provided by EDF as regards the fuel's satisfactory behaviour in normal operation (maximum thickness of zirconium oxide on claddings, maximum internal pressure of rod during irradiation). Supplementary substantiating data is thus awaited from EDF.

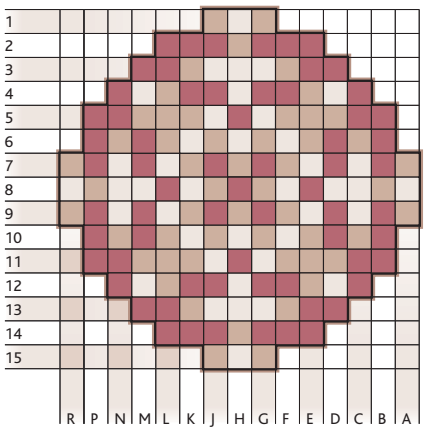
UO_2 pellet constituting the fuel for a PWR.

system generally means using new methods for safety studies relying, in particular, on the use of 3D computing tools and so reducing the conservatism introduced by the uncoupled methods used for power plant design.

In this context, it is worth mentioning:

- the utilisation of the CATHARE code for the analysis of loss of coolant accident studies, and the implementation of the realistic deterministic method coupled with a hot rod statistical method;
- the utilisation of a kinetic 3D method for the study of control rod ejection accidents.

In addition, the implementation of a new management may require changes in fuel. In this way, for the GALICE management, a modification in the fuel product is required in order to comply with design criteria: this entails the utilisation of M5 alloy as the cladding and structure material for the fuel assembly (AFA 3GLr AA). In 2004, IRSN examined the dossiers concerning this fuel assembly which must be inserted in the reactor a few years before a new fuel management can be implemented. IRSN also examined the dossiers regarding foreign fuels acquired by EDF in the context of its fuel procu-rement diversification policy. This concerned the ENUSA fuel assemblies loaded in 900-MWe and 1,300-MWe reactors.



Refuelling plan for a pressurised water reactor.

Some members of the IRSN severe accident risks analysis and study teams.

Examination of risks associated with **severe core meltdown accidents**

The examination of the risks associated with core meltdown accidents for power reactors is supported by research and development programmes and punctuated by meetings of the standing advisory group for nuclear reactors dealing with specific topics selected according to advances in knowledge.

Water reactors in service

In the context of the safety review for the third 10-yearly outage programmes for 900-MWe reactors (VD3 900), IRSN presented the standing advisory group meeting on 16 December 2004, with various topics concerning core meltdown accidents which could lead to modifications in equipment or procedures during 10-yearly outage programmes. The following points were discussed: management

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BASEMAT AT THE FESSENHEIM POWER PLANT

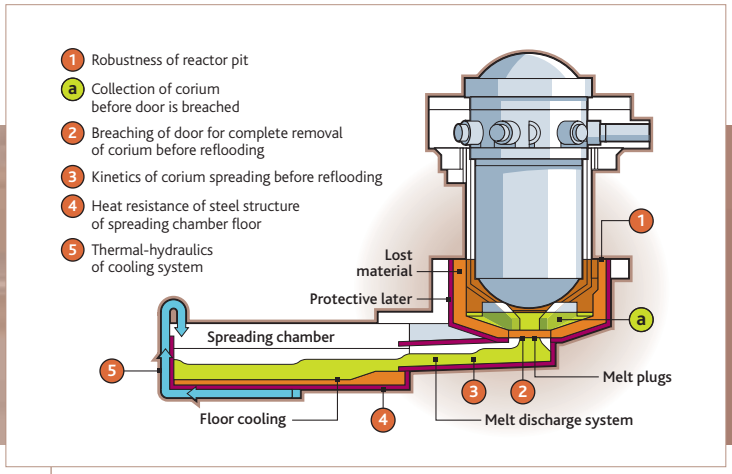
In the context of the modifications to be made during the third 10-yearly outage programmes, IRSN examined the basemat of the reactors at the Fessenheim power plant (Haut-Rhin) in 2004.

This basemat, directly above the reactor pit, is less thick than those in other EDF reactors in service. It therefore follows that, in the case of interaction between the corium and the concrete, the time taken to break through the Fessenheim basemat would be shorter and, as a result, radioactive products (gases and aerosols) would be released to the atmosphere more quickly.

Aerial view of the Fessenheim nuclear power plant (Haut-Rhin).

IRSN therefore analysed whether it would be useful to install supplementary devices which would delay penetration of the basemat in Fessenheim reactors. Using the MEDICIS corium-concrete interaction module of the ASTEC V1 software package, IRSN was able to assess the time required to break through the existing basemat and to show that adding water on the corium would not significantly delay the basemat penetration time. On the other hand, increasing the basemat thickness with a layer of refractory concrete would delay the penetration of the basemat enough to reach a time comparable with that for other 900-MWe reactors. IRSN also examined the dosimetric consequences for workers who would make this modification.

IRSN specialists for the design of the EPR corium recovery system.



Block diagram illustrating corium recovery in the PWR reactor.

of the molten core (corium) in the reactor pit, risk associated with direct heating of the containment, and instrumentation to be installed for the management and follow-up of a severe accident. In examining these topics, IRSN relied to a great extent on the current state of research and, in particular, studies conducted on the interaction between corium and concrete, and the risks of steam explosion. Some generic studies were conducted in the context of level-2 PSA development that IRSN undertook for 900-MWe reactors. In addition, IRSN's expertise in the field of instrumentation is based on experience acquired in the context of the PHEBUS programme.

IRSN recommended that EDF should increase the thickness of the basemat for reactors at the Fessenheim power plant *(see Focus p. 104)* and install a corium detection device in the reactor pit, after the reactor vessel penetration.

Furthermore, as a result of the analysis, EDF was led to plan a modification of the bolts on the equipment access hatch for CPY type reactors so as to ensure tight sealing for pressure peaks of up to 8 bars. EDF is also to modify the device used to depressurise the primary system via SEBIM valves, including in the case of a severe accident with total failure of electric power supplies (mains and diesel generators).

EPR reactor project

IRSN examined the following two topics in 2004:

- the new containment design and its capability of maintaining its integrity and tightness after global deflagration of the quantity of hydrogen which could be present in the containment in the event of a low-pressure core meltdown accident or after a representative fast local deflagration;
- the robustness of the corium recovery concept proposed by EDF *(see Focus)*.

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EPR CORIUM RECOVERY SYSTEM

The system for the recovery of molten material from the core (corium) planned for the EPR reactor represents a significant improvement for safety in case of a core meltdown accident.

Indeed, it would avoid the failure of the basemat and, thus, failure of the containment leaktightness. The corium flowing from the reactor vessel after its failure would be collected and received in a dedicated spreading chamber where it would be cooled by a passive water injection system.

Examination in 2004 of the system proposed by EDF led IRSN to identify several points requiring more thorough investigation. The Institute conducted studies on these points with its own calculation tools which confirmed that the system planned by EDF was appropriate to meet the objectives defined:

- complete collection of the corium in the reactor pit before failure of the door below the reactor pit;
- obtaining of a great enough breach size on failure of the door to allow rapid flow and spread of the corium;
- limited ablation of the sacrificial concrete layer;
- heat resistance of the steel structure of the spreading chamber;
- satisfactory operation of the cooling system under that chamber.

Some points should, however, be investigated further, especially the failure of the door separating the reactor pit from the spreading chamber and the analysis of a new device proposed by the designer, the thickness and the nature of the sacrificial concrete in the spreading chamber and the reliability of the passive basemat cooling device in that chamber.

Eurodif's enrichment plant on the Tricastin site (Drôme).

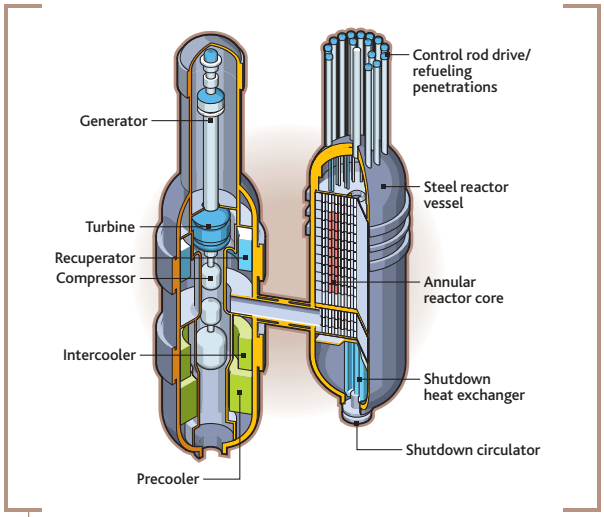
Safety expertise **for future reactors to follow EPR**

Looking beyond the EPR to future reactors, IRSN directed efforts in 2004 to the study of steps to be taken to prepare expertise on their safety.

Among the various projects for reactors and associated fuel cycle installations currently being developed in the context of the Generation IV International Forum (GIF), it is worth noting projects featuring:

- high or very high temperature reactors (HTR/VHTR) which are helium cooled;
- fast neutron reactors which are gas cooled (GFR) or sodium cooled (SFR).

In the case of these reactors, designers are seeking improvements, especially with regard to safety, reduction in waste and resistance to malicious acts.



GT-MHR module.

As for the schedule, reactors of this type could not replace the PWRs of generations II (existing) and III (EPR) and others until the middle of the 21st century. Nevertheless, for some types of reactor, designers envisage the building of "demonstrators" by 2010-2015.

As regards safety expertise, IRSN will initially focus on high or very high temperature reactors, proceeding with technical exchanges, in particular, with Framatome, which is developing a VHTR project. Furthermore, the Institute will monitor progress made in the study of gas-cooled fast neutron reactors and on the development of sodium-cooled fast neutron reactors.

In 2004, IRSN established international contacts in the field of future reactors, including with GRS and NRC in particular. IRSN will also take part in the integrated project for the 6th FPRD on "V/HTR-IP" concerning accident design codes in particular.

Working meeting to express opinions on the safety of installations.

Safety **of plants, transport and dismantling**

IRSN provides technical expertise for dossiers transmitted by nuclear installation operators and by applicants for radioactive material transport packages. The Institute also studies the risks of dispersal of radioactive materials and of criticality which are to be found in most installations. IRSN draws up reports on internal emergency plans (PUI) for sites containing nuclear installations.

Installations "upstream" of cycle

In 2004, IRSN assessed the dossier on the safety review of the installation operated by COMURHEX on the Pierrelatte site (Ardèche). In particular, IRSN pointed out inadequacies in the provision made for the risks of dispersal of radioactive and chemical materials, fire and external hazards.

The definition of safety options for the new uranium enrichment plant (Georges-Besse II) which AREVA plans to build on the Pierrelatte site were examined by IRSN in 2004. This plant, which is intended to replace the EURODIF plant, will use the enrichment process based on centrifugation of uranium in gaseous UF_6 form developed by URENCO. The centrifugation process considerably decreases the quantity of gaseous UF_6 present in the installation, which also reduces the risks of dispersal of radioactive and chemical materials. As a result of the survey conducted, it was concluded that the safety options proposed by AREVA appear to be acceptable at this stage of the project.

The United States is envisaging using MOX fuel assemblies made from weapon grade plutonium in American nuclear power plants. Four first-off assemblies intended for a PWR in the USA have been manufactured in France. This operation, known as EUROFAB, involves two French installations: the plutonium technology facility (ATPu) for the manufacture of fuel rods and the MELOX plant at Marcoule (Gard) for the manufacture of fuel assemblies. IRSN examined the specific provisions planned by the operators of these installations with regard to criticality risks. Indeed, the product used entails specific criticality risks owing to the high content of plutonium 239 and the low content of plutonium 240.

IRSN collaborated with DGSNR in the inspection of the plant's manufacturing fuels intended for PWRs in Europe. The information drawn from these inspections, in terms of comparison of provisions implemented to control risks and, in particular, to reduce the doses received by workers, were presented at an international conference organised by the IAEA in Beijing (China) in October 2004. This information will be used when the dossier is examined for the safety review of the French fuel manufacturing plant in Romans-sur-Isère (Isère).

Installations "downstream" of cycle

For installations "downstream" of the fuel cycle, a major portion of IRSN's work was dedicated to examining changes in the operating range of irradiated fuel reprocessing installations UP2-800 and UP3-A and of the COGEMA STE3 waste treatment installation at La Hague (Manche), and the provisions proposed by COGEMA in that respect.

Aerial view of the Cogema-La-Hague site (Manche).

The decrees published in the OJ on 11 January 2003 define the operating range of these installations, and any extension of the operating range in force is subject to specific authorisation, described as "operational" authorisation, granted by interministerial order. In the course of 2004, three specific dossiers for the extension of the operating range were examined by IRSN and laid to the publication of three interministerial orders. These concern:

- fuel assemblies, known as UOX3, with a mean specific burnup fraction for the assembly of less than 60 GWj/t and a mean content of uranium 235 isotopes before irradiation of less than 4.5%;
- MOX fuel assemblies with a burnup fraction not exceeding 55 GWj/t and a content by weight of plutonium and americium not exceeding 8.65% for irradiation;
- non-irradiated MOX fuel elements initially intended for the SNR 300 fast neutron reactor of Kalkar (Germany), with a plutonium content by weight not exceeding 40%.

The technical investigation by IRSN focused, in particular, on the changes in risks related to heat releases and radiolysis, risks of external exposure (especially to neutrons in the case of MOX), criticality risks and the modification of waste characteristics as a result of the treatment operations for those fuels. The Institute reached a favourable opinion on the provisions adopted for the protection of workers and the environment.

Assessment of internal emergency plans (PUI)

For laboratories and plants, the internal emergency plans for the CEA Valrhô and Superphenix centres, the COGEMA plant at Pierrelatte and the CEA centre at Fontenay-aux-Roses were analysed. The analysis of the internal emergency plan for the COGEMA plant at Pierrelatte included, in particular, a detailed examination of the accident situations considered.

Safety of radioactive material transport

TranSAS mission

In 2004, the IAEA arranged a 10-day meeting of about 15 foreign experts to assess the organisation of the inspection of radioactive material transport safety in France, in the context of a TranSAS mission. DGSNR and IRSN, along with the firms with the largest international transport flows (COGEMA and CIS bio international), were audited.
The mission concluded that the French inspection system was suitable for the volume and complexity of transport operations performed.

PATRAM conference

The 14th PATRAM international conference, held in Berlin (Germany), was the occasion for much discussion on the five topics presented by IRSN:

- a model for the calculation of the effects of surface contamination of packages: the study of the dosimetric impact of contaminations showed that the limits in force remain appropriate although the margins for some isotopes were found to be large;
- radioactive material transport flows and corresponding doses for workers and the general public: using the data collected, it was possible to specify the number of transportations of inspection equipment containing radioactive materials;
- the fire behaviour of two parcel models containing irradiated fuel or vitrified waste, respectively: the duration of fire resistance of these parcels is significantly greater than the statutory requirements. The

Rail transportation of vitrified waste.

results obtained will be used as a transport accident management tool;
- safety distances to be prescribed in case of a transport accident. These will be integrated in departmental emergency plans to deal with radioactive material transport accidents;
- a methodology to determine the exemption limits for fissile actinides.

Study on harmonisation of European practices regarding certification of package models

In 2004, the European Commission financed a study conducted by IRSN and BAM (Germany) on the harmonisation of European practices with regard to certification of package models for transport of radioactive materials.

This study included three phases:
- study of practices in force in France and Germany;
- distribution of a questionnaire covering the main points of those practices to all European Union member and candidate countries;
- analysis of answers received in order to draw up recommendations aimed at achieving greater harmonisation.

In this context, it was proposed that guidelines should be drawn up for operators to prepare safety dossiers and for the relevant authorities to assess those documents, and that standard formats should be defined for safety dossiers, survey reports and certificates of approval.

EUROFAB project

IRSN conducted a technical survey of safety dossiers for the various types of transport operations, by road and by sea, for the two package models concerned, FS 47 for plutonium oxide supplied by the USA and FS 65-900 for the four fabricated assemblies and supplementary rods.

IRSN also went on line with explanations of its assessment of the risks associated with possible transport accidents in response to two associations, WISE-Paris and Greenpeace International, and the results of the study carried out by the Large & Associates consulting firm.

Safety of dismantling decommissioned nuclear installations

In the last few years, the main nuclear operators (CEA, EDF, COGEMA) undertook major programmes for the dismantling of nuclear installations which will lead to the decommissioning of some 40 basic nuclear installations by 2025.

In the course of 2004, IRSN examined the following, in particular:
- decommissioning and dismantling operations for the SILOE and SILOETTE experimental reactors on the CEA site at Grenoble (Isère);
- decommissioning and dismantling operations for the enriched uranium processing workshops (ATUe) on the CEA Cadarache site (Bouches-du-Rhône);
- decommissioning and dismantling operations for the SICN plant at Veurey-Voroize (Isère).

On 24 and 31 March 2004, IRSN gave its opinion on EDF's strategy for the dismantling of "first generation" reactors, to the standing advisory group for basic nuclear installations other than nuclear reactors and excluding installations designed for long-term storage of radioactive waste (standing advisory group for plants).

Technical examination of a safety dossier on an installation in the process of being dismantled.

Melox MOX fuel manufacturing plant at Bagnols-sur-Cèze (Gard).

Assessment of risks of dispersal of radioactive materials

The risks of the dispersal of radioactive or toxic materials in normal, incident or accident conditions are the subject of a close study by IRSN.

In 2004, specific safety assessments on these risks were conducted for a variety of installations such as plants and laboratories (CIS bio international in Saclay, CEA Valduc – Côte-d'Or, FBFC in Romans – Isère, MELOX in Marcoule, COGEMA in La Hague), installations in the process of being dismantled (UP1 plant in Marcoule, Superphenix reactor), research reactors (OSIRIS in Saclay, RHF in Grenoble), the RES reactor at Cadarache and certain other auxiliary buildings for EDF reactors.

Generic topics concerning all nuclear installations were also studied, such as the quantification of discharges which could be caused by an earthquake, taking into account the conditions for cracking of buildings and pressure differences caused by wind, gas system leaks and heating of the air inside buildings.

Another noteworthy event in 2004 was IRSN's participation in the drawing up of ISO standards in the field of containment and, in particular, of a standard concerning the design and operation of ventilation systems in nuclear installations other than reactors. IRSN also began collaborating with its Ukrainian counterpart (SSTC) in the field of safety instructions to be applied to filtration equipment for nuclear installations.

Assessments of criticality risks

Specific technical analyses are conducted on criticality risks.

In 2004, IRSN conducted 104 assessments which led it to perform comparative calculations and specific studies to verify the substantiations put forward by nuclear operators in their authorisation requests and to evaluate the safety margins associated with calculations, according to the level of validation of the calculation tools used by the applicants. A study aimed at specifying the criticality risk in underground repositories for radioactive waste was conducted for changing scenarios in the very long term.

Furthermore, IRSN analysed incidents related to the criticality risk and provided support for surveillance inspections and crisis exercises for which questions of criticality could arise.

IRSN also took part in the IAEA's work on the modification of international regulations on the safety of radioactive material transport and the OECD's work on improving criticality calculation methods.

As part of its appraisal of the storage of high-activity waste, IRSN is conducting research on the properties of clay as a potential host rock at Tournemire (Aveyron).

Examination of safety dossiers concerning **mining waste** and participation in the writing of regulations

IRSN's role includes the safety of various stages of radioactive waste management: processing, packaging, transport, interim storage and disposal for various categories of waste with all activity levels, mining waste, contaminated soil, etc.

In 2004, in view of the time limit set by the law of 1991 for research in the management of high-level long-lived waste (HLLLW), the Institute concentrated its efforts mainly on examining dossiers concerning this waste.

Disposal in deep geological formations

Three dossiers on the feasibility of disposal in deep geological formations, drawn up by ANDRA, were examined by IRSN and the conclusions of these investigations were presented to the standing advisory group for radioactive waste long-term disposal facilities. These dossiers concerned:

- mechanical disturbances liable to occur in a repository in the clay formation studied by the Bure underground laboratory (Meuse/Haute-Marne);
- chemical disturbances in that repository;
- the current position of studies of the benefits of French granite formations as a location for a HLLLW repository ("2002 granite dossier").

The analysis of the first two dossiers completed a first cycle for the examination of key points on the safety of a possible repository, with regard to:

- the qualities of the geological site studied;
- the design features of a repository;
- the questions on safety raised by the operation and reversibility of a repository.

The investigations conducted on mechanical and chemical disturbances and their coupled effects and also on thermal and hydraulic disturbances resulted in an initial assessment of changes in the performance of the containment barriers of a repository and of the suitability of the design provisions envisaged by ANDRA to prevent those disturbances and reduce their effects.

In conducting its investigation, IRSN relies on its own research facilities such as the Tournemire experimental platform (Aveyron) and takes part in international experimental projects (Mont-Terri) and modelling projects (Decovalex, European projects such as SPA, BENIPA, NFPRO). It is in this context that IRSN was able, in particular, to formulate its opinion regarding transfers in semipermeable mediums, the potential role of colloids in potential radionuclide transfers in the repository and the geological environment,

Measuring the direction of cracks in a tunnel gallery at Tournemire (Aveyron).

Vacuum packing of clay samples taken at Tournemire for chemical analysis in the laboratory.

and the influence of hydraulic binders on the containment properties of clays.
The assessment of the "2002 granite dossier" provided the opportunity to analyse the possible options for a repository in a granite medium and to examine the capacity of French granites to accommodate such a repository. The analysis conducted on the basis of the bibliographical data contained in the ANDRA dossier, originating from French and foreign granitic sites, led IRSN to consider that these deep granitic formations did not have geological characteristics that were incompatible, in a generic manner, with a possible repository.
IRSN also examined the work and research pro-

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MIMAUSA PROGRAMME

Uranium mining activities may have led to modifications in the natural environment and to radiological marking in the air, water and soil.

This marking may be significant without necessarily having notable dosimetric consequences.
On the basis of its current and past work, IRSN has precise knowledge about several of these mining sites but only partial data is available for other sites. For this reason, DPPR, a department of the French Ministry for Ecology and Sustainable Development (MEDD), asked IRSN in 2003 to set up a programme aimed at preparing a radiological report on the environment around uranium mining sites.
This programme, called MIMAUSA, is being conducted in close collaboration with COGEMA. Its steering committee includes members from MEDD, IRSN, COGEMA and DARPMI from the French Ministry of Economy, Finance and Industry.

Mining areas in France.
The concept of "mining areas" was defined in the context of the MIMAUSA inventory as a means of grouping sets of sites in geographic areas.
The name allocated to each "mining area" can reflect either its inclusion within specific administrative boundaries or the name of a large city, or it can be drawn from a mining title.

For the "knowledge assessment" section of this programme, IRSN published a national inventory of uranium mines in June 2004 and this can be consulted on the following website: www.irsn.org. It lists the sites where uranium ore exploration, extraction or processing activities have been conducted in mainland France. There is a descriptive summary data sheet for each site.
In parallel, IRSN has started collecting detailed information focusing on two pilot sites: Gartempe (Haute-Vienne) and Ambert (Puy-de-Dôme).
A database containing mapping data is being created for the organisation and subsequent consultation of the information provided.

Redevelopment of the mining site at L'Écarpière (Loire-Atlantique).

grammes planned by ANDRA in the Bure underground laboratory in support of the application for authorisation to proceed with excavation of the experimental "niche" and galleries for the laboratory.

Waste packages

As regards waste packages, IRSN examined the following three dossiers:

- a first version of the specifications for packages obtained by bituminisation in the STE3 workshop at the COGEMA plant in La Hague (Manche), of sludge from the previous STE2 workshop;
- the application for authorisation to continue using package interim storage cell 124 (E-I-P) at the COGEMA plant in Marcoule (Gard) beyond the fourth interim storage level;
- an ANDRA dossier giving the inventory of HLLL and MLLL packages for the dimensioning of a possible repository in the clay layer studied at Bure.

Disposal facilities

In the field of surface disposal facilities for low and intermediate activity waste, IRSN examined specific dossiers concerning the Aube and Manche centres (statutory monitoring plan, internal emergency plan, resin storage, reception of sealed sources in a surface disposal facility).

On the COGEMA uranium ore processing waste disposal sites, the Institute conducted third-party surveys of the following in response to a request from DRIRE:

- the radiobiological impact for 2002 of the former L'Écarpière mining site (Gétigné, Loire-Atlantique);
- the environment monitoring conducted by COGEMA around the sites at Gueugnon (disposal of ore processing waste) and Bauzot near Issy-l'Évêque (disposal of waste slightly contaminated by natural radionuclides);
- the application for authorisation to store mining deads and demolition products from the SIMO plant at the open-cast mine on the Bois-Noirs-Limouzat site.

Furthermore, on the request of DDASS in Creuse, a study was conducted on a project to set up a swimming facility at a pond on the location of the former Grands-Champs open-cast mine (village of Gouzon, Creuse). The overall results showed that using this site as a swimming facility would not result in a significant increase in doses received compared with the average level of exposure for inhabitants of Limousin.

Regulations on waste safety

IRSN took part in work to revise and draw up policies concerning waste safety. In this way, it contributed to work in 2004 aimed at modifying basic safety regulations III.2.f and III.2.e dealing, respectively, with the safety of disposal of radioactive waste in deep geological formations (III.2.f) and favourable characteristics of waste packages with regard to their acceptance in a surface disposal facility (III.2.e). The Institute is also contributing to the preparation of a reference guide concerning HLLL and MLLL packages (referred to as "L542") for which elimination systems are currently being studied.

In 2004, IRSN drew up a guide concerning a final disposal facility for naturally radioactive waste whose activity level has been increased by the industrial process that produced it. The aim of this guide is to provide producers of this type of waste and, in particular, personnel responsible for the design of disposal centres with a method describing the various steps to be implemented for the assessment of radiological impacts. This work, conducted at the request of MEDD in the context of a working group comprising representatives of

IRSN's "human factor" team for reactor safety.

the administration along with producers and waste disposal agents, was presented to the SFRP congress in Marcy-l'Étoile (Rhône) in September 2004. In addition, in 2004, IRSN performed work in support of authorities involved in radioactive waste management (French and foreign safety authorities, IAEA, etc.) including in particular:

- participation in monitoring inspections of basic nuclear installations as technical support for DGSNR and DSND;
- participation in the work of the IAEA committee responsible for examining safety guides concerning radioactive waste management (WASSC);
- participation as consultant in the drawing-up of some of those guides (concerning geological disposal in particular);
- the drawing-up, in a Franco-Belgian context and in liaison with ANDRA, of a common position on the safety approach for geological disposal facilities;
- the training, in response to the IAEA request, of safety authorities from East European countries in the field of surface disposal facilities for radioactive waste.

Human and organisational reliability

Special assessments conducted by IRSN in the field of human and organisational factors were centred on three topics in 2004.

Control and supervision

IRSN examined the design principles of computerised control planned for the EPR reactor. These principles are, to a great extent, based on experience acquired on N4 power plants. They had passed an initial validation by EDF through tests conducted on mockups with operators. Owing to EDF's desire to increase the level of responsibility of the control team, IRSN examined, in particular, the assistance provided to operators by supervision interfaces. In the context of the standing advisory group for EPR, IRSN stressed that it was essential that the control team should retain its power over control and have an overall view of the evolution of the process, but that it should be provided with sufficient guidance in order to avoid inappropriate actions.

Organisation and management

Nuclear power plants undergo regular technical modifications that have a significant impact on operating procedures, work organisation and the competencies required from agents. IRSN examined the method and organisation implemented by EDF to allow for that impact during the design of those modifications *(see Focus)*.

Furthermore, during the updating of safety reports

Reports presented to the standing advisory group on nuclear reactors.

for various nuclear installations, IRSN examined the manner in which operators dealt with risks associated with human actions: starting up of the extension of the CEA irradiated fuel study laboratory (Saclay) and the "pit" section of the test reactor at Cadarache, commissioning of the Civaux power plant (Vienne), safety review of the CABRI reactor, and dismantling of Superphenix. These investigations focused on the operational provisions adopted by the operators to prevent and repair human errors liable to adversely affect proper control of the safety of installations.

Feedback

Two safety-related events which occurred in nuclear power plants were submitted to thorough analysis by IRSN with regard to human and organisational factors. This highlighted the fact that a team may experience difficulty in rigorously applying a control procedure when its view of the trend in operation parameters leads it to believe that the actions required by that procedure are ineffective.

FOCUS

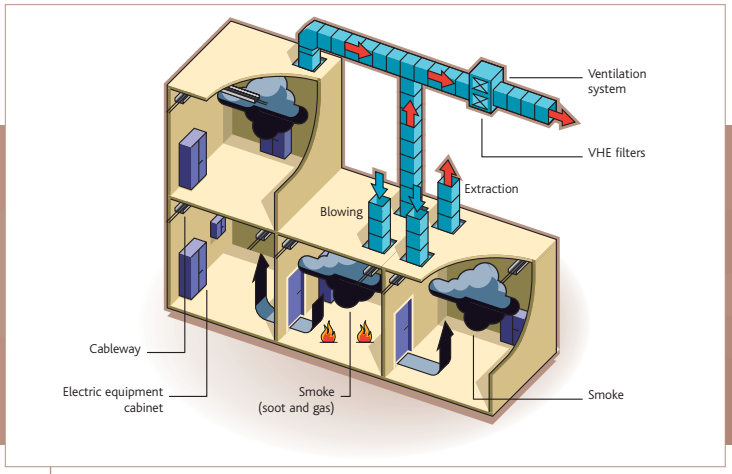
INTEGRATION OF HUMAN FACTORS IN THE DESIGN OF MODIFICATIONS TO EDF POWER PLANTS

The analysis of actions carried out in the early 2000s indicated that modifications made in power plants resulted in difficulties for some agents (operating and local servicing personnel), or even, incidents.

During the year 2003, IRSN conducted a retrospective study of the implementation of nine modification projects. Parties involved in the projects and the operating staff concerned by those modifications were interviewed. The main documents written during the projects were analysed. The study revealed inadequacies as regards the integration of human factors in the design of modifications.

At the end of 2003, EDF began to introduce a procedure for the analysis of social-organisational and human impacts of modifications (SOH procedure). In 2004, IRSN assessed this procedure by comparing it, firstly, with the results of its study of the projects and, secondly, with "good practices" for the integration of human factors in project control.

This assessment showed that the procedure, which was designed to be carried out upstream of modification projects, should be extended to include a study of the human factors at each stage of projects: analysis of needs, analysis of impacts, specification and implementation of solution, validation tests, implementation on site and follow-up during operation. In this context, IRSN emphasised the need to provide designers with more training in the field of human factors and to improve the assistance provided by the guides for this procedure.



Fire propagation studies.

Fire protection of installations

Assessing the fire protection of an installation means studying steps proposed by the operator for prevention, detection and action in order to avoid the outbreak of fire, to detect and control any fire outbreak that occurs, to limit the fire to within a predefined volume and to extinguish it.

Fires and explosions, whether they originate from inside the installation or are of external origin (forest fire, lightning, industrial environment or communication routes) are possible sources of accidents. Nuclear operators take steps to prevent or limit fires and explosions so they cannot result in serious direct or indirect consequences for personnel, members of the public and the environment.

Assessment work

IRSN assesses the validity of the means adopted and justified by the operator in installation safety dossiers. For this purpose, the Institute can rely on the results of research – especially research it has conducted itself –, the results of studies conducted using design codes in order to gain a better understanding of the phenomena involved, specific

FOCUS

FIRE PSA

In order to appraise the provisions adopted by EDF, against fire risks and to determine possible ways of improving safety, a specific probabilistic safety assessment (PSA) was made by IRSN for 900-MWe reactors.

This assessment included a systematic investigation of accident scenarios that could be caused by fire and their frequencies were determined.

The year 2004 saw the completion of the fire PSA version based on the event-related control of accident situations.

IRSN also conducted a sensitivity assessment in order to gauge the effect of implementing the fire action plan adopted by EDF to improve fire protection for 900-MWe and 1,300-MWe reactors.

In this way, the critical premises and sequences representing a major part of the risk of core meltdown were identified.

For the purposes of this study, fire scenario calculations were performed using the coupled FLAMME_S/SIMEVENT software.

The information drawn from the experimental programmes on fire (DIVA 0 and CARMELA) carried out in IRSN installations are to be integrated during a future update of the PSA. This work focused, in particular, on electrical cabinet fires and fire propagation from one room to adjacent premises.

The lessons drawn from the fire PSA were also used for the safety review associated with the third 10-yearly outage programmes for 900-MWe power plants.

IRSN personnel in ventilated protective suits take part in fire studies.

probabilistic safety studies, international practices, as well as feedback and data drawn from incidents that have occurred in nuclear and non-nuclear installations.

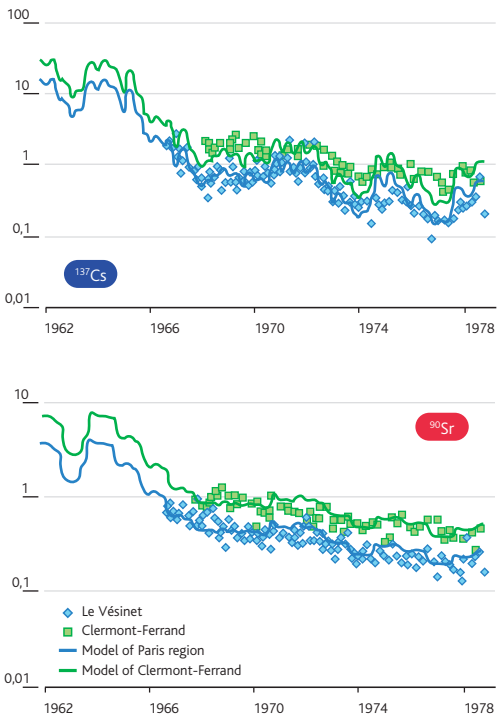
Owing to the specific features of nuclear installations, special care is taken to maintain the availability of safety functions in case of fire and to preserve the containment of radioactive materials. All the effects of fire (transfers of hot gases, soot, pressure, etc.) and their consequences on safety-related equipment are considered. The influence of ventilation on the development of a fire and on its consequences is also taken into account in order to examine, in particular, ventilation control strategies in case of fire. The main topics studied by IRSN in 2004 include, above all, the assessment of fire protection provisions conducted in the context of the definition of sets of modifications to be made during the third 10-yearly outage programmes for 900-MWe reactors, taking into account the results of the probabilistic safety assessments (PSA) on fire conducted by IRSN *(see Focus p. 116)*. In this context, IRSN also examined the operator's principles of prevention and protection to control risks concerning the presence of hydrogen in the buildings of the nuclear island. Other assessments of explosion risks were conducted for the industrial implementation of a method for the chemical dehydrogenation of reactors in N4 power plants, operations for the destruction of sodium described in the preliminary safety report on dismantling of the Superphenix reactor, and risks related to the external environment for several nuclear installations. In addition, an assessment of fire risks was conducted in support of the safety assessment of the Khmelnitski 2 reactor by the Ukrainian safety authority.

With the processing of the first results of experiments on heat and smoke propagation and studies on the fire behaviour of sectorisation and containment equipment conducted by IRSN in the DIVA and STARMANIA installations, it has been possible to obtain a better appraisal of the pressure effects associated with fire and to reduce the uncertainties in the evaluation of releases of radioactive materials to the environment during a fire. The suspension coefficients to be considered and the redeposition and retention coefficients for aerosols in an installation were determined for a number of materials which could play a part in a fire.

TPH pit fire in confined and ventilated premises.

Radioecological impact studies

In 2004, IRSN conducted two impact studies in the field of radioecology for the public authorities: one concerned the effects of floods of the Rhône river in late 2003 and the other examined the consequences in France of the above-ground testing of nuclear weapons.



Radioactivity of the daily food intake of children aged 8 to 12, between 1961 and 1978: SCPRI measurements in schools in two French cities and values calculated from the radioactivity reconstituted in various foodstuffs included in their food intake.

Study of impact of Rhone river floods of December 2003

In December 2003, the highest water level ever recorded on the Rhône caused flooding as the dykes in the river's low valley overflowed or gave way. When it is in spate, the Rhône carries large amounts of suspended matter (sediment and swell particles washed down from the catchment area), which can contain the major part of the annual flows of some radionuclides. Reflecting the concern of the inhabitants in the areas concerned, CLI in Gard and DRIRE for the PACA region asked the Institute to carry out a scientific survey and, in addition, DGSNR requested an assessment of the radiological consequences of the floods. The results of this survey were presented to CLI in June 2004 and a report was published in October 2004. They show that the levels of radioactivity measured in the soil in the flooded areas and in local produce were not significantly different from those measured in neighbouring areas. The same applied to the main chemical pollutants measured in a few samples.

Impact in France on atmospheric testing of nuclear weapons

Following controversy over significant caesium-137 activity levels measured in the mountainous Montagne Noire area (Aude) in 2002, the DPPR department of the French environment ministry asked IRSN in 2003 to carry out a survey of the fallout in France from all atmospheric weapons tests. This entailed reconstituting the variation with respect to time of the activity of the 14 main radionuclides present in the air, in deposits and in

During flood periods, the Institute takes greater numbers of samples of river sediments which may contain the main part of annual radionuclide flows.

the food chain, and then to assess the doses received by inhabitants. This survey was based on nearly 40,000 results for measurements performed in mainland France between 1961 and 1978. In spite of the large amount of data available, modelling was necessary to fill gaps in the sequences of measurements. Data for fruit and vegetables, wheat, milk and meat were used to adjust the transfer models. The highest activity levels in the air and deposits were due to those short-lived radionuclides. However, contamination of the food chain by those radionuclides remained limited owing to their short half life and their low mobility. Caesium 137 and strontium 90 were measured in practically all the compartments of the food chain during this period.

Iodine-131 contamination of foodstuffs was conducted in bursts after each test.

Overall, for all radionuclides, the activities measured hardly exceeded 1 to 10 Bq/kg^{-1} fresh except in leaf vegetables and grass where the values rose to as much as 1,000 Bq/kg^{-1} fresh in the early 1960s. At each stage of the calculation, IRSN studied the regional variability in order to modulate the very generic assessment of the dosimetric impact of the tests proposed by UNSCEAR.

In 2004, these results were set out in two reports by the Institute, presented to a congress and published in a magazine. A report concerning dosimetric aspects will be published in summer 2005.

Earthquake and flood risks

Seismic hazard

In 2004, the Institute conducted investigations on various dossiers:

- safety option dossier for the Ionisos installation at Sablé (Maine-et-Loire);
- long-term storage of medium- and high-level waste from CEA;
- examination of the preliminary safety report for the Georges-Besse II installation;
- earthquake detectors for the high-flux reactor in Grenoble (Isère);
- safety reviews for 10-yearly outage programmes VD3 900 and VD2 1300.

Assessments were also conducted on foreign installations: a survey concerning the Chernobyl site was carried out by teams from the Institute through RiskAudit, subsidiary of IRSN and GRS, and a study was also carried out on the probabilistic assessment of the seismic risk for the Krsko site (Slovenia) in the context of a European PHARE project.

Flood hazard

Following the flooding of the Le Blayais site (Gironde) at the end of 1999, EDF conducted a review of the protection arrangements for all its installations and of the methods used to characterise the flood hazard. Historically, the flood hazard was defined in the basic safety rule RFS I.2.e by means of the maximum design flood level representing an extreme high water level for sites near rivers or the sea. After the flood at Le Blayais, it appeared to be necessary to allow for additional associated hazards, such as rain, sea swell and

Recording of samples taken from nuclear installations for the analysis of radioactive releases.

ground-water. EDF drew up a dossier for each of its sites with the aim of justifying the protection provisions it had taken against external flooding risks. In addition to the work related to the protection of reactors, IRSN examined, in 2004, the points considered for the dimensioning of protective dykes for the sites at Belleville (Cher) and Le Bugey (Ain). For the Belleville site, this activity more especially concerned the effect of rising groundwater and the "lapping" phenomenon in the case of extreme high water levels. The Le Bugey site chose the solution of percolation under the protective structures.

Environmental **monitoring**

Technical support for authorities with regard to environmental monitoring covers a number of actions: radiological analyses, metrology, cross-comparisons and assistance with inspections.

Monitoring of effluent releases from nuclear installations

IRSN carried out monitoring of radioactive releases from nuclear installations. This undertaking involved a continuous assessment on the basis of radiological analyses of gaseous and liquid effluent samples taken from main drains. The objective is both to verify the release values declared by the operators and to improve knowledge of the nature and activity of the radionuclides released, along with their variations in the course of time, in order to define suitable environmental monitoring plans.
In case of incident or accident, this data is completed by that obtained from samples at stations set up

FOCUS

SETTING UP THE NATIONAL NETWORK FOR ENVIRONMENT RADIOACTIVITY MEASUREMENTS

An order issued on 17 October 2003 placed the technical management of the National network for environmental radioactivity measurements under IRSN's responsibility.

This network will collect the results of measurements conducted over the years by public establishments, government departments, nuclear operators, local authorities and associations. In particular, IRSN is to provide the secretarial services for the steering committee prescribed by the order and take charge of the centralisation, processing and archiving of analysis results. It is also required to make data available to the general public on a website. This network will help to estimate the doses inhabitants are currently exposed to by the whole range of nuclear activities. In order to join the network, laboratories must be able to guarantee the quality of its measurements by obtaining approval from the French Ministries for Environment and Health after nomination by an approval commission. In this context, IRSN organised four cross-comparison exercises in 2004. The Institute also supervised several working groups for the steering committee and the approval commission in order to register all the measurements made and draw up the specifications of the future database. A temporary web portal was developed at the end of the year and will be accessible to the general public in 2005.

Analysis of alkaline elements by atomic absorption spectrometry.

in the environment near the relevant site in order to quantify the extent of releases and their impact on the environment. In 2004, with the monitoring facilities used, it was possible to complete the information given by the operator regarding the events during which accidental gaseous releases of limited size were noted.
Study was pursued in 2004 with DGSNR in order to optimise monitoring by seeking greater relevance of the radionuclides searched for and a decrease in the number of samples analysed (5,300 in 2004), which will reduce the waste produced by the laboratory concerned.

Metrology to support IRSN missions

As the radioactivity contained in samples decreases as time passes owing to the reduction in releases, IRSN is developing increasingly efficient techniques for the processing and measurement of radionuclides found in samples taken from the environment. Thanks to the competencies developed and the means used, the Institute is able to process and analyse radioactivity at low levels (a few tens or hundreds of Bq/kg) and very low levels (a few Bq/kg) in samples taken during radioactivity monitoring operations, by applying protocols and techniques with a COFRAC-approved reference level. In this way, some 30,000 samples entailing nearly 90,000 measurements are processed every year in the IRSN laboratories on its Le Vésinet site (Yvelines). The measuring facilities used can be mobilised for accident or post-accident situations if necessary.

Conducting of cross-comparisons

The Institute organises and prepares samples for annual cross-comparison campaigns in the context of public health code at the request of DGSNR for the approval of measurement laboratories. Four cross-comparisons were made in 2004, on the analysis of low-activity radionuclides of natural or artificial origin in various environmental matrices (water, algae, plants).

Support for inspections

In its capacity as technical expert, IRSN provides support for basic nuclear installation inspectors conducting unexpected plant inspections, such as at Nogent-sur-Seine power plant (Aube) in January 2004.

Technical support in the field **of radon**

IRSN provided support in the following ways in 2004:

- some 30 predictive mapping surveys were conducted by various organisations using a variety of methods to identity areas concerned by radon in certain French departments, in response to requests from DDASS and DRASS. DGSNR asked IRSN to prepare a report on these surveys and to propose criteria for the classification of geographic areas according to the level of their "radon potential";
- as the reference organisation on the subject of radon, IRSN contributed to the work of the French national commission for the approval of organisations authorised to conduct radon activity concentration measurements in locations accessible to the public;
- IRSN prepared technical data sheets giving examples of the reduction of radon concentrations in public, private and industrial buildings. These data sheets were circulated to DDASS and DRASS.

Operation to recover a high-level irradiator in a clinic in Toulouse.

Radiation protection **response and assistance**

In 2004, public authorities at both national and local levels called on IRSN on a dozen occasions for various operations which led to the discovery of ionising radiation in inappropriate locations.

One example was the case where radioactive material was found in a private home in Huningue (Alsace). At a first stage, these operations consist in establishing the qualitative and quantitative characteristics of the radionuclides found and the extent of the areas which may be contaminated. IRSN then undertakes to make the locations safe by placing the contaminated equipment or sources in appropriate packaging and storing it pending its subsequent elimination by a suitable process.

Other types of operations are also carried out by IRSN, such as: assistance with radiation protection on tritium-contaminated work sites at Ganagobie (Alpes-de-Haute-Provence), technical support for inspections carried out by public authorities (train carrying irradiated fuel at Bordeaux railway station) and action taken on radon-contaminated sites.

Radiation protection of workers

IRSN contributed to the drawing-up of decrees and orders required by modifications to French regulations on radiation protection of workers.

The Institute also participated in the monitoring of the worker exposure and was involved in the screening of applications for the approval of external dosimetry laboratories and in the organisation of cross-comparisons.

Impact of changes in regulations on IRSN activities

Changes in French regulations on worker radiation protection were stipulated in decree No. 2003-296, issued in 2003 and supplemented in 2004 by decree No. 2004-1489 authorising IRSN to use the national population register. IRSN played a part in the drawing up of these decrees and the relevant implementation orders which entrust IRSN with keeping the national inventory of ionising radiation sources (SIGIS) and managing worker monitoring system (SISERI). Decree No. 2003-296 also mentions the Institute's role in the measurement of individual external and internal doses for exposed workers, in the provision of expertise such as surveys of work stations and consulting services to assist industrial doctors and radiation protection officers. It also opens up prospects for studies and research for IRSN, such as the processing of dosimetric data for epidemiological purposes.

Follow-up of worker exposure

IRSN uses the following two tools to follow up worker exposure:

Passive dosimetry.

■ SIEVERT is used to assess doses in flying crew. This system, developed in collaboration with DGAC is now operational. The model allowing for solar eruptions for the calculation of doses has been improved since 2004.

■ SISERI centralises all the dosimetric data on exposed workers on a nation-wide basis. 2004 was a key year for the setting up of SISERI. The tasks started were successfully completed:

- fitting out of renovated, secure premises for the team responsible for running SISERI and computer servers;
- installation and acceptance of computer system with, in particular, the recovery of data from the earlier database;
- testing of the system's various components (legal, IT, etc.) during the pilot phase (second half of 2004), with a limited number of establishments consulting or transmitting dosimetric data;
- communication of information on the system's time limits, features and statutory provisions to the various partners and users (industrial medical officers and radiation protection officers);
- publication in the OJ of: the decree of 30 December 2004 authorising IRSN to use the national register of persons (RNIPP); the order concerning the medical supervision form and individual dosimetric data on workers exposed to ionising radiation; the favourable opinion issued by CNIL on 24 June 2004 regarding the management of confidential data in SISERI. These three statutory instruments were necessary to officially start up SISERI.

The system will come into operation in 2005, when all contributors and users must be able to access the database in accordance with stipulated protocols. Work on the integration of the oldest dosimetric data in the database will be continued. In this manner, SISERI should soon become an essential tool for the follow-up of workers exposed in corporate environments and a powerful survey tool for the processing of the centralised data for the purposes of prevention and protection.

Approval and cross-comparison

In pursuance of the order of 6 December 2003, about four out of 10 external dosimetric laboratories submitted applications to IRSN for approval by the Work Relationship Directorate in 2004. IRSN gives its opinion on the suitability of the equipment and methods used by those laboratories. The order also requires IRSN to organise a cross-comparison of the dosimeters proposed by the laboratories. This cross-comparison was carried out in October 2004.

Scanner acquisition console at Cochin Hospital.

Radiation protection in the **medical field**

The justification of medical acts and the optimisation of exposures are the two principles underlying the protection of personnel exposed for medical reasons. These principles are mentioned in the Euratom directive 97/43. In France, they are reflected in decree No. 2003-270 of 24 March 2003 and the corresponding provisions are included in the public health code (articles R.1333-55 to 74).

Reflection on the actions to be taken for the radiation protection of patients began in 1998 with a study mission entrusted to Professors Bonnin and Lacronique concerning measures for the improvement of patients' radiation protection, i.e., reducing doses administered to the lowest possible level, while maintaining the quality of the radiological treatment. Thereafter, a working group of experts from institutional bodies and health professionals gave recommendations published by InVS in 2002. Then, in 2003, DGSNR

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RADIOGRAPHIC EXAMINATIONS IN SPORTS MEDICINE

An order issued on 11 February 2004 defines the nature and frequency of medical examinations, which may be common to all sport disciplines or conducted for a specific sport discipline.

Radiographic examinations may be prescribed, such as x-rays of the lumbar spine (front, side, 3/4 views) performed annually before the age of 15 and then every two years, or of the cervical spine (front, side with measurement of the Torg ratio) every two years. The Sports Department of the French Ministry for Youth, Sport and Associations asked IRSN in 2004 to conduct a study to assess the risks associated with prescribed radiographic examinations.

IRSN examined several cases characterised by the morphology and age of the sport practitioner (in order to adapt the parameters of radiographic examinations) and duration of the sporting career:

- slim or heavily-built sport practitioner;
- adolescent aged under 15 or over 15;
- sporting career of six years or ten years.

For each of these cases, the doses received (in mGy) by the most exposed organ, by the thyroid gland and by the reproductive organs, and the effective dose (in mSv) were calculated. As regards the individual effective dose received over a whole sporting career, they are between 0.4 and 5.6 mSv, i.e., no more than approximately the dose received in a single scanning examination.

Scanner interpretation room.

– in close cooperation with the relevant departments of IRSN and InVS – drew up an action plan for the monitoring of the exposure of patients to ionising radiation of medical origin (PASEPRI). The courses of action adopted meet two objectives:

- improve knowledge of patients' ionising radiation exposure doses so they can be further optimised;
- gather the knowledge required for the subsequent development of action for the epidemiological monitoring of the effects of ionising radiation on patients.

The relevant actions are classified into six categories: regulations, exposure information system, monitoring of effects of ionising radiation, surveys, the scientific triality of information/training/technology monitoring, and research. All these topics concern IRSN to varying degrees and some are actually included in its missions. Two topics concern IRSN in particular: diagnostic reference levels and medical exposure observatory.

Diagnostic reference levels

The order of 12 February 2004 specifies in article 5: "IRSN is responsible for collecting the data required for periodic updating of diagnostic reference levels. For this purpose, it receives, from the operator or the authorised party, the results of the assessments conducted in pursuance of articles 2 and 3." The examinations concerned by these provisions include conventional x-ray examinations (six for adults, four for children), four scanning examinations in

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JOINT IRSN/AVN/GRS GUIDE TO SAFETY ASSESSMENT

IRSN and its German and Belgian counterparts (GRS and AVN, respectively) have been developing close collaboration in many fields for several years, including research, safety studies and exchanges of information on problems encountered in nuclear installations in order to improve their competencies in nuclear safety. After in-depth comparison of the safety assessment practices implemented by the three organisations, they decided to draw up a joint guide to safety assessment.

The purpose of this guide is to give recommendations on the performance of safety analyses with reference to safety dossiers submitted by nuclear operators. It specifies the rules to be complied with in order to ensure the quality of those analyses and stresses, in particular, the objectivity and technical quality of assessments as these are essential factors for the credibility of the resulting appraisals. The guide is applicable to assessments for all types of nuclear installations or activities, including transport and storage of radioactive materials.

The work completed in 2004 concerned, in particular, the general principles of conducting safety assessments. This will be followed by more technical aspects concerning safety principles and the key points of assessments for the various types of nuclear installations and activities.

Positioning a patient for a scanning examination.

adults and 10 nuclear medicine examinations. IRSN's action in 2004 mainly consisted in presenting the modes of application of these provisions to healthcare professionals and updating data sheets along with experts from learned scientific societies. Data collection has been started. By late 2004, about 10 nuclear medicine departments (out of approximately 300) and one radiology department (out of about 5,000) had sent IRSN the data required by the order. In addition, several radiology departments asked IRSN for help in validating the dosimetric data supplied by their installations or measuring the doses delivered to patients' skin.

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STRENGTHENING COOPERATION WITH CHINESE SAFETY AND RADIATION PROTECTION ORGANISATIONS

Having started some twenty years ago when French companies built the Daya Bay nuclear power plant (China), cooperation between IRSN and its Chinese partners in the field of nuclear safety and radiation protection mainly concerned the training of personnel and the sharing of analysis methods and tools.

In 2004, the Chinese authorities and IRSN agreed to give this cooperation a new boost which resulted in the performance or start-up of several actions in the course of the year. In this context, the Director General of IRSN met the managers of the Chinese safety and radiation protection authority and of nuclear safety assessment and research organisations. In addition, a new programme was arranged to receive Chinese trainees at IRSN and a study was started to promote joint projects on radiation protection and nuclear safety including the setting up of associated laboratories. Preliminary discussions were also held on the association of Chinese organisations with IRSN research programmes such as the international CABRI programme and the SOURCE TERM programme.

Cardiological radiology installation at Cochin Hospital.

Observatory of medical exposures to ionising radiation

The frequency of the various radiological examinations and the corresponding doses must be known in order to assess what contribution medical exposure makes to the population's total exposure. This data is also required in order to meet the increasing public demand for information on medical practices, the number of treatment sessions and the corresponding doses. For this reason, IRSN and InVS are working together to create an observatory of medical exposure to ionising radiation for the purposes of public assessment.

In 2004, preliminary work was carried out to draw up an analysis of the data available in France from institutional databases (CNAM-TS and SAE). This resulted in a count of approximately 44.3 million treatment sessions per year including 3.5 million scanning examinations but the data did not provide any information on the exact nature of the treatment sessions or their corresponding doses. However, this initial summary forms the basis on which the observatory will rely for future tasks in two main categories to be performed in 2005:

- creation of a network of establishments representative of French practices;
- more specific investigations to obtain more detailed analyses of practices.

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HOSTING TRAINEES FROM CHINESE SAFETY ORGANISATIONS

Having accepted a request for support from the IAEA regarding fire protection, IRSN welcomed a representative from China Atomic Energy Authority and three engineers from Beijing Institute of Nuclear Engineering in early May 2004.

For two weeks, IRSN agents gave explanations of their methods of assessment and the standards applied, illustrated by actual analysis cases. This new contact marks the beginning of a collaboration with Chinese nuclear organisations in the field of fire and explosion protection.

Furthermore, in the context of collaboration between IRSN and NNSA-NSC, two engineers from the Beijing Nuclear Safety Centre (China) arrived at IRSN in October 2004 for a one-year stay: one of them working on nuclear power plant safety reviews and the other taking part in probabilistic safety assessments.

IRSN's fire and explosion protection specialists received a Chinese delegation on 14 May 2004 at the Fontenay-aux-Roses site.

Discussion between parties in the crisis is facilitated by using maps showing measurement points around the accident-affected installation.

Operational support in the event of a crisis or radiological emergency

In the event of a crisis or radiological emergency, IRSN provides operational support during the emergency phase itself but also during the post-accident phase. The Institute has the means to deal with all these situations. It implements and sizes them according to the magnitude of the event.

In 2004, IRSN took part in the revision of official texts related to radiological emergencies and how to deal with them and in the transposition of European directives in these fields conducted by SGDN. This work particularly involved drawing up an interministerial directive on the action of public authorities in the event of a radiological emergency and on the development of a directive related to the performance and processing of environmental radioactive measurements in the event of a radiological emergency. The first directive dates from 7 April 2005 and gives IRSN a central role in the technical coordination and interpretation of environmental radioactivity measurements. To prepare for this role, the organisation of crisis management within IRSN evolved in 2004.

Emergencies

In the event of an emergency, IRSN provides public authorities with operational support based on fixed and mobile means that can be mobilised rapidly: emergency response centre, resources for assessing individual exposure, etc.

Developing crisis resources

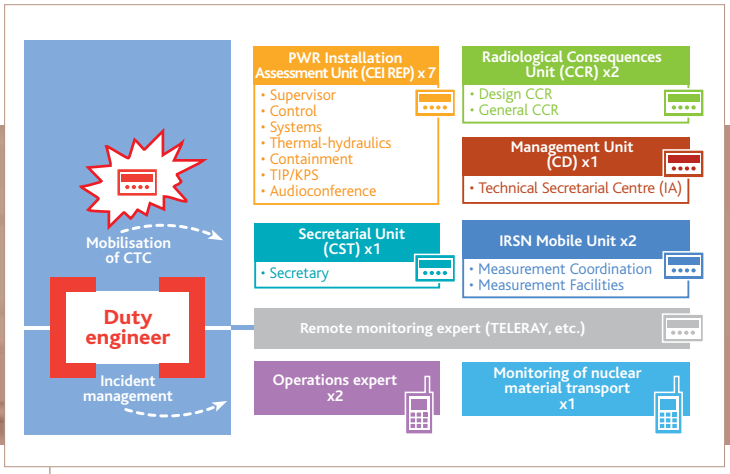
Renovating the emergency response centre (CTC)

Renovation on the Institute's CTC started in 2003 and was completed in 2004. As well as renovating the infrastructures, the premises used for the technical units were enlarged and their ergonomics improved. Telephone equipment and audiovisual equipment was resized and access to documentation was facilitated.

Improving the duty system

In 2004, the Institute carried out an overall reorganisation of its on-call system. Former practices, inherited from IPSN and OPRI were harmonised so as to produce a coordinated, homogenous and coherent system. Moreover, the role of "duty engineers" was clarified: they are now IRSN's only point of entry for emergency calls.

The system also includes agents who can be mobilised for IRSN's mobile unit. They will be rushed to the site of the accident in addition to the CTC agents.



The duty engineer is IRSN's sole input point for all types of emergency calls 24 hours a day.

Organisation, methods and materials

The crisis organisation, the methods and the expert assessment materials are constantly being improved. Discussions on the expert assessment methods to be adopted for an accident affecting EDF reactors were pursued. Material to assist in the expert assessment of the state of installations and the estimation of consequences for laboratories and plants was completed. In addition, in 2004, work was carried out on emergencies that could affect an installation or ship of the French Navy. This work resulted in the definition and implementation of a specific organisation for the Unit in charge of assessing the installation ("CEI-Marine") in the CTC. The Institute and naval staff entered into discussions with a view to drawing up a common expert assessment method and developing tools to estimate the consequences of accidents.

Exercises and feedback

IRSN took part in 12 exercises organised by public authorities to test the national crisis organisation, via the activation of its CTC and the dispatch of its mobile unit to the prefecture's operational control centre (PCO). It should be emphasized that the type of accidents envisaged (military installations, transport) and the subjects dealt with during the exercises are more and more diversified, especially during the post-accident phase.
Among the lessons learnt from these exercises is that it is essential to continue developing expert assessment methods. For EDF reactors, this concerns specific situations (shutdown). For laboratories, plants and transport, we should continue developing pre-calculated data sheets on the three types of discharge, the consequences and specific tools. Finally, these exercises emphasized that a great effort should be devoted to improving coordination,

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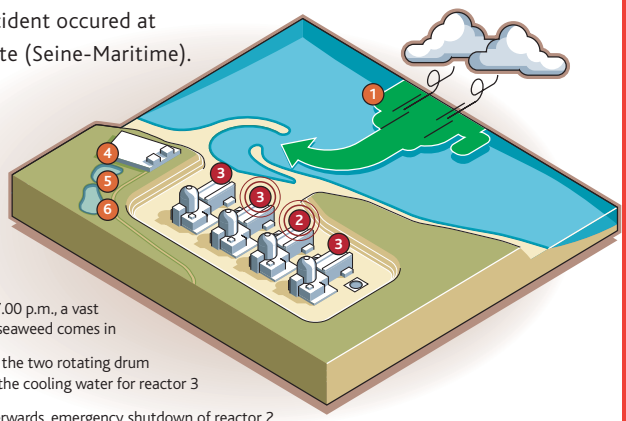
REAL ACTION TAKEN BY THE CTC

IRSN's Emergency response centre (CTC) went into action in 2004 when two real incidents affected EDF's nuclear power plants:

■ **on Sunday 16 May,** a fire broke out in reactor 2 of the Cattenom power plant (Moselle), causing the destruction of electric cables. As a preventive measure, the operator activated the "safety and radiological" internal emergency plan (PUI). Alerted by DGSNR's warning device, IRSN's duty personnel arrived at the CTC at about 03.00 p.m. and monitored how the situation was developing.
At about 06.00 p.m., in the absence of anything worrying, the CTC was deactivated and personnel were put on standby in their homes until the next day *(see Focus p. 92: Incident at Cattenom)*;

■ **on Wednesday 23 June** at about 07.00 p.m., a second incident occured at the Paluel site (Seine-Maritime).



1. At about 07.00 p.m., a vast amount of seaweed comes in
2. Clogging of the two rotating drum screens for the cooling water for reactor 3
3. Shortly afterwards, emergency shutdown of reactor 2 was unavoidable and then reactors 1 and 4 were shut down as a precaution
4. At the requests of EDF and DGSNR, IRSN mobilised its Emergency Response Centre (CTC) at about 11.00 p.m. to monitor the development of the situation
5. The CTC remained mobilised all night long
6. The decision to demobilise was made at about 03.00 p.m. the next day after various reviews

Although these two incidents presented little risk as far as reactor safety was concerned, they showed the CTC's capacity for reaction and the high level of professional motivation on the part of the duty teams.

Discussion between the doctor and contamination measurement experts in IRSN's Master Gemini mobile laboratory.

interpreting environmental measurements and managing the post-accident phase. Furthermore, the CTC should renew its mapping tools to be able to meet the requirements of outside contacts more effectively.

Fixed operational resources for assessing individual exposure

In the event of a crisis, in addition to its mobile resources, IRSN may have to use the fixed resources located on the sites of Fontenay-aux-Roses (Hauts-de-Seine) and Le Vésinet (Yvelines). These resources are dedicated to the dosimetric monitoring of exposed workers and in the event of an accident, suspected external irradiation or internal contamination, they are used to assess the doses received by a small number of victims. For each of these resources, the operational capacities have been estimated by associating the number of examinations it is possible to carry out with the acceptable detection limits for emergency assessments.

The biological assessment of the dose received by external irradiation is based on the number of unstable chromosomic anomalies in the circulating blood lymphocytes. IRSN has implemented a technique that can process 200 blood samples in two

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EXERCISE IN DEALING WITH VICTIMS OF A RADIOLOGICAL ATTACK

IRSN took part in exercise R 53 concerning operations to deal with victims of a radiological terrorist attack. It was carried out at the Necker Hospital (Paris) on Sunday 10 October 2004 and organised by the Paris Public Hospitals, SAMU 75 (mobile accident unit), Police Headquarters of Paris and DGSNR.

The Paris Fire Brigade, SPRA and IRSN were invited to take part. The Minister of Health and the representative of the Minister of the Interior were present during the exercise.

The scenario involved a "dirty" bomb exploding in a public place, leading to the spontaneous arrival at a hospital of 50 people, plus three seriously injured people brought by ambulance. The aim of the exercise was to test whether the required equipment was in place in the event of radioactive contamination. Personnel from the Necker Hospital Nursing College played the role of contaminated victims. The tents for receiving victims and for decontamination had been put in place beforehand so that they could be put up quickly.

IRSN sent the following personnel to the Necker Hospital:

- two operators to carry out internal contamination tests with the mobile laboratory (Master Gémini);
- three operators to carry out radioactivity tests upstream and downstream of the decontamination chain;
- a doctor to observe operations;
- a specialist at the local emergency control centre called the "Control Tower";
- a doctor in charge of communication.

IRSN was involved in sorting the people who arrived at the hospital and carrying out individual contamination tests.

IRSN experts are called upon to create suitable scenarios for all crisis exercises.

weeks with a dose uncertainty of ± 1 Gy. In 2004, a convention of mutual assistance was signed with NRPB (United Kingdom) and BfS (Germany) whereby each signatory can request assistance from the two other parties if more than 300 samples have to be processed. If those involved need to be provided with passive dosimeters, IRSN has 4,000 dosimeters that it can process in two batches of 2,000 dosimeters in one and a half days for each batch.

Internal contamination is judged by measuring bodily retention via whole-body radiometry and by measuring radionuclides in excreta (urine, stools). The operational capacity of IRSN's fixed whole-body radiometry resources for measuring pulmonary retention of actinides, retention of radioactive isotopes of iodine in the thyroid and retention of fission and activation products in the whole body is presented in table 1. The operational capacities of IRSN in radiotoxicological analysis are presented in table 2. Depending on the complexity of the exposure situation and the information available (the physico-chemical characteristics of the contaminant for example), it takes between thirty minutes and four hours to assess the dose received by a contaminated person.

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EXERCISE IN DEALING WITH AN ACCIDENT INVOLVING TRANSPORTED RADIOACTIVE MATERIAL

On 30 September 2004, a national crisis exercise was carried out to simulate a transport accident involving radioactive material.

For the first time, the scenario concerned rail transport. There was supposed to be a collision between a tanker and a railway wagon loaded with a package of irradiated fuel from an EDF power plant, at a level crossing near Saint-Pierre-des-Corps railway yard (Indre-et-Loire).

The expert assessment involved making a diagnostic of the condition of the package and forecasting its evolution so as to evaluate the environmental consequences of the accident and assess the solution proposed by the sender for recuperating the package.

As well as preparing and coordinating the exercise, IRSN deployed its crisis organisation to provide support to public authorities (it activated the emergency response centre and sent a mobile unit to the site of the accident).

The exercise highlighted the progress made since the previous exercise, especially in the organisation of the mobile unit, and the main points the Institute needs to improve, i.e., feedback from the site of the accident, autonomy in means of communication, etc.

Setting up an accident scenario.

At the operational control station, IRSN experts explain the action plan to be implemented around the accident-affected installation to representatives of the fire brigade.

Operational capacity of IRSN's fixed whole-body radiometry resources

	Pulmonary retention of actinides			Retention of iodine in the thyroid			Retention in the whole body of fission and activation products			
Radionuclide	239Pu	241Am	U natural	125I	129I	131I	57Co	60Co	134Cs	137Cs
Detection limit (*) (Bq)	13,800	60	750	3	5.2	6.4	100	72	64	100
Counting time	10 minutes			10 minutes			5 minutes			
Operational capacity	210 people per week			210 people per week			560 people per week			

(*) Detection limits were estimated for a standard man of 70 kg and increased to take into account a possible increase in the ambient background in the case of an accident.

Operational capacity of IRSN's radiotoxicological medical analysis laboratory

	Direct measurement of gamma emitters in urine	Direct measurement of beta emitters in urine (3H, 14C, 90Sr)	Beta measurement of strontium 90 in urine	Measurement of alpha emitters in urine or stools (238-239Pu, 234-235-238U)	Weighted measurement of uranium (natural or depleted) in urine
Detection limit	16 Bq/l	3,840 Bq/l	1 Bq/l	2 Bq/l	5 µg/l
Counting time	15 minutes	7.5 minutes	60 minutes	36 hours (*)	Immediate measurement
Operational capacity	270 samples per day	480 samples per day	60 samples per day	32 samples per day	50 samples per day

(*) A fixed period of at least three days must be added to the counting time for the pre-processing of the samples.

Support in **managing post-accident situations**

Two working groups were set up within IRSN to develop proposals for guidelines on the management of post-accident situations and a strategy for measuring individual and environmental radioactivity.

The group working on "Guidelines" discussed the lifting of the sheltering directive after a nuclear accident. Sheltering protects the population from the immediate consequences of an accident but cannot be prolonged for very long. A decision has to be taken on whether to keep the population in

During the exercise, the fire brigade has the task of taking field samples specified by IRSN.

the area concerned or whether to move them away temporarily (or even definitively). This difficult subject has received little attention from the international community and cannot be settled with technical criteria alone. The parties involved (public authorities, elected representatives, the population) would, no doubt, have to confer with each other in depth during the post-accident phase. During this phase, the radiological risk comes from long-term, low-dose rate exposure.

The group working on "measuring radioactivity" started by stating the main objectives of the radioactivity measurements at the different stages of a nuclear or radiological crisis:

- during the emergency phase, the area affected by the passage of the radioactive plume has to be determined, the radioactive release has to be assessed and the various consequences of the accident evaluated;
- at the beginning of the post-accident phase, measurements enable an initial radiological characterisation to be made and help public authorities take decisions regarding the protection of the population concerned;
- then, during the post-accident phase, measurements will make it possible to define contaminated areas where the maximum levels acceptable for the marketing and consumption of foodstuffs have been exceeded and to define rehabilitation strategies for agricultural and built-up areas.

Moreover, in 2004, the Institute continued developing computer tools for accident situations to measure environmental radiation (DATARAD) and produce graphic representations of these results (CARTORAD). This work should allow IRSN to effectively carry out its mission of centralising and interpreting, at national level, all the results of the contamination measurements taken during the accident situation

FOCUS

PIERRELATTE EXERCISE

The main crisis exercise of 2004 was carried out at the Tricastin site (Drôme) on 18 and 19 November under the coordination of SGDN.

This greatly mobilised the Institute in various ways. In addition to organising the technical scenario, activating the CTC and sending a mobile unit to the operational control centre, a new element was introduced, i.e., a person was sent the CICNR, placed under the authority of the Prime Minister, and to a crisis unit set up by the Ministry of the Interior's COGIC. These inter-governmental units do not systematically take part in all exercises.

IRSN's role here is to provide technical advice.

Moreover, the Pierrelatte exercise presented a certain number of characteristics: it was aimed at testing the ability of the national crisis organisation to manage the emergency phase of the accident and also the start of the post-accident phase. Among the issues addressed was the lifting of the sheltering directive for populations living near the site. During the exercise, IRSN made various recommendations to the safety authorities (DSND then DGSNR), related to consumption restrictions, rehabilitation of contaminated areas, taking a census and checking the population. This exercise highlighted that IRSN needed to increase its presence at local level in the event of crises.

At the operational control station, IRSN reviews aspects regarding the measurements taken in the environment.

In IRSN's truck, equipped with a radioactivity measurement laboratory, 12 people at a time can be given thyroid and chest check-ups.

FOCUS

CD-ROM – "INFORMATION ON NUCLEAR RISK AND HOW IT IS MANAGED"

In April 2004, IRSN distributed a CD-ROM on nuclear risk and how it is managed.

The purpose was to provide clear information, accessible to non-specialists, on nuclear accidents, their possible short - and long-term consequences and the way an accident situation can be managed.
Indeed, it became clear that all parties concerned should possess the same knowledge on nuclear risk and how to manage it.

This CD-ROM is mainly intended for decentralised bodies in charge of managing crises – prefectorial bodies, departments in charge of civil defence, fire protection, emergency services, departments in charge of health, agriculture and facilities, the police force, etc. It is also intended for CLIs, given the diversity of the missions they carry out.

In 2004, the Institute supported the distribution of this tool by organising detailed presentations of the CD-ROM, at the request of DSND, ANCLI's Scientific Board, SGDN's protection and safety of the State division and the CLI of Nogent-sur-Seine (Aube).

and the post-accident situation by the various teams, especially the fire brigade and the operators. To evaluate how the contamination of the food chain and the different parts of the biosphere evolve over a period of time, the Institute's CTC relies on a specialised team located at Cadarache (Bouches-du-Rhône) that uses impact calculation tools like ASTRAL and cartographic representation software programs. The team can thus integrate the environmental data from the field and from modelling. This organisation was tested during the SECNUC, post-accident phase, crisis exercise. It concerned an accidental release from the COGEMA installations in Pierrelatte (Drôme) on 18 and 19 November 2004. Indeed, IRSN was very involved in the preparation of this exercise, coordinated by the SGDN and the MARN (DDSC). It was also involved in the exercise carried out in Belleville-sur-Loire (Cher) in March 2005. The Institute's support in this field included:

- preparation of the strategy to measure radioactivity in the environment and in foodstuffs;
- identification of the actions that could be implemented during the hours following the lifting of the sheltering directive;
- development of a draft version of a tool that would help IRSN's CTC decide upon the first actions needed for the rehabilitation of agricultural and built-up areas.

The renovation of mobile facilities entails the updating of a whole range of equipment (vehicles, measuring equipment, data processing equipment).

Operational support in case of crisis

IRSN provides the State's decentralised departments with in-the-field operational support for the coordination and validation of radioactivity measurements performed by different operators in the environment and on the population.

This support concerns the emergency phase and the post-accident phase. In 2004, for each exercise, the Institute's mobile unit, composed of a team to coordinate measurements and a team with a mobile measurement system, was mobilised for real or fictive situations and put at the disposal of the site's operational control centre. During the "transport" exercise at Saint-Pierre-des-Corps (Indre-et-Loire), the unit was reinforced by a unit head who also gave operational radiation protection advice to those involved in the exercise.

FOCUS

PLAN TO RENEW MOBILE RESOURCES

In 2004, IRSN started drawing up a plan to renew its mobile resources. This mainly concerns the resources needed for the different situations that the Institute may have to deal with.

The Institute has a stock of mobile resources, the oldest of which was developed in the 1970s but most of which date back to the 1980s. They are intended for carrying out large-scale anthropogammametric measurements on people likely to have been exposed to radioactive releases. The purpose of these measurements is to sort the population according to their level of internal contamination in order to direct them to the suitable medical departments.
These resources can also be used to measure radioactivity present in food chain samples or environmental samples via γ spectrometry.

These resources have been used in France during emergency exercises in which IRSN participated and for various other operations: at polluted sites (the Bayard site in Saint-Nicolas-d'Aliermont, Seine-Maritime), to monitor transportation (SNCF wagons), to measure exposure to radioactive fallout from the Chernobyl accident (Saint-Jean-d'Ormont, Vosges, and in the Mercantour) or for incidents involving contamination during the shutdown of nuclear power plants.
The stock of mobile operation resources has, on the whole, been maintained in operational condition but due to its age, it is becoming more and more difficult to maintain.


1,714,000
personal dosimeters supplied and used
1,019
analyses of drinking water carried out
150
analyses of foodstuffs carried out
Almost
150
radiation protection operations

Contractual services of expert appraisal, research and measurement

Selling services enables IRSN to turn to account the know-how and specific skills it has acquired in the nuclear field that are applicable to other fields of activity. Selling services is also a way of optimising the use of technical platforms developed for research programmes. It also enables the Institute to diversify its sources of income.

Excluding the co-financing of research, the services provided by IRSN correspond to about 5% of its present budget. Once developed, they should not exceed 15% of this budget. Moreover, the Institute is careful to ensure that these services remain compatible with its mission of support and technical assistance to public authorities.

> 138 Services related to statutory requirements

> 142 Services not related to statutory requirements

Evaporator room of the water analysis laboratory at Le Vésinet (Yvelines).

Services related to statutory requirements

Radiological testing of water intended for human consumption

The evolution of regulations aimed at providing better consumer protection has led to a high demand in radioactivity measurements of water intended for human consumption. IRSN provides radiological water analysis services to manufacturers and regulatory bodies (DDASS).

The radiological quality of water is assessed via two parameters: the total indicative dose (TID) and the tritium activity. The measuring strategy consists in measuring the tritium activity and the overall activity of alpha and beta emitting radionuclides. If these activities are less than 100 Bq/l, 0.1 Bq/l and 1 Bq/l respectively, the TID is considered as less than 0.1 mSv per year. If this is not the case, further analyses are carried out to identify the natural or artificial radionuclides responsible for these excessive values and a dose calculation is conducted for a consumption of 730 litres of water per year. This dose is then compared with the 0.1 mSv/year defined by the Euratom directive, based on the WHO recommendations.

The time required to conduct the analyses varies from 4 to 12 weeks, depending on the tests. In 2004, about 20% of the cases processed required further analyses. As a result of new regulations, IRSN tested three times more samples in 2004 than in 2003.

Radon detection

Within the framework of risk management related to radon in buildings, IRSN provided detection services and conducted further investigations as defined in the regulations. In 2004, radon measurements were taken in several establishments open to the public. The IRSN department concerned (Radiation protection Response and Assistance Service) received ISO 9001 certification from AFAQ for studies and expert assessments conducted in radon control.

Cobalt 60 irradiator, "ICO 4000".

Radiation protection **of workers**

Decree 2003-296 of 31 March 2003 and the associated application orders, aimed at protecting workers from ionising radiation, have led IRSN to provide services involving the measurement of individual, external and internal doses in exposed workers, expert assessments involving workstation studies and consultancy services for industrial physicians and people skilled in radiation protection.

Monitoring external exposure of exposed workers

Over 250,000 workers are at risk of external exposure to ionising radiation in France. According to regulations, the monitoring of occupational exposure is conducted via passive dosimetry whatever the field (medicine, the nuclear industry or not). There are various techniques for measuring doses: photographs, thermoluminescence or trace detection. They result in a wide range of dosimeters adapted to various radiation fields and variable doses. In 2004, IRSN monitored about 150,000 workers in 18,000 establishments. The breakdown of dosimeters used for this is as follows:

- 1,600,000 photographic dosimeters;
- 61,000 thermoluminescent dosimeters;
- 53,000 trace-detection dosimeters.

Monitoring the internal contamination of exposed workers

Assessing the exposure of workers at risk of internal contamination is conducted by determining the incorporated activity in the body. Two types of analyses are used, i.e., measurement of incorporated activity via whole-body radiometry and measurement of excretion activity via the radiotoxicological analyses of urine and stools. In 2004, IRSN:

- conducted 131 whole-body radiometry examinations;
- and regarding radiotoxicological analyses:

- 3,889 people were monitored;
- 7,790 biological samples were tested (urine, stools, hair, nails, blood);
- 21,089 tests were conducted;
- 64 different radionuclides were measured during analyses.

Qualification of measuring installations

In 2004, IRSN was requested on several occasions to examine whole-body radiometry installations: Civaux nuclear power plant (Vienne), CEA centres in Valduc (Côte-d'Or) and Grenoble (Isère) in order to check the calibration quality of these installations.

Studying workstations on SNCF trains transporting radioactive material

Regulations regarding the rail transport of dangerous goods require operators to have a radiological protection programme for the transport of radioactive material. Within this framework, SNCF entered into a contract with IRSN whereby the latter will carry out dosage measurement campaigns at workstations for the nine types of radioactive materials transported. In 2004, IRSN characterised four types of transported material. The five other types will be studied in 2005.

Approval of protection equipment by technical centres.

Conformity of materials and equipment

IRSN has two technical centres in charge of checking that equipment and materials comply with standards (or any other pre-defined baseline). These centres can intervene at the request of operators, manufacturers or authorities, within the framework of programmes involving the development of materials or processes or to meet statutory requirements.

In their fields of expertise, they take part in drawing up statutory and normative texts for France and for other countries.

The activities of IRSN's Technical Centre for Radiological Protection Instrumentation Approval (CTHIR) involve individual dosimetry, atmospheric or environmental dosimetry, measurements of contamination (water, air, surfaces) and detection of criticality accidents.

In 2004, CTHIR participated in standardisation working groups within the framework of the SC45B subcommittee in charge of radiation protection instrumentation within IEC. 2004 saw the publication of standard IEC 62022 for which the CTHIR was project manager. It concerns systems to detect sources of γ radiation transported in vehicles. CTHIR is also part of the French delegation to CENELEC (European standards) and is in charge of transcribing IEC standards into European standards.

After analysing test results and technical dossiers, CTHIR gave its opinion on the compliance to relevant standards of an operational dosimeter and a detection set for criticality accidents. It calibrated 17 probes associated with this type of system – this is done before they are first put into service or when they are returned for maintenance.

Examinations on the compliance of radiation protection equipment are carried out in accordance with CTHIR's quality management system which received ISO 9001 certification, version 2000, at the end of 2002.

CTHIR operates the IRMA irradiator (Saclay, Essonne). This installation can irradiate equipment and material within the framework of studies on their resistance to radiation (dose rate of up to 20 kGy/h). Campaigns conducted in 2004 represent a total of twenty-eight weeks and were mainly directed at research units and manufacturers of radiation detectors.

The expertise of IRSN's Technical Centre for Nuclear Equipment Approval (CTHEN) involves the approval of safety equipment used in the nuclear industry (mainly high-efficiency filters and fire dampers) and the certification of individual protection equipment.

Operational dosimetry.

CTHEN receives notice from the Ministry of Labour to carry out EC type examinations on clothing and gloves intended to protect workers from ionising radiation or radioactive contamination. Its missions are governed by an agreement signed on 23 August 2004 between IRSN and the Ministry. Two types of ventilated clothing received "EC" certification in 2004 and 118 "extended" certificates were issued (following modifications to previously certified equipment or associated technical dossier).

FOCUS

NON-NUCLEAR THIRD-PARTY EXPERTISE

Expertise gathered in the field of nuclear safety enables IRSN to conduct critical analyses of studies on the environmental dangers of classified industrial facilities belonging to different sectors of activities (agri-food industries, fine chemistry, petrochemistry, etc.).

Among the 50 or so critical analyses conducted by IRSN in 2004, we can cite those linked to ARKEMA's sites in Balan (Ain), Carling (Moselle), Saint-Fons (Rhône) and La Chambre (Savoie), Cristal Union's alcohol distillation plants in Bazancourt (Marne) and Bray-sur-Seine (Seine-et-Marne), Grande Paroisse's plant in Grandpuits (Seine-et-Marne) that manufactures ammonium nitrate-based fertilisers, SOGIF-Air Liquide's sites in Fos-sur-Mer (Bouches-du-Rhône), Tavaux (Jura), Richemont (Moselle) and Grand-Synthe (Nord).

Staff of the non-nuclear installations safety analysis centre.

To conduct these analyses, IRSN relies on its expertise in the following fields: fire, explosion, atmospheric dispersion, command control, reliability of components, human factors, seismology, flooding, etc.

The Institute also takes part in different working groups set up by the Ministry of the Environment and Sustainable Development: technological risk prevention plans, toxicological reference values, a group of third-party expert bodies as well as several sector-based working groups (chlorine, LPG, ammonia, flammable liquids, etc.). Finally, IRSN provides the administration with technical support when discussions are held at European level on the best technologies available in terms of risk prevention.

Checking a filter with a radiation measuring assembly.

Services not related to statutory requirements

Study regarding the presence of radionuclides in the Toulouse urban area sewer system

In 2004, IRSN conducted a study at the request of the Toulouse water company, *Compagnie Générale des Eaux de Toulouse* (Haute-Garonne), on the origin of low-level radioactivity found in the Toulouse urban area sewage system.

A portable Telehydro probe has been developed to take measurements at precise points along water courses.

This study, in fact, was focused on the presence of radionuclides in discharges from hospitals using unsealed sources for diagnostic or radiotherapy purposes. Having a half-life of about eight days, the iodine 131 used was found in waste water, sludge and incineration residues at water treatment plants. Technical landfill centres could refuse to accept these residues owing to the presence of this radionuclide.

The study comprised four successive phases: verification of the origin of the radionuclides with a Telehydro portable detector, identification of the source (urine or faeces) of the radioactivity, study of its dilution in the sewer network, and measurement of the dose rate at various points of the purification plant. The results were presented in December 2004 and the study report was delivered to the customer in February 2005.

The radiological monitoring of nuclear power plants entails taking samples from all environmental milieus.

Operational radiation protection services

IRSN's services in operational radiation protection cover all entities possessing or using ionising radiation sources, mainly in France but also in other countries.

These services consist in consulting and study activities (sealed or unsealed sources, contaminated sites), monitoring of equipment and installations (statutory radiation protection inspections, inspections on the efficiency of VHE filters and iodine traps) and action (such as safetying of sources, radon detection and measurements) especially in abnormal conditions. In 2004, the Institute provided about 150 service missions of all types. Its customers included industrial firms in the nuclear field (EDF, COGEMA, DCN) and also public and private organisations.

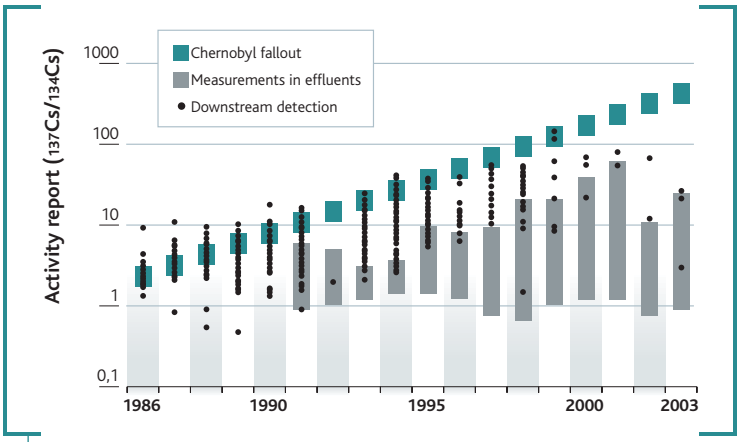
Radioecology services

IRSN provides measurement and study services in the radioecological field for industrial firms and public authorities.

Radioecological follow-up of nuclear power plants

Every year since 1991, IRSN has conducted radioecological monitoring of French nuclear power plants for EDF. This entails identifying and characterising the marking due to effluent releases from those power plants as opposed to radioactivity of other exogenous origins: atmospheric nuclear tests in the 1960s to 1980s, the Chernobyl accident and releases from hospitals.

This annual study involves the sampling and processing of between 600 and 700 samples in land, aquatic, continental and marine environments. IRSN has developed the necessary tools and know-how in the fields of sampling, sample processing and analysis and in the interpretation of results in order to take into account the very low activity levels to be measured. These chronological series complete those supplied by IRSN's OPERA network and can be used to annually update the environmental baselines for areas near nuclear power plants whether or not they are affected by releases.



137Cs/134Cs activity reports measured in continental aquatic samples taken downstream of power plants, from power plant effluents and fallout from the Chernobyl accident.

Tricastin nuclear power plant (Drôme).

The services agreement with EDF also encompasses applied studies, particularly regarding the behaviour of carbon 14, tritium and iodine 129 in the environment. This agreement was renewed for the years 2005-2007.

Studies around the COGEMA site in La Hague

The radioecology services contract of several years' standing between IRSN and COGEMA has been extended to cover two topics concerning the irradiated fuel processing plant in La Hague (Manche). As a result, a first study in 2004 was conducted to validate the DISPRO calculation code used to predict the dispersal of radionuclide releases in the Manche area of France from the La Hague plant. This required offshore measurement campaigns off the coast of Nord-Cotentin. A second study concerned granulometric distributions of aerosols discharged by the stack of plant UP2-800. It showed that the aerosols released were scattered in the environment in liquid form and probably contained organic components.

Operating method for **radon measurement**

In the context of its "quality" policy, Gaz de France regularly analyses the composition of the gas it distributes. An operating method to measure radon in natural gas was defined by IRSN. This process involves special technical skills which required the training of Gaz de France personnel by IRSN.

Services concerning **dispersal of contaminants**

IRSN provides contractually specified services regarding the ventilation of installations and the dispersal of radioactive and non-radioactive contaminants (such as malodorous contaminants) in nuclear and non-nuclear fields.

These services include studies on the behaviour of installations' ventilation systems in normal or accident conditions. They are based on the use of calculation codes developed by IRSN (SIMEVENT or FLAMME_S/SIMEVENT when the accident situation studied consists in a fire outbreak in ventilated premises).

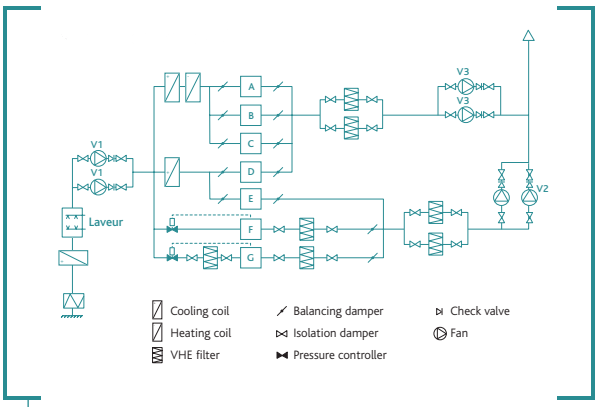
Modelling and study work

The modelling used in the SIMEVENT code is based on an electrical analogy in which the ventilation system is divided into nodes (pressure, temperature and uniform concentrations) connected by branches representing the behaviour of various items of equipment (fans, pipes, filters, valves, regulators, etc.). The code simulates air flows in the system

LPG storage spheres.

in steady-state or transient operating conditions (calculation of pressure values at nodes and flow rate values in branches). It also processes the transport and retention of gaseous and particulate species and the clogging of filters by aerosols. The main input data is the air resistance values of the various resistant equipment (calculated on the basis of pressure and flow rate values measured with the installation in a given state) and the operating curves for the various fans.

Conducting a study with the SIMEVENT code begins with the modelling of a reference state for the ventilation system on the basis of the study of drawings, an on-site study and measured results generally provided by the firm. It is then possible to calculate the ventilation systems after modifications to the installation, for example, or the sequences of degraded or accident situations on



Ventilation drawing.

FOCUS

PROBABILISTIC SAFETY ASSESSMENTS APPLIED TO INDUSTRIAL SITES

Owing to the experience IRSN has acquired on pressurised water reactors, the Ministry of Ecology and Sustainable Development has entrusted it with a pilot project for the development of a probabilistic safety assessment (PSA) for an industrial installation of the Seveso type.

The objective of this project is to clarify the contribution that a probabilistic assessment could make to the study of the safety of industrial installations.

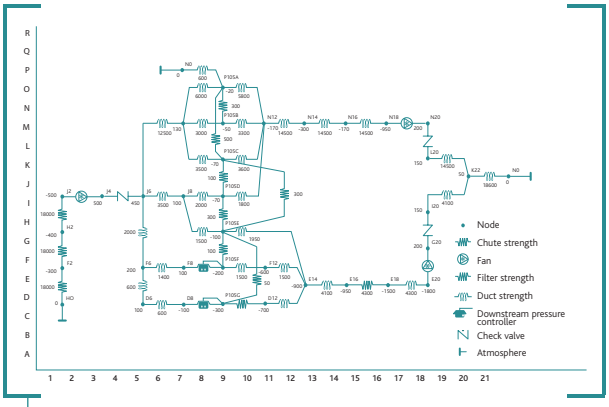
The site chosen is the filling centre at Herrlisheim (Alsace), operated by Rhône Gaz, which volunteered for the project. The selected plant receives, stores, packages and ships liquefied petroleum gas (LPG).

The study entails identifying the various accident sequences which could lead to a BLEVE and identifying the probabilities of those sequences. The scenarios examined feature the occurrence and then the ignition of a gas leak resulting in a fire affecting, in the short or medium term, one of the storage containers: either a road tanker or a tank wagon.

After defining a suitable study procedure for the installation, IRSN performed modelling in 2004 for a case representing the initiating event leading to BLEVE (leak on an LPG pipe). The method adopted, drawn from the method used for PSAs performed by IRSN for nuclear power plants, was validated and then generalised to cover all triggering events.

The final report will be delivered in 2005.

Control panel of the irradiation room for radiobiological studies or high-level dosimetry.



SIMEVENT drawing.

containment in the installation. These calculations are performed using scenarios and hypotheses which are precisely described by the firm in its specifications. Some studies have the aim of balancing the ventilation of an installation by calculating the position of balancing dampers so as to obtain the desired pressure values in the premises concerned.

As a result of an increase in the number of requests for services, five major CEA installations were studied in 2004. This type of service is of great interest to IRSN as it is a means of obtaining useful feedback on actual applications of the calculation codes it has developed. It is important to emphasise that these services do not constitute a safety demonstration and that the results obtained in this context do not give any indication of the conclusions that may be drawn by IRSN when, in response to a request from a safety authority, it assesses a safety dossier incorporating those results.

Dosimetry services

IRSN's installations, certified by COFRAC, specify reference radiation levels for photons and neutrons. They are ideally suited for the provision of services in the field of metrology: qualification and calibration of dosimeters and measuring instruments for radiation protection. IRSN also performs studies to characterise various installations: determining the dose rates and energy spectra for ionising radiation present in the installations examined. IRSN is also called upon in the field of biological dosimetry to assess doses received in cases where irradiation is suspected. In all fields, it receives requests for its services from within France and other countries.

Characterisation of radiation fields in installations

CALIBAN installation

In 2004, on request from the CEA centre at Valduc (Côte-d'Or), IRSN carried out a measurement campaign on the CALIBAN reactor (CEA-Valduc) which is able to generate intense pulses of neutrons and fission gamma rays. The study consisted in characterising the beam of mixed neutron-gamma radiation produced by the reactor.

Proton therapy centre

Ophthalmic and intercranial tumours are treated using proton beams at the Orsay proton therapy centre (Essonne). Secondary radiation, mainly

Measurement with a tissue equivalent proportional counter for the CPO proton beam line.

consisting of high-energy neutrons, is produced simultaneously and causes additional exposure outside the beam, during treatment. To assess these exposures for patients and the doses delivered to the various electronic systems, IRSN conducted the mapping of dose rates in the treatment room in 2004.

Krsko reactor

In October 2004, IRSN carried out neutronic measurements at the Krsko nuclear power plant (Slovenia) on request from the operator. For highly irradiating locations, the measurements were performed with a set of Bonner spheres.

Reactor of *Le Vigilant* nuclear submarine

Technicatome is a company with a multi-sphere system that is almost identical to that at IRSN for neutron spectrometry. This system was used to conduct measurements in 2004 on ISO reference sources from IRSN and then in the environment of the *Le Vigilant* nuclear submarine's boiler room in order to verify whether the fluence response functions of the spheres in the IRSN system were transferable to the Technicatome system.

Metrology activity

In 2004, the IRSN ionising radiation dosimetry laboratory, certified by COFRAC for reference photon beams, issued 53 calibration certificates: nine for IRSN and 44 for external customers. In addition, it supplied two test reports in the context of the approval of dosimetric instruments. Furthermore, in response to demand from some manufacturers, seven weeks were spent perfecting dosimeters with calibrated beams.

The IRSN neutron metrology and dosimetry laboratory, certified by COFRAC for reference neutron radiation, issued 11 calibration certificates. In addition, IRSN contributed to the European EVIDOS project which aims to compare the responses of individual active or passive dosimeters exposed in mixed neutron-photon fields representing those encountered in the nuclear industry. IRSN is responsible for providing neutron energy spectra and reference magnitudes (dose equivalent Hp(0.07) and Hp(10)).

In accordance with regulations, IRSN organised, at the end of 2004, a cross-comparison of dosimeters supplied by organisations that had applied for approval for the assessment of external exposure by means of individual passive dosimeters (516 dosimeters concerned). As the reference laboratory, IRSN also participated in the cross-comparison of passive dosimeters organised by the IAEA.

Assessment of activity in biological dosimetry

The estimation by biological dosimetry of doses received in cases of suspected or proven radiation is based on the observation of unstable dicentric chromosomal aberrations formed in the lymphocytes of the individuals concerned. Since 1992, the IRSN biological dosimetry laboratory, the only recognised laboratory in France for this type of assessment, has performed more than 200 estimates of individual doses, including five in 2004.

For cases among the assessments performed in 2004, the individuals had been exposed several tens of years previously for various reasons and were, in particular, present in locations with high radioactivity. Owing to specific pathologies, these persons consulted a doctor who looked for a link between their pathologies and possible

Development of passive dosimeters.

exposure to ionising radiation. In three of the four cases, the number of chromosomal aberrations observed was greater than that for the non-exposed population taken for reference. On the basis of these results, it may be considered that these individuals were indeed exposed to substances, radioactive or not, which could cause chromosomic aberrations.

In four other cases, IRSN was called in for individuals whose dosimeters indicated exposure although the circumstances of that exposure were not clear. To confirm the doses received, the only way of clearing up any doubt is to perform dosimetry on the individuals themselves: two of them had a positive biological dose of borderline statistical significance and two had a biological dose that was not different from zero.

IRSN was also asked to carry out a biological dosimetry assessment for three persons working on the demolition site of a former clinic and who may have been in contact with radium needles. In fact, none of them had been exposed to any significant extent.

Reading and interpreting films.

Conventional radiology at Cochin Hospital, Paris.

Assessment of **dose received by the foetus** during a diagnostic examination on a pregnant woman

IRSN is regularly called upon to conduct dosimetric assessments for pregnant women who have undergone radiological examinations.

When exposure to ionising radiation is envisaged for a woman of child-bearing age, the consulting doctor and the doctor who performs the examination must check whether she is pregnant. If pregnancy is confirmed or cannot be ruled out, special attention must be paid to the justification for the examination. Allowance must be made for the urgency of exposing the woman and the unborn child. Nevertheless, every year there is a number of accidental exposures of pregnant women. It is therefore not unusual for medical physicists to be asked to assess the dose received by the foetus. Nearly all these requests concern conventional

FOCUS

CONSULTING AND ASSISTANCE FOR HEALTHCARE PROFESSIONALS

The IRSN medical radiation protection assessment unit circulated a leaflet in 2004 to inform healthcare professionals of its missions regarding the radiation protection of patients and workers in the medical field:

- collection and periodic updating of diagnostic reference levels;
- assistance and consulting of healthcare professionals;
- information to healthcare professionals and radiation protection training for personnel in the medical field;
- performance of studies and assessments for healthcare professionals, patients and, more generally, persons exposed to ionising radiation in the medical field;
- technical support for national authorities and organisations concerned by the radiation protection of medical personnel and patients;
- contribution to knowledge of medical practices which may result in exposure to ionising radiation, through an observatory set up in collaboration with InVS.

These missions concern about 18,000 professional staff, 130,000 workers and a great many patients for an equipment population of approximately 50,000 installations ranging from the dentist's x-ray equipment to the 30-MV linear accelerator. The leaflet was circulated during the French national radiology conference days (between 5,000 and 6,000 participants) and conference days for radiation protection officers (nearly 500 participants). These events provided the opportunity to meet professionals requiring advice and assistance in order to implement decree 2003-270 of 24 March 2003 and its implementation orders.

Control desk of the interventional radiology department at Cochin Hospital, Paris.

radiology and scanning, with the foetus located in the region examined or not.

In 2004, dosimetric assessments were conducted by IRSN on 51 pregnant patients who had undergone one or more radiological examinations. These cases were divided between conventional radiology (38) and scanning (23).

Reconstitution of the dose received by the foetus is based, as far as possible, on the actual characteristics of the examination. For this purpose, forms to be filled in by radiologists have been created for scanning, conventional radiology, vascular radiology and interventional radiology. These forms specify all the parameters required in order to reconstitute precise doses (type of installation, detector used, high voltage, exposure time, charge, dose index for conventional radiology and scanning, etc.). Allowing for technological developments and, in particular, the complexity of the medical equipment, the data is transmitted with more or less detail and accuracy by the requesting parties. As a result, the dose values for the foetus are assessed either on the basis of data specific to typical radiological procedures (in cases where little information is known) or by simulation software after entering the exact parameters of the examination.

Scanner interpretation console.

For the assessments conducted in 2004, the estimated doses range from less than a few micrograys, when the foetus is within the diffused radiation (13 cases) to 55 milligrays (µGy), when the foetus is in the region examined by scanning. For 14 cases (27.5%), the dose was less than 1 mGy; for 20 cases (39.2%), the dose was between 1 and 10 mGy; for 12 cases (23.5%), it was between 10 et 30 mGy; for five cases (10%), it was between 30 and 55 mGy. Compared with international recommendations and especially the recommendations in ICRP publication 84, these doses are lower than the value of 100 mGy below which no effect has been demonstrated regardless of the number of weeks into pregnancy.

The Rovno plant in Ukraine.

Collaboration with **Eastern European countries**

Since the beginning of the 1990s, the international community has developed a high level of collaboration with Eastern European countries in order to improve the safety level of their nuclear installations and reinforce the regulations they have introduced.

Nuclear safety in Eastern European countries is a major target for IRSN's international action. Co-operation in this field, in partnership with GRS and in close collaboration with other European technical safety organisations and those of the countries concerned, involves in particular the development of statutory frameworks, the transfer of design codes and training in their utilisation, and the conducting of safety assessments.

FOCUS

ASSISTANCE TO EASTERN EUROPEAN COUNTRIES

IRSN took part in about 30 projects providing assistance to Eastern European countries in 2004 in order to improve the safety of their nuclear installations. In particular, the Institute participated in safety reviews for the RBMK reactors in Lithuania and Russia and the WER reactors in Ukraine.

In Lithuania: In 2004, IRSN continued its participation in the safety review for the new emergency shutdown system for reactor 2 at the Ignalina power plant whose installation was completed in summer 2004. This review was conducted in the context of a European project providing support for the Lithuanian safety authority (VATESI) managed by Riskaudit.

In Russia, the in-depth review of the safety report on reactor 1 of the Kursk power plant, which began in December 2001, was completed in May 2004. Financed by the nuclear safety fund (NSA) managed by EBRD, the project worth about 1.5 million euros brought together some 50 Western experts representing about 10 nuclear safety organisations from seven countries: IRSN (France), GRS (Germany), SERCO Assurance and NNC (United Kingdom), ES Konsult (Sweden), NRG (The Netherlands), AECL (Canada), Scientech and PNNL (United States) and about 50 Russian experts. This in-depth safety analysis led by IRSN, was the first of this type conducted in Russia for an RBMK type reactor.

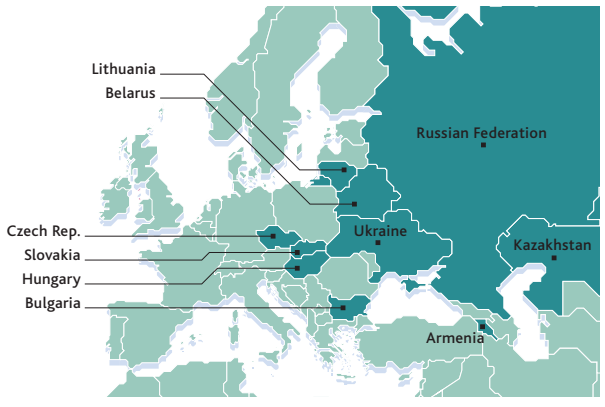
In Ukraine, the authorities decided in 2003 to commission the two VVER-1000 reactors on the Khmelnitski and Rovno sites (K2-R4) the following year. Their construction had been interrupted during the 1990s. In the context of a European contract signed by Riskaudit, subsidiary of IRSN and its German counterpart GRS, the two organisations presented the Ukrainian safety authority (SNRCU) in 2004 with a report on the safety of these reactors, allowing for modernisations carried out or planned. The Ukrainian operator then submitted, for approval, an improvement plan for the reactors taking into account the recommendations expressed. Reactors K2-R4 were placed in service in the second half of 2004. IRSN and its partners are continuing to provide SNRCU with technical support in the context of the technical appraisal of requests for authorisation regarding the implementation of modernisations planned after start-up of the two reactors.

Second edition of the annual seminar for cooperation on hazardous industrial sites, on 23 March 2004 in Ville-d'Avray (France), attended by about 100 key players: experts, industrial firms, nuclear operators, administrations, representatives of associations and professional societies, and members of Local Information Commissions (CLI).

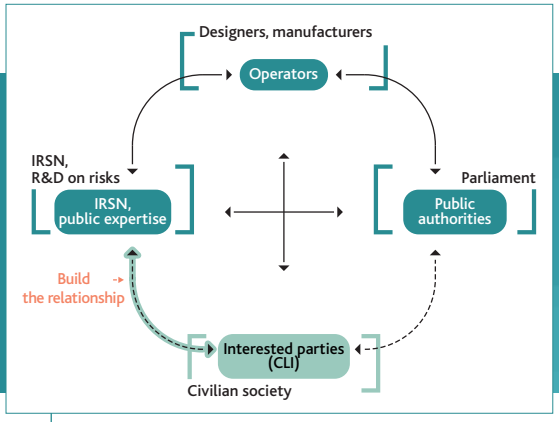
RISKAUDIT

RISKAUDIT is a European group of economic interest (EGEI) founded in 1992 by IPSN and GRS to coordinate joint international projects. Since its founding, RISKAUDIT has managed more than one hundred projects involving its two parent establishments and other European and American technical safety organisations in the context of programmes to provide assistance to Eastern European countries in nuclear safety, financed by the European Commission and EBRD.
RISKAUDIT has its headquarters in Fontenay-aux-Roses (Hauts-de-Seine) and two permanent offices in Moscow (Russia) and Kiev (Ukraine).

Depending on the state of progress of the projects concerned, assessments may be focused on defining safety objectives or requirements, determining weak points to be corrected, assessing improvement programmes, and analysing and evaluating detailed solutions proposed by operators.
This cooperation is mainly carried out in the context of contracts managed by Riskaudit, a subsidiary of IRSN and GRS, and financed by the European Commission (PHARE and TACIS programmes) or by the European Bank for Reconstruction and Development (EBRD).
In 2004, IRSN contributed to some 30 projects, mainly in Bulgaria, Lithuania, Russia and Ukraine. Cooperation in this part of the world is seeing new developments with the setting up in Russia and, in the near future, in Ukraine of the "Global partnership against the spread of weapons and materials of mass destruction" adopted by G8 in 2002. In this context, IRSN took part, in 2004, in the preparation of a number of projects regarding nuclear safety, radioactive source management and physical protection of installations and nuclear materials.



RISKAUDIT's activities in Central and Eastern European countries.



The reform of 2002 incorporates safety and radiation protection, separates the functions of technical policy, study and R&D policy, and operators' policies.

Expertise and assistance for **civilian society**

IRSN embarked upon an approach to involve the interested parties that was consistent with the guideline adopted by the government for greater transparency in the field of nuclear and radiological risk management.

The opening up of IRSN's expertise to civilian society involves, in particular, pilot actions which may lead to the setting up of groups with pluralist expertise, similar to GRNC, in order to deal with complex or disputed topics. This undertaking also requires participation in national and international networks for information, promotion and feedback as well as the creation of such networks.

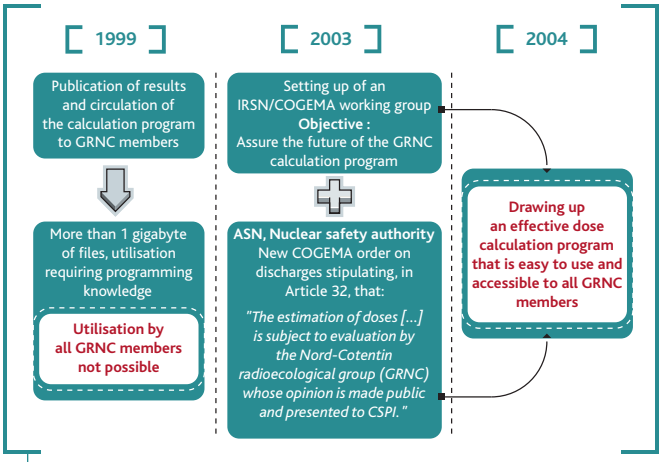
In order to make headway in this matter, the Institute organised a second seminar on concerted action, in March 2004, around the industrial sites of Ville-d'Avray (Hauts-de-Seine). About one hundred participants (associations, experts, representatives of administrations and nuclear and chemical industries) were able to exchange views on this occasion with the prospect of a change in the governance of industrial activities.

Furthermore, in the context of their protocol, IRSN and the French national association for local information commissions (ANCLI) organised a meeting, on 24 March, to define actual concrete actions. The topics cover, in particular, monitoring of the environment and releases. A survey targeting three CLI had already ascertained their expectations in these fields.

Acadie, a joint assessment tool

In 1997, the French Ministries of the Environment and Health entrusted Mrs Sugier with the mission of forming a pluralist group in order to assess the leukaemia risks which could result from exposure of the inhabitants of the Nord-Cotentin area to ionising radiation. The study, conducted by the Nord-Cotentin Radioecology Group, GRNC, led to the design of a calculation tool which included, in particular, a database containing the parameters of transfer to the environment. Development of this tool continued until, in June 2004, the Acadie software was unveiled. This application for the calculation of internal and external effective doses allows GRNC members (associations, foreign experts, institutions, industrial firms and operators, etc.) to perform their own dose calculations and to share data on the assessment of the radiological impact.

Furthermore, at the initiative of IRSN, a round table to discuss the subject of transparency attracted experts in public debate, CLI members, journalists and associations. It revealed high expectations with regard to IRSN as a public expertise organisation.



Manufacture of a dose assessment tool accessible to interested parties.

1
crisis exercise related to the security of installations

3
crisis exercises related to the safety of Defence-related installations

198
inspections related to the control of nuclear materials

32
support missions carried out by international inspectors to check nuclear and sensitive materials

103
technical notices related to the safety of Defence-related installations and activities

9
meetings of safety commissions and small groups of experts

54
participations in national and international working groups

Aerial view of the *Charles-de-Gaulle* aircraft carrier.

Defence **nuclear expertise**

In accordance with the decree relating to IRSN dated 22 February 2002, the Assistant Director General in charge of implementing the Institute's Defence-related missions, has a specific department, the DEND, which conducts expert appraisals, tests, studies and research related to:

- the protection and control of nuclear and sensitive materials;
- the protection of nuclear installations and transportations of radioactive materials against malicious acts;
- the safety and radiation protection of Defence-related installations and activities.

Aerial view of the Marcoule site (Gard).

Assessing the **safety of military nuclear systems, basic nuclear installations** and **Defence-related transportations**

TECHNICAL SUPPORT WITH REGARD TO NUCLEAR AND RADIOLOGICAL RISK

OPERATIONAL SUPPORT IN THE EVENT OF A CRISIS OR RADIOLOGICAL EMERGENCY

In 2004, IRSN examined the safety of installations, laboratories and plants involved in National Defence on the basis of the dossiers transmitted by the operators concerned, and gave its recommendations to the DSND.

Activities concerning Defence-related laboratories and plants

In 2004, IRSN examined the safety of installations operated by CEA's Military Applications Division (CEA/DAM) or by COGEMA. These two operators conduct all the operations (production, storage, processing) necessary for the supply of nuclear materials for weapons and the manufacture of fuel for nuclear propulsion reactors. They are also in charge of cleaning up production installations which have now been shut down. The risks presented by these installations are very varied, depending on the missions assigned to each installation. Different specialists from different IRSN units have taken part in expert appraisals in fields as varied as civil engineering or risk prevention related to criticality, fire, exposure to ionising radiation and the dispersal of radioactive material.

For the COGEMA establishment in Marcoule (Gard) and the installations on this site, the Institute transmitted recommendations to the DSND on the following:

- the implementation of an internal authorisation process;
- an authorisation request for releases and water sampling;
- the revision of the operating authorisation for the conventional waste recycling plant;
- receiving and processing incinerable waste from different sources.

The Institute also monitored operations carried out in the framework of the definitive shutdown of the UP1 plant. IRSN transmitted recommendations to DSND on the following:

- cleaning-up of the stores;
- storing of waste created by the definitive shutdown operations;
- risks associated with cutting operations, including hot spots;
- work done on an evaporator in the UP1 plant;
- updating of the general operation rules;
- operations to clean up the dissolvers.

IRSN monitored the COGEMA establishment in Pierrelatte (Drôme) and the installations on this site. Within this framework, IRSN transmitted recommendations on the following:

- introduction of a production line within the recycling and elaboration plant (URE);
- flooding that occurred in the Rhône valley in December 2003;
- commissioning of the processing and salvaging workshop after improvement works were carried out;
- dismantling operations on annexes of gaseous diffusion plants (GDP).

Le Vigilant, a French nuclear-powered ballistic missile submarine (SNLE).

Activities concerning naval propulsion reactors

In 2004, IRSN gave its opinion on the modifications that the Navy plans to make to basin 8 at Brest's naval dockyard, with a view to increasing the docking capacity for SNLE such as *Le Triomphant*. The Institute also analysed the radiological surveillance programme drawn up in anticipation of the stop over by *Charles-de-Gaulle*, the aircraft carrier, in the port of Le Havre.

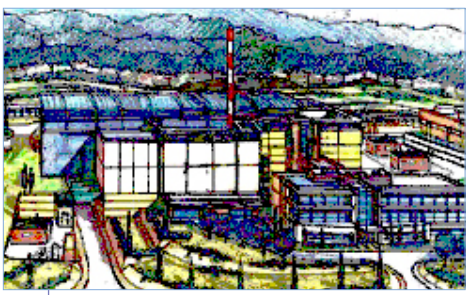
In 2004, IRSN followed the design process of the next generation of French nuclear attack submarines *(see Focus p. 157)* and assessed the latest safety dossiers on *Le Vigilant*, allowing DSND to issue favourable recommendations on the final operating permit. IRSN examined the safety of the test reactor (RES) in 2004. This installation, located within the area of the secret basic nuclear installation (INBS) "Nuclear Propulsion" at the CEA centre in Cadarache (Bouches-du-Rhône), will replace the RNG installation currently operating.

The RES installation is made up of a "pit" part and a "reactor" part, under construction. The "pit" part needed for reactor operations is already built. It can be used to store fuel and other naval propulsion boiler equipment.

At the end of 2003, CEA requested a temporary permit to use the pit part of the RES installation. To this end, it transmitted a provisional safety report and general operating rules. In 2004, IRSN examined how the civil engineering works behave when subjected to the different possible stresses. The evaluations also concerned:

- the inherent risks at the "reactor" construction site (fall of crane, etc.);
- criticality risks associated with the storage of fissile materials in the different channels of the pit;
- the risk of the fuel dewatering;
- the risks associated with dynamic containment loss;
- the risk of fire.

In addition, IRSN examined the radiation protection measures taken by the operator. The operator took



Model of the reactor test installation under construction in Cadarache (Bouches-du-Rhône).

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BARRACUDA PROGRAMME

Since 2001, IRSN has supported the control exerted by the DSND on the development of the BARRACUDA programme, the next generation of French nuclear attack submarines.

Even before the examination of the preliminary safety report scheduled for 2005, IRSN studied several important safety aspects in 2004 – the architecture of security systems and the risks associated with the presence of conventional weapons on board a ship, for example. The security systems are designed to bring the nuclear reactor back safely and maintain it in safe conditions in the event of an accident. To ensure this, IRSN checks that the architecture of these systems and the design of their components can guarantee a level of reliability equal to the safety objectives assigned to submarines like *Barracuda*. These objectives take into account the fact that the submarines will be docked and maintained at the French Navy's naval bases located in urbanised areas.

The DGA made suggestions for procedures and IRSN assessed them and passed them on to the DSND.

A working meeting for defence nuclear expertise teams.

great advantage of the experience acquired in similar storage installations (EDF spent-fuel pits, port pits, etc.) to optimise the doses used.
As the monitoring of operations carried out in the "pit" part requires a lot of human intervention, IRSN examined the measures taken by the operator regarding possible human error during handling activities in particular (ergonomics of bridge control boxes, training of agents, organisation of operations, etc.).
IRSN's assessment report was used as a support document in the Reactor Safety Commission meeting on 9 and 10 November 2004 at Cadarache.

Activities concerning radioactive sources

As part of the gradual implementation of the new regulations on radiation protection (decree No. 2001-592 of 5 July 2001), IRSN listed about 10 installations in 2004 whose radioactive sources now come under DSND control. This number should soon increase following changes to regulations and the resulting transfer of authority. This concerns installations whose authorisation was issued by the CIREA before 2002. For these installations, IRSN monitors movements of sources by issuing the necessary forms and recording the movements in the national inventory of radioactive sources.

PUI-related activities

In 2004, IRSN transmitted technical recommendations concerning the internal emergency plans (PUI). It examined:

- the PUI and the accident situations covered by the PUI at COGEMA's establishment in Pierrelatte;
- INBS's PUI called " Basin 8 " at Brest's naval dockyard (Finistère).

In addition, IRSN analysed the evolution of geo-mechanical stability at the Mururoa and Fangataufa atolls. This expert assessment particularly concerned the mechanisms responsible for instabilities observed at these atolls in the past, the pertinence of the monitoring system installed and also the evolution of rock movements.

Crisis exercises involving INBSs and SNMs

IRSN took part in three national crisis exercises related to "Defence" in 2004. In addition to the main exercise of the year, which took place in November at COGEMA's Pierrelatte site *(see Focus p. 133)*, two exercises were carried out at Mont-de-Marsan's air base (Landes) and Toulon's naval base (Var):

- the first simulation involved a weapon in a fire. It tested relations between the technical units of IRSN and those of the air force;
- the second one concerned a nuclear attack submarine (SNA). Prior to this exercise, work had been carried out to adapt the CTC organisation and develop specific documentation. This work was carried out in close collaboration with naval staff from the French Navy.

Determining the isotopic composition of plutonium.

Protection and control of **nuclear and sensitive materials**

There are several aspects to the protection and control of nuclear and sensitive materials: physically protecting, monitoring and accounting for nuclear materials, tracking transportations and applying international controls on the non-proliferation of chemical and nuclear weapons.

TECHNICAL SUPPORT WITH REGARD TO NUCLEAR AND RADIOLOGICAL RISK

Physical protection of nuclear materials

The physical protection of nuclear materials is ensured by a series of material and organisational measures designed to guarantee an in-depth defence that is appropriate to the risk of theft or diversion of these materials. These measures include delaying systems, detecting systems, access control systems and response resources.

Public authorities, under the responsibility of the Ministry of Industry (HFD), define the required objectives as regards physical protection and verify that the measures implemented by nuclear operators and possessors of nuclear materials ensure compliance with these objectives.

IRSN places its technical expertise at the disposal of public authorities to assess the efficiency of physical protection measures adopted or proposed by operators and possessors.

In this matter, IRSN's expertise specifically concerns:

- the capacity of installations or equipment to resist theft or diversion of materials;
- the pertinence of procedures for access to nuclear materials and the removal of these materials from their containments or from establishments that possess them;
- the capacity of systems to detect the loss or theft of nuclear materials.

In 2004, IRSN analysed about 80 dossiers sent by operators and possessors of nuclear materials. In addition, IRSN personnel carry out inspections for the HFD in installations possessing nuclear materials. The aim of these inspections is to check *in situ* the implementation and operational nature of the measures to protect and control nuclear materials and the measures to protect them from malicious intent (application of articles L.1333 and L.1332 of the Defence Code, respectively). About 50 inspections were carried out in 2004. For some of them, the Institute took *in situ* measurements of the protection systems' physical characteristics.

At international level, in 2004, the Institute directed an IPPAS mission organised by IAEA in Iran. IRSN was also involved in teaching at international courses on design basis threats in Iran and physical protection of research reactors in the Republic of South Africa.

Moreover, in cooperation with the United States Department of Energy (US DOE), IRSN developed an assessment method and training course on internal threats. The aim of this initiative is to suggest to the IAEA that a document based on this method be published in the "Tecdoc" section with the associated training course.

Monitoring and accounting for materials

At the request of HFD, IRSN examines the measures taken by operators to monitor and account for nuclear material held in installations. It proposes any corrective action it deems necessary, especially

Marking of nuclear material packages.

regarding the risk of theft, loss or diversion of such materials. IRSN then checks that the operators take HFD's requirements into account and reports back to HFD.

In this respect, the Institute analyses the reports required by regulations and carries out technical inspections of installations.

In particular, it examines the measures implemented by operators to:

- have precise, quantitative and qualitative information on all the nuclear materials that enter and leave the installations;
- track the materials, i.e., always know where they are located, what they are used for and the operations they undergo (movements, transformations, etc.);
- check that the actual stock of materials held corresponds to the accounting figures they are obliged to keep updated.

In 2004, IRSN analysed about 140 dossiers transmitted by operators within this framework. About 30 technical meetings were required to carry out these analyses. In addition, IRSN produced nearly 100 analyses of nuclear material inventory reports.

In addition, IRSN personnel carry out inspections for the HFD in installations possessing nuclear materials. The aim of these inspections is to ascertain that regulations applying to the possession of these

FOCUS

IMPACT OF THE NEW EURATOM REGULATION ON NATIONAL CONTROL

IRSN is responsible for updating the accounting declaration rules on nuclear materials according to the requirements of authorities and industrial firms, so that the former can fulfil their role as controllers and the latter can comply with their statutory obligations.

A specific feature in France is the strong link between the accounting required by the law of July 1980 and that required by European regulations.

In 2004, IRSN studied the impact of the latter on the 85,000 annual accounting declarations. IRSN is to study changes that should be made to declaration rules because firstly modifications have been made to the information required and declaration methods, and secondly the control of waste processing facilities has been handed over to EURATOM.

The preliminary study underway aims to assess the impact on IRSN's work load, the modifications that need to be made to the information system used for national accounting of nuclear materials, and the definition of a new interface with operators' information systems.

The results of the study will be discussed with the authorities and industrial firms in 2005, so as to come to a precise definition of statutory and operational changes. 2006 will be devoted to carrying out these changes, which will include a renovation of national accounting support documents. All this, associated with reinforced training, should be operational for all French nuclear operators at the beginning of 2008.

One of the difficulties will be ensuring compatibility between the computer application of national accounting and the operators' computer applications, while at the same time coordinating the production start of the different computing tools.

Preparing an irradiated fuel transport convoy in Cherbourg (Manche).

materials are respected. For the record, regulations distinguish between installations subject to a prior authorisation and installations subject to a prior declaration, depending on the nature and quantity of materials possessed.

In 2004, IRSN carried out more than 70 inspections at installations subject to a prior authorisation, several of which involved physical measurements to test materials. In addition, the Institute carried out about 20 technical inspections of installations subject to a prior declaration.

As well as this ongoing activity, IRSN took more targeted action regarding certain installations, after anomalies or malfunctions were discovered. The most notable example is the discovery, in 2004, of nearly 400 kg of depleted uranium that were not accounted for in the records. It was found on the site of a company specialised in metal recovery.

Transporting nuclear material

IRSN manages transportation dossiers and tracks the transportation of nuclear materials on behalf of HFD. Current regulations oblige transport companies that have received prior ministerial authorisation to abide by measures relating to the organisation of movements and their declaration. Within IRSN, it is the Operational transport section (EOT) that performs this mission. Its scope of competence includes the transportation of nuclear materials via road, rail, river, sea or air. These transportations must be declared to EOT fifteen days before the planned date of transport. Thus, about 1,700 trans-portations are declared to EOT every year. On receipt of the transportation notice, the following checks are carried out:

- the dates and times;
- the appropriateness of the physical protection in relation to the material being transported;
- the validity of authorisations held by transporters and any of their subcontractors, who also have to be approved by the Ministry;
- the route taken;
- the members of the team;
- the means of transport, which must also have obtained ministerial approval according to the nature and quantity of nuclear materials transported.

When the transportation is confirmed, EOT gives its consent for the movement of materials and informs all the authorities and organisations concerned (Ministry of Industry [HFD], Ministry of the Interior [including DDSC], Ministry of Finance [customs]). EOT is also responsible for the smooth running of very sensitive transpor-tations, to ensure that nuclear materials are cons-tantly protected and controlled in an appropriate manner.

In 2004, EOT monitored a special international transportation: the transportation of military plutonium between the United States and France (EUROFAB operation). On this occasion, EOT prepared the dossiers on the transport equipment authorisations and approvals, on the transportation plan approval and on the real-time monitoring of movement throughout French territory, including territorial waters.

International controls on non-proliferation

International treaties, to fight proliferation or for-bid nuclear and chemical weapons of mass destruction, implement supranational systems of control. In France, IRSN provides assistance and technical support to authorities in charge of

Checking nuclear material transport packages.

monitoring these inspections.

The inspection systems implemented by the Treaty of Non-Proliferation, the Treaty of Rome and the Chemical Weapons Convention may be different, but they all involve international officers checking, in declared facilities, the information transmitted by States to international inspection bodies (IAEA, Euratom, OPCW).

Within this framework, IRSN acts on behalf of French authorities, collecting and preparing the French declarations to inspection bodies.

It is also in charge of ensuring the smooth running of international inspections in French nuclear or chemical facilities. To this end, it prepares the inspections, accompanies them (as representative of French authorities) and negotiates the practical aspects of the inspection with the inspection team.

As part of the technical support it provides French public authorities, IRSN carries out a prior analysis of the technical documentation that sites send to the inspection bodies. IRSN also assists French authorities by analysing and keeping up with changes to national or international regulations relating to the fight against proliferation. When necessary, it takes part in interministerial work and joins groups of international experts set up by the OPCW or IAEA.

In 2004, IRSN prepared and transmitted to the OPCW:

- the annual declaration on the activities of chemical sites listed in France in 2003 (over 130);
- the annual declaration on the planned activities of chemical sites listed in France in 2005.

It processed and sent to the European Commission:

- 610,000 lines declaring movements and stocks of nuclear materials;
- 260 notifications on the import or export of nuclear materials;
- the programme of activities for the 220 declared French nuclear facilities;
- the list of about 250 French possessors of small quantities of nuclear materials (plus the value of their stocks).

It prepared and sent to the IAEA:

- the monthly and six-monthly accounting reports on stocks of nuclear material in France subject to safeguard agreement measures;
- the monthly and six-monthly accounting reports on the international transfers of crude materials and ores;
- 500 notifications on the import or export of nuclear materials;
- France's initial declaration for the application of the additional protocol *(see Focus p. 163)*;
- France's quarterly declarations on the export of nuclear equipment.

IRSN accompanied OPCW's seven inspections of French, civil, chemical facilities. It also accompanied verifications carried out on the inventory of nuclear materials in 27 French facilities.

It took part in opening discussions between the European Commission and French authorities concerning the definition of international procedures for inspecting new facilities.

As far as regulations are concerned, 2004 saw the arrival of one decree and three amending orders

Manipulation in the Euratom laboratory at the La Hague plant (Manche).

for the application of the Chemical Weapons Convention. During the same period, draft legislation on the application of the additional French protocol was transmitted to the Council of State.

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ADDITIONAL PROTOCOL

Since 30 April 2004, the effective date of the additional protocol to IAEA's safeguard agreements covering all the European Union, the control of nuclear materials, initially provided for in the Treaty on the Non-Proliferation of Nuclear Weapons of 1970 and the safeguard agreements that followed, has been extended to include research and development and nuclear facility equipment.
The secretariat of the Interministerial Technical Committee has been put in charge of implementing the additional protocol in France with technical support from a specialised IRSN department.

In 2004, IRSN put together a declaration manual which was sent to a selection of 1,700 bodies at the beginning of May.
Industrial firms and research centres working on various subjects related to the nuclear fuel cycle were contacted but so were boilermakers, pump and tube manufacturers, etc.

At the same time, IRSN provided telephone assistance to industrial firms on a dedicated line.
In September, the French declaration was drawn up on the basis of declarations made by the French bodies concerned. This involved a great deal of compilation work. The declaration was sent to the IAEA on 28 October 2004 within the set deadline, i.e. 180 days from the effective date of the protocol. For future declarations, IRSN will regularly contact about 150 entities.

Recording of operators' declarations in accordance with the supplementary protocol.

Nuclear power plant at Dampierre-en-Burly (Loiret).

Protecting **installations** from **malicious acts**

As far as security is concerned, the general context has changed and this has led the HFD to seek possible improvements to regulations related to the protection of nuclear installations from malicious acts, given the reassessment of threats associated with such acts.

TECHNICAL SUPPORT WITH REGARD TO NUCLEAR AND RADIOLOGICAL RISK

DEFINING AND IMPLEMENTING NATIONAL AND INTERNATIONAL RESEARCH PROGRAMMES

Improving regulations

Within this context, IRSN was associated in the definition of a new set of reference threats in 2004. These reference threats specify the characteristics and resources attributed to aggressors and are used to size the physical protection systems of nuclear facilities and check that they are appropriate. The Institute also suggested that these regulations should include provisions on the protection of nuclear materials with regard the risks of loss, theft or diversion and provisions on the protection of nuclear facilities and materials from malicious acts. The aim is to produce a set of coherent protective measures based on a global conception of protection systems.

IRSN was keen to specify:

- the respective missions and responsibilities of public authorities and operators;
- the protection objectives that operators should respect;
- the general principles to apply when designing and using physical protection systems (defence in depth, material measures, security guards and organisational measures);
- the nature of the installation areas to be protected, with the associated protection instructions;
- how to manage requirements that could turn out to be contradictory in terms of nuclear safety and physical protection of installations;
- the approval process of statutory dossiers required from operators;
- the method and content of protection studies (relating to malicious acts) and security studies (relating to theft of nuclear materials). To be specific, protection studies should be based on a sensitivity study aimed at assessing the radiological consequences of a malicious act and also on a vulnerability study that assesses how difficult it would be to carry out such an act;
- the scheduled review process that should be implemented to ensure that the protection system is appropriate;
- the declaration process for events related to malicious acts;
- the control and inspection process.

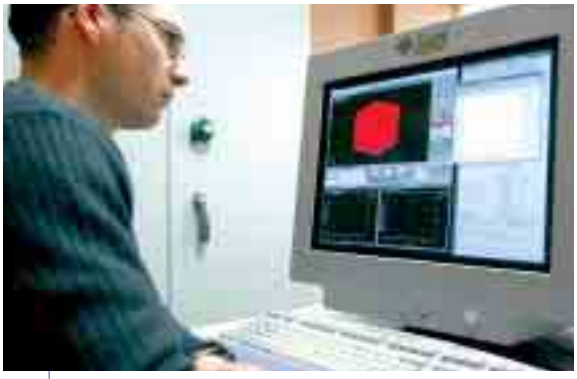
Studying and developing assessment tools

In 2004, IRSN continued working on the structural resistance to malicious acts programme. It aims to assemble tools that can predict the damage that weapons or explosives can cause to structures and equipment. These tools are used when analysing the dossiers sent in by operators.

Physical protection.

There are two stages to this work:
- listing all the possible "targets" and the destructive means involved in the reference threats;
- classifying the "targets" and destructive means into categories which, once grouped together, define all the generic cases that have to be dealt with. A matrix of cases is thus produced, made up of "weapon/target" pairs. To give a few examples, reinforced concrete structures, tanks, piping and some mechanical systems that act as safety devices are considered as targets.

Two categories of tools have been developed:
- simplified tools that are quick to use, based on analytical methods. Analytical methods are used to develop numerical simulation tools requiring only limited resources. The main advantage is that they are quick to use and this makes it possible to carry out parametric studies. These methods usually allow us to correctly determine the magnitude of the stresses we want to study. For example, they are used to study how reinforced concrete walls react to the blast of an explosion in the far field or the specific approach for loading in close field;
- numerical models from mechanics calculation codes. The studies carried out using mechanics calculation codes are complementary to those conducted via analytical methods: numerical simulation provides more accurate results, makes it possible to introduce more complex and more realistic models and to determine the evolution of local parameters.



Studying and developing assessment tools for the physical protection of installations.

Defence crisis exercise at a military base.

Managing **emergencies** caused by malicious acts

TECHNICAL SUPPORT WITH REGARD TO NUCLEAR AND RADIOLOGICAL RISK

Exercises relating to the application of the July 1980 law

At the request of HFD, IRSN organises exercises related to installation protection. They aim to test the decision-making process and the coordination and interfaces between the parties involved (operators, public authorities).

Defence crisis exercise at a military base.

Therefore, in 2004, the Institute:

- started to prepare and organise a large-scale exercise that will take place in 2005;
- examined the lessons to be learnt from a similar exercise held in 2003.

IRSN is also in charge of managing crisis situations relating to nuclear materials. It organises nuclear material inventory exercises during crisis situations with a view to testing the effectiveness of the system set up for this purpose. In 2004, an exercise was conducted at the CERCA facility in Romans (Isère) and the ORPHEE facility in Saclay (Essonne) *(see Focus p. 167)*.

Nuclear materials inventory crisis cell.

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CRISIS EXERCISE INVOLVING THE INVENTORY OF NUCLEAR MATERIALS

The aim of the exercise is to carry out an unexpected test to check the ability of one or more installations to detect the disappearance of nuclear materials and thus find out whether the disappearance of the materials could escape the attention of the operator of the installation in question.
To do this, operators have a very short time to carry out an inventory targeted at the types of materials suspected of being diverted or stolen.

Several crisis units are implemented for this purpose:
- at IRSN, a unit grouping together the business managers of the installations concerned and different experts in charge of monitoring, accounting, transporting and ensuring the physical protection of the nuclear materials. It reports to the HFD on the evolution of the situation and the initiatives it takes,
- at the head offices of the operating companies concerned and at the installations, units decide on the action to take and follow the progress of operations. They report on the progress of verifications to HFD and IRSN.

These units communicate with the media in their area of expertise, within the framework of simulated media pressure.
Operators take the required measures until an accurate view of the situation is obtained.
Encrypted networks are used between the different units to exchange classified information if necessary (isotopic quantity or composition of sensitive nuclear materials for example).

The lessons learnt from these exercises enable us to improve the systems that would be implemented in the event of a real crisis (written procedures, means of communication, etc.).
The exercise conducted in 2004 enabled us to find a means of improving the identification of material on one of the sites.

3 Management **and Support**

Research
for understanding


164
press requests processed
100
men/year in terms of time spent on international activities
64
people from IRSN participated in international expert groups
68%
of IRSN personnel are engineers, researchers or managerial staff
32%
of IRSN personnel are technicians or employees providing technical and administrative support
77%
of staff are employed by IRSN and
23%
were seconded from CEA at the end of 2004
106
people were hired in 2004
3,218
hours of teaching/training were given
1,150,000
euros were spent on training
126
trainees were received by IRSN in 2004

Scientific and technical **excellence**

Meeting of the central echelon of the department of scientific and technical excellence and quality.

Scientific and technical **excellence**

Competence plays an important role in ensuring the credibility of the Institute's work and earning the trust of its partners, customers and society. This competence lies in the scientific and technical excellence of its teams and its research and expertise activities.

Seminar on scientific and technical excellence

Therefore, with this in mind, IRSN decided to clarify its policy and orientations. So on 16 March 2004, IRSN organised a seminar on the scientific and technical excellence of its activities in Le Vésinet.

After this seminar, the Institute's orientations regarding the implementation of a policy of scientific and technical excellence at IRSN were formalised. This policy is based on the following three objectives:

- promoting scientific and technical excellence within the Institute;
- implementing an internal system to assess the scientific and technical excellence of the Institute's activities;
- developing activities that contribute to IRSN's outreach. It was presented to the Scientific Board on 15 November 2004 and to the Board of Directors on 28 January 2005.

Debates at the seminar highlighted the advantages of setting up a committee on scientific excellence that would coordinate and monitor the progress of action taken to achieve and obtain recognition of scientific and technical excellence.

A PhD student in the radioecology lab using a binocular microscope to select larvae.

Launching of targeted scientific and technical assessments – a pilot project

Targeted assessments can concern all the Institute's scientific or technical activities (services, expert appraisals, research, studies). They are conducted by independent experts who have not been involved in the activity in question and who are from outside the Institute if possible.

To establish the type of questions to be asked and the practical details of these assessments in consultation with the teams concerned, it has been decided to conduct a certain number of pilot operations. These assessments concern:

- the results of a research programme;
- a scientific collaboration;
- the reorientation of a research programme;
- an expert appraisal of safety;
- a team.

These assessments are in progress and should gradually lead to a convergence of ideas on the generic aspects of the assessment process, despite the diversity of subjects and teams concerned

Training through research

Every year, IRSN receives about 20 doctorands (18 in 2004) and 15 post-doctorand trainees who contribute to relations with the academic world. Therefore, most of the advisors for these undertaken at IRSN are researchers from outside the Institute.
IRSN wishes to reinforce its training through research initiative, so in 2004 it started to draw up a plan aimed at increasing the number of new theses to 30 per year and the number of post-doctorand placements to 30 per year.
At the same time, the Institute encourages its researchers to support the authorisation to supervise research (ASR), thus showing its willingness to open up to the world of university research.

Discussion between a PhD student and his tutor in the Cadarache radioecology and ecotoxicology laboratory (Bouches-du-Rhône).

(phasing of assessments, support documents, nature of questioning, etc.).

Establishing indicators for an overall scientific and technical assessment

Scientific and technical assessment with the establishment of indicators is another approach – these indicators must be in-house tools for attaining improvement objectives. They should be used to position the Institute in relation to the outside world. They should finally contribute to the recognition of the scientific and technical quality of its production.
Links are being initiated with the *Observatoire des sciences et des techniques*. The aim is to enter into the circle of research organisations currently trying to standardise indicators to make them as comparable as possible.

Implementing action to promote cross-unit scientific awareness

In-house scientific and technical awareness actions are gradually being organised in order to share knowledge and better identify, coordinate and use the cross-departmental action of the operational units.
In 2004, two subjects were defined for which there is a need of experience exchange within the Institute: the use of MONTE-CARLO codes and the use of experimental designs. In 2004, a state of the art was conducted on the MONTE-CARLO codes.

Draft version of a scientific and technical excellence programme

The aim of implementing such programme is to ensure a better understanding, transparency and recognition of the Institute's activities, thus specifically contributing to the promotion of scientific and technical excellence, to its implementation and its recognition by the outside world:
- training through research and teaching;
- scientific activities;
- scientific and technical assessment;
- outside recognition;
- exploratory research.

This programme is also a management tool, allowing us to set objectives when strategic orientations have to be developed, to monitor the progress of the action taken to achieve these objectives or to suggest changes.

Secretaries from DESTQ (Department for Scientific and Technical Evaluation and Quality) at the reception desk of the seminar on scientific and technical excellence on 16 March 2004.

Relations with universities and scientific organisations

These are essential for a research body like IRSN. Although the Institute is orientated towards acquiring knowledge related to its expertise, outside experts should be allowed to give their opinion on this research, to analyse it, evaluate it and enrich it with new ideas. Given the very wide scope of its missions, the Institute should call upon outside skills to complement its own skills. Forming relationships with universities is a good way of developing and improving the skills that are useful and essential to IRSN. Through these relationships, IRSN experts can take part in the training given at these universities and *Grandes écoles* and in this way enable the Institute to acquire a reputation, attract young people and fulfil its training mission.

When studies are carried out jointly with Universities, *Grandes écoles* and CNRS laboratories, cooperation agreements concerning the joint research and the hosting of trainees are signed. In 2004, cooperation agreements were signed with various universities *(see box)*. Within the framework of the national cooperation agreement with the CNRS signed in 2003, eight specific agreements on various subjects were signed with different CNRS laboratories: "comparison of numerical models for calculating percolation through dykes", "modelling of geo-chemical perturbations in the near field of waste stored in a deep clay repository", "paleo-seismicity of Middle Durance fault in the region of Manosque", "characterisation of sources and processes at the origin of natural radioactive tracers (U^{234}, U^{238}, Ra^{222}) in a fractured environment", etc.

Agreements between IRSN and universities signed in 2004

- **6 January:** agreement with the Institute of Nuclear Physics, Lyon, a CNRS / University of Lyon 1 joint research unit (UMR).
- **13 January:** agreement with FAST, a CNRS / University of Paris 6 joint research unit (UMR).
- **19 January**: agreement with the laboratory of fluid mechanics and acoustics, a CNRS / École centrale de Lyon joint research unit (UMR).
- **28 January**: agreement with the Toulouse Institute of Fluid Mechanics, a CNRS / INP Toulouse joint research unit (UMR).
- **28 January**: framework agreement with the University of Pau.
- **18 March**: agreement with Géosciences Rennes (UMR / CNRS).
- **30 March**: agreement with the laboratory of hydrosystem ecology, (CNRS / University of Toulouse 3 UMR).
- **17 May**: framework agreement with the ARMINES association.
- **17 May**: agreement with CEREGE (CNRS / UMR).
- **4 August**: agreement with the department of civil engineering and construction (CNRS / ENTPE UMR).
- **2 November**: framework agreement with the University of Versailles - Saint-Quentin.
- **24 November**: agreement with the laboratory of analysis, topology, probability (CNRS / University of Aix-Marseilles 1 UMR).

Library of the Scientific Information Resources Centre.

Scientific and technical **knowledge engineering**

Activities in scientific and technical knowledge engineering (ICST) concern two main fields: scientific and technical information (STI) and management of IRSN's archives. The purpose is to facilitate and expand access to IRSN's scientific and technical documentation that engineers and researchers need to fulfil their missions.

In 2004, several projects were launched to meet these two objectives.

The Centre for Scientific Information Resources (CRIS) completely reorganised its Intranet site to make its range of services more accessible. A club for CRIS users was set up to improve these services. There were discussions on the possibility of extending access to include electronic journals. The CRIS, in collaboration with the club of users, chose an online bibliographical database. This tool completes the bibliographical databases made available to IRSN personnel.

The Archives project was also launched in 2004. Indeed, IRSN has kept the archives of the former IPSN and OPRI. The project involves collecting the 12 km of existing archives in order to present the French Department of Archives and CEA (of which IPSN was a division) with a statement, and to provide the Institute with a tool that will allow the gradual introduction of a sustainable archive management organisation. At the end of 2004, an inventory of more than 50% of the archives had been drawn up.

Finally, IRSN set up an organisation allowing it to draw up annual reports on training through research, teaching and publications. These reports provided several of the figures presented in this report.

Active sample laboratory: radiological check to verify the non-contamination of a fume chamber laboratory.

Security

In terms of security, the action undertaken by IRSN in 2004 concern both the security of facilities and the security of personnel.

Bringing the Institute's facilities and activities up to standard, IRSN conducts most of its activities in facilities inherited from the former OPRI and CEA, some of which require a lot of work to bring them up to technical and regulatory standards. In order to define priorities, a major action plan was drawn up in 2004 concerning facilities presenting a high level of risk and which play a strategic role in the Institute's missions.

Work started at the Le Vésinet site (Yvelines), with the renovation of electrical installations and the ventilation of facilities for measuring environmental radioactivity.

Authorisations allowing laboratories to possess and use radioactive sources within the framework of the Institute's research programmes were also brought up to standard. In 2004, 80% of these laboratories (excluding activities conducted in authorised ICPEs) obtained the necessary authorisations from the DGSNR in accordance with the Public Health Code. It should be noted that IRSN inherited more than 1,300 radioactive sources, including 900 that are unusable and for which a disposal provision was drawn up at the time of CEA and IPSN's separation. In 2004, an agreement was signed with all the source suppliers, mainly the CEA (80% of the sources requiring disposal), and this allowed 20% to be eliminated.

Staff training

In 2004, 764 employees followed a basic-security training course, 450 of whom followed it because they were newcomers to the Institute.
In addition to these general training courses, specific training courses are organised, mainly within the Institute. In 2004, 93 employees were trained in radiation protection and 31 in the transportation of radioactive material.

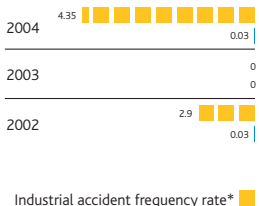
Radiation protection of workers

The Institute took several initiatives to implement the decree of 31 March 2003 relating to labour protection. For example, it appointed radiation protection officers (RPO) for the sites in Le Vésinet, Agen (Lot-et-Garonne) and Les Angles (Vaucluse).

Security at the sites

A local security team was set up at the Le Vésinet site in 2004, which enabled us to make a precise diagnosis of risks and an assessment of the facilities' compliance with regulations. Preventive action was targeted at outside companies working on the site and at the reduction of fire risks. This involved the systematic implementation of prevention plans and security protocols during the loading and unloading of dangerous goods by outside companies and the reduction of fire loads within the facilities. At Cadarache (Bouches-du-Rhône), operations at the classified facility for environmental protection

IRSN security indicators



*Number of accidents with work stoppage multiplied by one million and divided by the number of hours worked.
**Number of working days lost multiplied by 1,000 and divided by the number of hours worked.

Checking the dose rate on a radioactive sample.

were taken over by the Institute and new facilities subject to an authorisation (AMANDE and EPICUR) were commissioned. This led the Prefect to request an in-depth revision of the 1986 bylaw which applied to the Institute. In 2004, the Inspectorate of listed facilities wrote the draft general requirements on the basis of the updated description of the activities and releases of IRSN's facilities.

The Institute's regulated facilities and activities

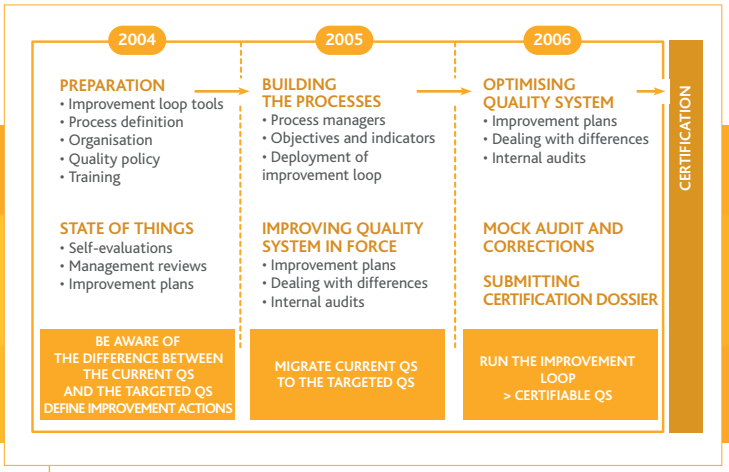
Activities subject to the Code of the Environment (amended decree of 21 September 1977 relating to classified installations for the protection of the environment (ICPE),

- **ICPEs subject to an authorisation:**
  - **11, 9 of which are covered by sections 1,700 (use or storage of radioactive substances).**
- **ICPEs commissioned:**
  - **CEZANE AMANDE, a facility that produces neutron radiation beams within the framework of dosimetry programmes (Cadarache);**
  - **EPICUR, a cobalt-60 irradiator used to assess the behaviour of iodine under radiolysis or radiation (Cadarache).**
- **ICPEs subject to declaration:**
  - **15, 14 of which are covered by sections 1,700.**
- **ICPEs commissioned:**
  - **gammametric test bench to analyse rocks and study radionuclide transfer mechanisms in the soil and subsoil (Fontenay-aux-Roses, Hauts-de-Seine).**

Activities subject to the Code of Public Health (amended decree of 4 April 2002 relating to the protection of persons from ionising radiation).
Number of permit requests filed with the DGSNR in 2004: 19.
Number of permits issued: 14 (5 are being examined).

Personnel exposed to ionising radiation:

- **category A: 114;**
- **category B: 678.**



The main stages of the certification project.

Quality: IRSN's Certification project

Launched in the summer of 2003, the Certification project consists in implementing a management system based on quality at IRSN with a view to obtaining ISO 9001 certification for the Institute by 2006. In 2004, the foundations of this project were laid.

The main results of the work carried out within this framework in 2004 are:

- a detailed schedule of the project was drawn up, taking into account the tasks falling to the Institute's different quality managers and the tasks related to the deployment of the system in all the units;
- most of the unit heads and quality managers received training in the Process approach and the requirements of standard ISO 9001;
- efforts went into making personnel aware of the action undertaken, i.e., the quality Intranet site was reorganised and several brochures were prepared presenting the various aspects of this action to staff;
- the three main aspects of the Institute's quality policy were explained: satisfying its partners and

FOCUS

RENEWAL OF ACCREDITATIONS FOR THE SAMPLE ANALYSIS DEPARTMENT

The IRSN department in charge of sample processing and metrology for the environment (STEME) obtained the renewal of its COFRAC accreditations until 2009, according to the baseline of standard NF EN ISO 17025, for programmes 135 "Laboratory analysis of radionuclides present in all types of samples from the environment", and 99/4 "Analysis of chemical contaminants in animals, in their products and the foodstuffs intended for humans and animals: radionuclides".

COFRAC accreditation offers companies, consumers and public authorities a guarantee of confidence in the services provided. As a signatory of the multilateral, European, mutual recognition agreement for tests, calibrations and certification and equivalent international agreements, the COFRAC is also a passport to exportation.

Preparing renewal audits involves putting together a large number of documents.

Activities covered by accreditation include:

- the measurement of tritium in fresh water and sea water;
- the measurement of global beta radioactivity index (air-aerosol);
- the measurement of alpha ^{238}Pu, ^{239}+^{240}Pu, ^{241}Am emitting radionuclides in water;
- the measurement of ^{14}C in solid samples;
- the measurement of gamma emitting radionuclides in fresh water, solid samples and aerosol sampling filters.

Audits to monitor accreditation will be held in 2005 and the scope will be extended to include the measurement of uranium in water.

Audits

In 2004, 21 internal audits were carried out at IRSN. These audits were a continuation of the work that had been carried out in previous years. Among these, we find two inter-relating audits: the one, preparatory to the audit carried out in spring 2004 by the IAEA on the French baseline for the radioactive material transport safety, and the one from the Reactor section of the process Elaboration of a notice for a standing advisory group. Moreover, to anticipate the gradual increase in the audit programme linked to the Certification project, the team of auditors has been considerably strengthened.

Accreditations and certifications

The IRSN currently has six accredited units (ISO 17025) and two certified units (ISO 9001 version 2000). In 2004, we saw the renewal of accreditations held by the ionising radiation dosimetry laboratory (for the calibration of measuring instruments used in photon dosimetry) and the department in charge of sample processing and metrology for the environment *(see Focus p. 178).*

customers (internal and external), demonstrating the professional nature of its various activities and in some cases, the benefits to society of its activities;

- IRSN's quality organisation was clarified. This is based on the distinction between the line of action, composed of the chain of command in charge of defining and implementing the system's various measures (presenting the state of things, defining objectives and indicators, drawing up action plans, implementing improvements, etc.) and the network of different quality managers in charge of coordinating, developing and monitoring the system and providing method support to the Institute's different units;
- each unit, at various levels of hierarchy (Institute, management, department, etc.) drew up a quality inventory taking stock of the existing situation and comparing it to the standard requirements. After the inventories, these same units held management reviews at which action plans appropriate for each unit were drawn up;
- on 27 September 2004, IRSN's management review was held and the Institute's plan of action until the next management review was drawn up.


IRSN

Communication

IRSN web portal.

Communication

There are three main fields of communication at IRSN: in-house communication, information to the public on nuclear and radiological risk and reputation-building and promotion of the Institute, a multi-skilled public expert.

In-house communication

It helps encourage a sense of belonging to IRSN by developing a shared culture.

The main initiative of the year in the field of in-house communication is the creation of *Repères IRSN*, the quarterly 16-page house journal containing a 4-page supplement for each operational department. This medium aims to inform people of all the different jobs and activities at the Institute, to help them understand the new organisation and the strategy of IRSN. Four issues were published and circulated between February and December 2004. A readership survey was conducted and the conclusions were quite positive: people read *Repères IRSN* and look forward to it. They appreciate the content and the regularity of its publication.

Intranet portal.

As far as the Intranet is concerned, efforts were put into providing information on daily life at the Institute and on more regular updating, via more dynamic sections. We will continue our efforts to make the Intranet a better organised and more widely used interactive tool.

Finally, in 2004, the construction of the Institute also led to the creation of its visual identity with a new logo: development of a graphic charter, an editorial charter and the deployment of these tools via stationary, signposting, outfits worn by response personnel, etc. In-house support on the use of these charters was given at the Institute's different sites.

Information

The aim is to provide information of reference that is explanatory, educational and documentary, and suited to every audience. Relations with the press also have to be conducted by fulfilling their requirements.

As far as informing the public is concerned, IRSN continued action with the general public and professionals in 2004 *(see Part 2, Public information chapter)*.

As far as media relations are concerned, the Institute promptly responded to press requests (164 requests and six TV reports), gave its own news (15 press releases) and provided in-depth information allowing a better understanding of events. As well as the Institute's real-time watch on the media and on public debate on nuclear matters, relations with the media also included a meeting with the

IRSN's house journal.

AJE in 2004 and the organisation of two press trips: to Chernobyl (Ukraine) for the FGI closing conference (5 and 6 October), and to Cadarache (Bouches-du-Rhône), for the last test in the PHEBUS-FP programme (18 November).

Reputation-building and promotion

This should help establish the reputation of the Institute:

- as a scientific expert working for public authorities, operators and society in France and Europe;
- as an organisation that encourages exchanges with civil society;
- as an expert that helps people understand nuclear and radiological risks.

In 2004, the Institute's reputation-building and promotional action included the publication of technical data cards highlighting the services that the Institute provides, i.e., 10 data cards on "products" (radiotoxicological analyses, quantification of low level radioactive elements, etc.) and five cards on "training" (radon metrology in buildings, etc.) were distributed, especially during the shows and conferences the Institute attended.

Part of the communication team and the communication management network at IRSN.


IRSN

Human resources and social relations

Welcoming young people and PhD students.

Human resources and social relations

Human resources: an active policy to support the development of IRSN

Significant initiatives were undertaken in terms of human resources management in 2004. In line with the orientations defined by the Institute, they are based on the key objective: using competence as the basis of human resources policy.

Discussions were initiated and actions launched

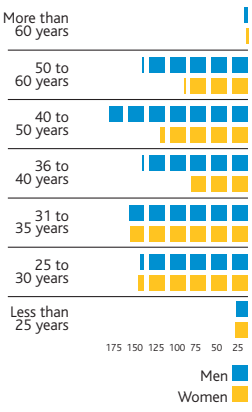
IRSN's management of human resources is in line with the Institute's global project. Within this framework, several schemes were launched in 2004:

- **developing a line of Experts:** IRSN wishes to develop its employees' career prospects and offer new and motivating careers through the creation of a line of Experts. Employees who distinguish themselves through their recognised skills and noteworthy productions will be appointed to the position of Expert. Their position shall be defined through missions fully contributing to the accomplishment of objectives set out in the Institute's scientific and technical policy and its recognition within the international scientific community;
- **strengthening management:** IRSN reaffirmed the central role that unit managers play in making the Institute's strategy operational and in motivating their teams to achieve this. In this spirit, individual and collective interviews were organised with managers in 2004. These should lead to a training programme on how to assume hierarchical responsibilities;
- **managerial staff pay:** after improvements to the pay grid of employees and non-managerial staff in 2003, discussions and negotiations started in 2004 on how to simplify and boost the pay system for managerial staff, engineers and researchers. IRSN wants to be able to attract young people, better reward those who assume responsibilities, possess expertise and achieve personal results and it wants to motivate its staff throughout their career.

The policy governing human resources management was redefined, and initiatives concerning its main processes were taken in 2004. The aim was to define or revise these processes and then formalise them to make them clearer and more effective.

- **Recruitment:** the recruitment process was completely reformulated – simplification of the administrative management of dossiers and clearer follow-up by operational units. The Director of Human Resources will systematically interview the applicants who have been pre-selected by the departments. This will provide managers with advice and a wider point of view, thus helping them make their decision.
- **The annual interview:** the annual interview is a good individual and collective management tool. It has been completely redefined to effectively

Pyramid of ages



meet IRSN's priorities and ensure the dynamic management of its human resources.

■ **Mobility:** in 2004, employees joined organisations outside IRSN in order to pursue and enlarge their careers. Mobility is one of IRSN's main objectives, and it intends to sign agreements with research bodies in France or abroad. This will make it more open to the scientific community and contribute to the development of relations with its main partners.

An evolving workforce

On 31 December 2004, IRSN had 1,471 employees for a target workforce of 1,515 positions: 77% of the employees are under permanent contract (CDI) with IRSN, and 23% are seconded to the Institute from CEA. Managerial staff, engineers and researchers represent more than two thirds of the total workforce and the average age is quite young, with 48% of women and 38% of men between 25 and 35 years of age. Women represent 45% of IRSN's human resources.

Social policy

IRSN's social environment was clearly defined in 2003 (Board of Directors, Works Committee, personnel representatives, occupational safety, health and working conditions committee (CHSCT), etc.), and the company-wide agreement signed in 2003, together with a series of additional agreements signed in 2003 and 2004, provide employees with a high level of protection within a context of active and constructive industrial relations.

During 2004, negotiations between management and labour were held according to a fixed schedule. They concerned the choice of a new mutual insurance company offering a much better cover of health expenses for the same cost, the signing of an agreement on non-managerial staff pay grids, and the signing of a salary settlement for 2004.

The works committee and personnel representatives held regular meetings in 2004. This represented a total of more than 40 meetings. The works committee has been directly in charge of all its missions since 1 January 2004 so its work load has increased.

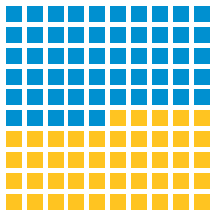
2004 also saw a gradual increase in the opening of IRSN's company saving plans. At the end of 2004, just over 20% of employees subscribed to them. Moreover, the Institute defined its housing assistance policy and chose two partner-collector organisations. Finally, a direct loan system for personnel has enabled about 15 employees to receive financial aid to buy a house/flat or a vehicle.

Receiving young people

In 2004, IRSN received 63 young researchers under a thesis contract, 18 of whom were hired during the year. During the same period, 27 post-doctorands worked at the Institute, 12 of whom arrived in 2004.

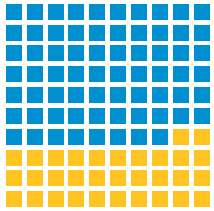
IRSN provided 107 higher-education students with placements, 74 of whom were post-graduate students or coming from engineering schools. The Institute signed eight new contracts of apprenticeship and two contracts of qualification. These young people are mainly preparing senior technician or engineering diplomas in electronics, chemistry and information technology.

Breakdown according to sex

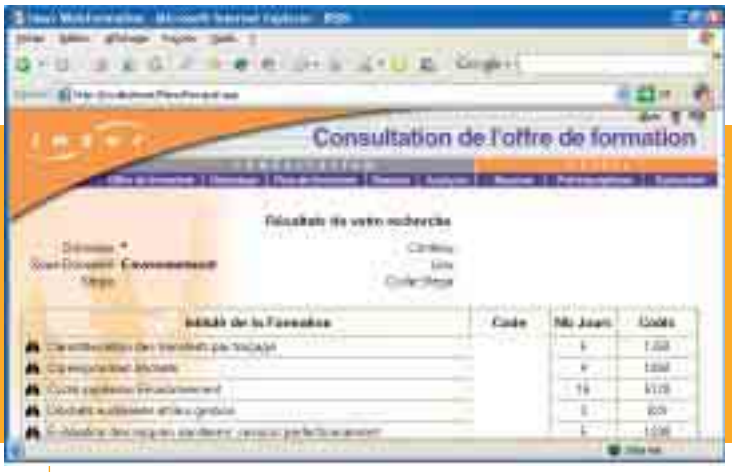


Men **55%**
Women **45%**

Breakdown according to socioprofessional category

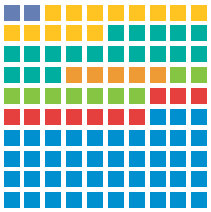


Engineers, researchers and managerial staff **68%**
Non-managerial staff **32%**



INSER, training management software.

Breakdown of training hours per field in 2004



Economy, management **2%**
IT **13%**
Languages **18%**
Management, communication **5%**
Project quality **9%**
Security **10%**
Science and Technology **43%**

Continuing professional development

Further professional training contributes to the development of the skills that the Institute requires for its different fields of activities. 40,000 training hours were given in 2004, for a total teaching cost of 1,150,000 euros.

Two particular points are to be noted for 2004:

- the implementation of new software to manage training: in the second half of 2004, the acquisition and installation of dedicated software enabled us to prepare an inventory of the training needs for 2005. Training courses on the centralised and decentralised use of this software were given and this will be continued in 2005, especially for reporting requirements;
- a consolidation of scientific and technical training: scientific and technical training represented 40% of training hours and 42% of teaching costs.

> Glossary

[A]

ACT ▪ Advanced Communication Tool – networking tool used within the framework of the SARNET

ADN ▪ *Accord européen pour le transport de marchandises Dangereuses par voie de Navigation extérieure* (European provisions concerning the international carriage of dangerous goods by inland waterway)

AECL ▪ Atomic Energy of Canada Limited

AFA 3GLr AA ▪ Advanced Fuel Assembly (2nd generation assembly) – name given to a certain type of fuel assembly

AFAQ ▪ *Association Française d'Assurance de la Qualité* (French Quality Assurance Association)

AFSSAPS ▪ *Agence Française de Sécurité SAnitaire des Produits de Santé* (French Agency for the Safety of Health Products)

AJE ▪ Association of journalists specialised in the environment

Alpha (α) ▪ Radiation composed of helium 4 nuclei, highly ionising but not very penetrating. A sheet of paper is sufficient to stop alpha radiation

AMANDE ▪ *Accélérateur pour la Métrologie et les Applications NEutroniques en Dosimétrie Externe* (Accelerator for metrology and neutronics applications for external dosimetry) – IRSN, Cadarache

ANCLI ▪ *Association Nationale des Commissions Locales d'Information* (French association of local information commissions)

ANDRA ▪ *Agence Nationale pour la gestion des Déchets RAdioactifs* (French National agency for radioactive waste management)

ANTHRO-Si ▪ Prototype of a whole-body counting measurement system that can rapidly determine the radiation of radionuclides incorporated by a person

Aplasia ▪ Arrest or insufficiency in the development of a tissue or organ

AREVA ▪ Industrial group including the companies AREVA T and D, COGEMA, FRAMATOME, FBFC, COGEMA logistics, ANP, TECHNICATOME and FCI

ARMINES ▪ Association for contractual research, partner of French Engineering Schools

ASR ▪ Authorisation to Supervise Research

ASTEC ▪ Accident Source Term Evaluation Code – Scientific software used to simulate a core meltdown accident in a water reactor, from the initiating event to the release of radioactive products out of the containment. It is developed jointly by IRSN and GRS

ASTRAL ▪ *ASsistance Technique en Radioprotection post-AccidenteLle* (Technical assistance in post-accident radiological protection). Quantifying the transfer of radioactive elements to the agricultural environment following a nuclear accident.

ASTRID ▪ Assessment of Source Term for emergency Response based on Installation Data

ATPu ▪ Plutonium technology facility (COGEMA)

ATUe ▪ Enriched uranium treatment workshop

AVN ▪ *Association Vinçotte Nucléaire* (Association Vinçotte Nuclear) - Belgium

[B]

B_4C ▪ Boron carbide used as a neutron absorber in the control rods that equip the most recent French reactors as well as the boiling water reactors in service in Europe

BADIMIS ▪ Computer database related to the suspension of radionuclides

BAM ▪ *BundesAnstalt für Materialforschung und -prüfung (German Federal)* – Institute for materials research and testing

BARRACUDA ▪ Programme dedicated to the next generation of French nuclear attack submarines

Basemat ▪ Foundation of reactors in nuclear power plants

BECARRE ▪ *Essais de dégradation de Barres En CArbure de boRe et RElâchements associés* (Tests on the degradation of boron carbide control rods and associated releases)

Becquerel (Bq) ▪ Official international unit for radioactivity measurement. The becquerel is equal to one disintegration per second

Beta (β) ▪ Radiation composed of electrons of negative or positive charge. A few-millimetre air screen or a simple sheet of aluminium can stop this type of radiation

Biokinetics ▪ Refers to all the accumulation and excretion kinetics of an element in an organism

BLEVE ▪ Boiling Liquid Expanding Vapour Explosion

BNI ▪ Basic Nuclear Installation

BORIS ▪ Bioavailability Of Radionuclides In Soils. European project aiming to study the behaviour of radionuclides in former Russian nuclear weapon complexes where liquid radioactive waste was injected in-depth

Burnup fraction ▪ Thermal energy produced by nuclear fissions in a fuel mass unit. It is measured in megawatts-day per ton (MWj/t)

BWR ▪ Boiling Water Reactor

[C]

CABRI ▪ Test reactor concerning fuel safety used by IRSN

CABRI REP-Na ▪ Water reactor with sodium loop

CABRI-CIP ▪ CABRI International Program with water loop

Caesium ▪ (Cs, atomic number 55) Noble, toxic metal whose characteristics are comparable to those of potassium

CALIBAN ▪ Experimental reactor (CEA-Valduc), which can produce intense pulses of neutrons and fission gamma rays

Callovo-Oxfordian ▪ Layer of sedimentary rock from the Jurassic period (160 million years) which is the layer studied in the Bure laboratory

CAMARI ▪ *Certificat d'Aptitude à Manipuler des Appareils de Radiographie ou de radioscopie Industrielle* (Certificate attesting the ability to handle radioscopy and industrial radiography equipment)

CANEL ▪ Experimental installation for the instrumentation of radiological protection, which can reproduce neutron spectra like those found at workstations in facilities (IRSN, Cadarache)

CARMELA ▪ IRSN research program on fires in nuclear facilities aimed at gaining further insight into electrical cabinet fires

CARMELO ▪ *Combustion ARMoires ÉLectriques essais glObaux* (Global test electrical cabinet combustion)

CAROL ▪ *CAmargue-RhÔne-Languedoc*, project for studying the distribution of artificial radionuclides in the Lower-Rhône region

CARTORAD ▪ Software used to map radioactive measurements

CASTEAUR ▪ *CAlcul Simplifié des Transferts dans les cours d'EAUx Récepteurs* (Simplified calculation of transfers in receiving waterways). Simplified calculation of transfers of radioactive elements into receiving waterways for impact studies on accidental releases like routine releases from fuel cycle plants

CATHARE ▪ Advanced thermal-hydraulic calculation code used to study the behaviour of pressurised water reactors in accident situations

CATHARE-SIMU ▪ Version of the CATHARE code adapted to the SIPA simulator

CDI ▪ Open-ended contract

CEA ▪ *Commissariat à l'Énergie Atomique* (French atomic energy commission)

CENELEC ▪ European committee for electrotechnical standardisation

CERCA ▪ Company for the study and the realisation of atomic fuels (Romans – Isère)

CESAR ▪ Software of the ASTEC system simulating the thermal-hydraulics of the primary and secondary systems in a water reactor

CHIP ▪ Experimental program on "Iodine chemistry in the primary system" of a PWR during a core meltdown accident

CHRONIC RAD EPID ▪ Research project carried out within the framework of 6th FPRD and dealing with epidemiological cancers associated with chronic exposure to ionising radiation

CHSCT ▪ *Comité d'Hygiène de Sécurité et des Conditions de Travail* (Health, safety and working conditions committee)

CICNR ▪ *Comité Interministériel pour la gestion des Crises Nucléaires et Radiologiques* (Interministerial committee for the management of nuclear and radiological crises)

CIEMAT ▪ *Centro de Investigaciones Energéticas, MedioAmbientales y Tecnológicas* (Research centre for energy, environment and technology), Madrid – Spain

CIP ▪ Competitivity and Innovation framework Programme

CIREA ▪ *Commission Interministérielle des RadioÉléments Artificiels* (Interministerial commission for artificial radioelements)

CIS bio international ▪ Company that develops biomedical technologies for industrial and commercial purposes

CLI ▪ *Commission Locale d'Information* (Local information commission)

CMS ▪ *Cote Majorée de Sécurité* (Maximum design flood level)

CNAM-TS ▪ *Caisse Nationale d'Assurance Maladie – Travailleurs Salariés* (French employee's national health insurance fund)

CNES ▪ *Centre National d'Études Spatiales* (French space agency)

CNRS ▪ *Centre National de la Recherche Scientifique* (French national organisation for scientific research)

COFRAC ▪ *Comité français d'accréditation* (French accreditation committee)

COGEMA ▪ *Compagnie générale des matières nucléaires* (French general company for nuclear materials)

COGIC ▪ *Centre opérationnel de gestion interministérielle des crises* (Interministerial operational crisis management centre)

COMURHEX ▪ Company that converts Uranium into metal or hexafluoride

CONRAD ▪ Radiological consequences – software used to simulate the dispersion of accidental radionuclide releases into the atmosphere and the short-term impact

Containment ▪ Building or reactor building. Leaktight concrete building housing the reactor pressure vessel, primary system, steam generators and main auxiliaries ensuring reactor safety

CORE ▪ COoperation for the REhabilitation of living conditions in contaminated areas – programme concerning 15 Byelorussia villages, financed by the UNDP, the World Bank, the EC, the diplomatic representations in Minsk and Belarus. CORE operators include Médecins du Monde, Patrimoine sans Frontières, University of Caen, National Agronomic Training Institute of Paris-Grignon, IRSN, CEPN, the French Ministry of Agriculture, FERT, À tous vents du monde, Mutadis

COWAM 2 ▪ COmmunity WAste Management 2 – research programme initiated as part of the 6th FPRD, coordinated by Mutadis and in which IRSN participates. The programme aims to improve the governance of radioactive waste management and storage in Europe

CPHR ▪ *Centro de Protección e Higiene de las Radiaciones* (Centre for health and protection against radiation). Scientific and technical unit of the Nuclear Energy Agency based in Havana

CRIS ▪ IRSN centre for scientific information resources

CRISTAL ▪ New French criticality package developed as part of a joint project between IRSN, CEA and COGEMA. It aims at assessing the criticality risk in all nuclear fuel cycle plants and transport packages where fissile materials are used

Criticality ▪ Risk of uncontrolled fission phenomena in fissile materials

Criticality accident ▪ Uncontrolled chain fission reaction triggered in an environment containing fissile materials such as uranium-235 or plutonium-239

CRPPH ▪ Committee on Radiation Protection and Public Health (NEA)

CRSSA ▪ *Centre de Recherches du Service de Santé des Armées* (Army health service research centre)

CTB ▪ *Centre de Traitement des Brûlés* (Treatment Centre for Burn victims) Percy hospital, Clamart

CTC ▪ IRSN's emergency response centre

CTGF/CCN2 ▪ Connective Tissue Growth Factor

CTHEN ▪ *Centre Technique d'Homologation des Équipements Nucléaires* (Technical Centre for nuclear equipment approval)

CTHIR ▪ *Centre Technique d'Homologation de l'Instrumentation de Radioprotection* (Technical centre for the radiological instrumentation approval)

[D]

DAM ▪ *Direction des Applications Militaires du CEA* (CEA's military applications division)

DARPMI ▪ *Direction de l'Action Régionale et des PMI* (Department for regional action and small and medium sized firms)

DATANET ▪ SARNET experimental database network

DATARAD ▪ Database of radioactivity measurements

DCN ▪ DCN company, former shipbuilding division of the DGA (French defence procurement agency)

DDASS ▪ *Direction Départementale des Affaires Sanitaires et Sociales* (French department direction of health and social affairs)

DDSC ▪ *Direction de la Défense et de la Sécurité Civiles – Ministère de l'Intérieur* (French directorate of civil defence and security – Ministry of the Interior)

DECOVALEX ▪ DEvelopment of COupled models and their VALidation against EXperiments

DEND ▪ *Direction de l'Expertise Nucléaire de Défense* (Department for nuclear defence expertise) - IRSN

DGA ▪ *Direction Générale pour l'Armement* (French defence procurement agency)

DGAC ▪ *Direction Générale de l'Aviation Civile* (French Civil Aviation Authority)

DGSNR ▪ *Direction Générale de la Sûreté Nucléaire et de la Radioprotection* (French department for nuclear safety and radiation protection)

DISCO ▪ German experimental programme on the direct heating of the reactor containment when corium is ejected out of the vessel – DISpersion of Contamination test bench (IRSN – Saclay)

DISPRO ▪ Near-field dispersion

DIVA ▪ *Dispositif expérimental pour l'Incendie, la Ventilation et l'Aérocontamination*

(Experimental system for fire, ventilation and air contamination)

DM1 ▪ Modifying decision No.1 of IRSN budget

Dosimetry ▪ Detection, by assessment or measurement, of the dose of radiation (radioactivity) absorbed by a substance or a person

DOSMAX ▪ DoSimetry of aircrew exposure during solar Maximum. Research programme conducted as part of the 5th FPRD and in which IRSN took part

DPPR ▪ *Direction de la Prévention des Pollutions et des Risques majeurs du ministère de l'Écologie et du Développement durable* (French department for the prevention of pollution and risks from the Ministry of Environment and Sustainable Development)

DRASS ▪ *Direction Régionale des Affaires Sanitaires et Sociales* (French regional department of health and social affairs)

DRIRE ▪ *Direction Régionale de l'Industrie, de la Recherche et de l'Environnement* (Regional directorate of industry, research and environment)

DRT ▪ *Direction des Relations du Travail* (Staff relations branch)

DSND ▪ Delegate for nuclear safety and radiation protection for activities and installations related to defence

[E]

EBRD ▪ European Bank for Reconstruction and Development

EC ▪ European Commission

ECC ▪ European Community Commission

ECORAD ▪ International Conference involving eco-toxicology and radioactivity

EDF ▪ Électricité de France (French national electric utility)

EDZ ▪ Excavation Disturbed Zone

EMRAS ▪ Environment Modelling for Radiation Safety

ENUSA ▪ Empresa Nacional del Uranio, SA (Spain) – Spanish nuclear organisation – (Industrias Avanzadas S.A.)

ENVIRHOM ▪ IRSN research programme aimed at studying radionuclide accumulation processes and the biological effects, during this accumulation, induced in the living organisms of plants, animals and humans subjected to chronic exposure

EORTC ▪ European Organisation for Research and Treatment of Cancer

EOT ▪ Operational transport section (IRSN)

EPICUR ▪ A cobalt-60 irradiator used to assess the behaviour of iodine under radiolysis (Cadarache)

EPR ▪ European Pressurised Reactor

EPR ▪ Electron Paramagnetic Resonance (France)

EPRD ▪ Forecast statement of revenue and expenditure

EPRI ▪ Electric Power and Research Institute (US)

EPS2 ▪ Level-2 probabilistic safety assessment. IRSN is currently assessing the 900 MWe reactors

ERICA ▪ Environmental Risk from Ionising Contaminants Assessments and management

ES Konsult ▪ Consulting firm specialised in risk assessment, safety, quality assurance (Sweden)

ESTRO ▪ European Society for Therapeutic Radiology and Oncology

EURANOS ▪ European approach to nuclear and radiological emergency management

EURATOM ▪ European Atomic Energy Community

EURODIF ▪ European uranium enrichment by gaseous diffusion plant (COGEMA, Pierrelatte – France)

EUROFAB ▪ The project named EUROFAB (for *"FABrication en EUROpe"*) is part of the programme for disposal of Russian and American military plutonium exceeding defence requirements

EUROSTRATAFORM ▪ European margin strata formation – research programme of the 5th FPRD

EVIDOS ▪ Evaluation of individual dosimetry in mixed neuton-proton fields – research programme financed by the European Community within the framework of 5th FPRD

EXTREME ▪ Research programme aimed at studying the consequences of extreme climatic events on the transfers of radioactivity between in the compartments of the environment

[F]

FASSET ▪ Framework for ASSessment of Environmental ImpacT

FBFC ▪ Société Franco-Belge de Fabrication de Combustibles (Franco-Belgian fuel manufacturer)

FGI ▪ French-German Initiative for Chernobyl

FIRST ▪ Further Improvement of Radiotherapy of cancer through side-effect reduction by innovative application of adult Stem cells transplantation for prevention and Treatment of deterministic radiation effects

FLAMME_S ▪ Software developed by IRSN that simulates in a simple manner the evolution of carbonated product fires in installations made up of mechanically ventilated, confined premises

FLAMME_S/SIMEVENT ▪ FLAMME_S software combined with SIMEVENT software that simulates a fire in a group of premises connected by a ventilation system and doors

FLIP ▪ *Feux de Liquide en Interaction avec une Paroi* (Liquid fuel fire interacting with a wall)

FPRD ▪ Framework Programme for Research and Development (European Community)

FPT-3 ▪ PHEBUS FP test dedicated to studying the effects of B_4C on the degradation of a reactor core and on the release of fission products

FS 65 900 ▪ Fresh MOX fuel shipping container

Fuel assembly ▪ Cluster of fuel rods, connected with a metallic structure, used in nuclear reactors

FzK ▪ *Forschungszentrum Karlsruhe* – German advanced nuclear research centre

[G]

GALICE ▪ Name of a fuel management method used in French power plants

Gamma (γ) ▪ Highly penetrating but not very ionising electromagnetic radiation, emitted by the disintegration of radionuclides. This type of radiation is stopped by concrete or lead screens

GATeL ▪ *Génération Automatique de Tests à partir d'une description Lustre* (Automatic generation of tests from a lustre description)

GDP ▪ Gaseous Diffusion Plants (INBS Pierrelatte)

GEIE ▪ *Groupement Européen d'Intérêt Économique* (European economic interest grouping)

GIF ▪ Generation IV International Forum

GLP-2 ▪ Glucagon-Like Peptide

GP ▪ Standing advisory group

GPR ▪ Standing advisory group of experts for nuclear reactors

GPU ▪ Standing advisory group of experts for plants

GRNC ▪ *Groupe Radioécologie du Nord-Cotentin* (Nord-Cotentin radioecology group)

GRS ▪ *Gesellschaft für Anlagen – und Reaktorsicherheit* (Germany)

GWj/t ▪ Fuel burnup rate. Giga Watt days per tonne of fuel. The customary unit for measuring fuel assembly irradiation, i.e., the energy extracted from the assembly in the reactor per tonne of initial uranium

[H]

HAEA ▪ Hungarian Atomic Energy Authority

Hematopoietic cells ▪ Cells where red blood cells are formed

HFD ▪ *Haut Fonctionnaire de Défense du ministère de l'Économie, des Finances et de l'Industrie* (French Senior Defence Official of the Ministry for Economy, Finance and Industry)

HLLL ▪ High-Level and Long-Lived

HLLLW ▪ High-Level and Long-Lived Waste

HRD ▪ Human Resources Division

HTR/VHTR ▪ High Temperature Reactor/Very High Temperature Reactor (United Kingdom)

[i]

IAEA ▪ International Atomic Energy Agency

IARC ▪ International Agency for Research on Cancer

ICARE-CATHARE ▪ Software that accurately describes the reactor core degradation up until tank rupture during a core meltdown accident

ICPE ▪ *Installation Classée pour la Protection de l'Environnement* (Classified installations for the protection of the environment)

ICRP ▪ International Commission on Radiological Protection

ICSBEP ▪ International Criticality Safety Benchmark Evaluation Project

ICST ▪ *Ingénierie de la Connaissance Scientifique et Technique* (Scientific and technical knowledge engineering)

IEC ▪ International Electrotechnical Commission

IFREMER ▪ Institut Français de Recherche pour l'Exploitation de la MER (French research institute for exploitation of the sea)

IGR ▪ Institut Gustave-Roussy (Gustave Roussy Institute) - France

INBS ▪ Secret basic nuclear installation

INERIS ▪ Institut National de l'Environnement industriel et des RISques (French national institute for the industrial environment and hazards)

InVS ▪ Institut de Veille Sanitaire (French health watch institute)

IPPAS ▪ International Physical Protection Advisory Service

IPS 47 ▪ OECD/CSNI's International Standard Problem dedicated to calculations on the THAI tests carried out in Germany and TOSQUAN

IPSN ▪ Institut de Protection et de Sûreté Nucléaire (French institute for protection and nuclear safety)

IRMA ▪ Cobalt-60 IRradiation unit with test facilities to study the behaviour of Materials and equipment to irradiation (IRSN – Saclay)

IRPA ▪ International Radiation Protection Association

IRSN ▪ Institut de Radioprotection et de Sûreté Nucléaire (French Institute for radiological protection and nuclear safety)

ISIS ▪ Calculation software that precisely simulates the progress of a fire, gas, smoke and structures in confined spaces with mechanical ventilation

ISO ▪ International Standard Organisation

ISO 9001 ▪ European standard for quality management systems

Isotopes ▪ Elements whose atoms have the same number of electrons and protons, but a different number of neutrons. They have the same name and the same chemical properties. Around 325 natural isotopes and 1,200 artificially created isotopes are currently listed

IUR ▪ International Union of Radiology

IUR ▪ International Union of Radioecology

[K]

K2-R4 ▪ Abbreviations for phase 2 of the Khmelnitsky power plant and phase 4 of the Rovno power plant, both in Ukraine

kV ▪ KiloVolt

[L]

LERISS ▪ Laboratoire d'Étude et de Recherche en Instrumentation Signaux et Systèmes (Laboratory that carries out studies and research in signals and systems instrumentation)

LFI ▪ Initial finance law

LMND ▪ Laboratoire de Métrologie et de Dosimétrie des Neutrons (Laboratory for Neutron Metrology and Dosimetry), IRSN – Cadarache

LPG ▪ Liquified Petroleum Gas

[M]

M5 ▪ Type of pressurised water fuel cladding

MARN ▪ French nuclear risk management aid committee

MCNP ▪ (Monte-Carlo N-Particule Transport). Monte-Carlo code for simulating the transportation of different particles: neutrons, photons, electrons, coupled neutrongamma. This code, developed in Los Alamos (USA), is the same as the TRIPOLI-4 code, developed by CEA (France)

MEDD ▪ Ministère de l'Écologie et du Développement Durable (French Ministry for Ecology and Sustainable Development)

MEDEC ▪ French health exhibition

MEDICIS ▪ ASTEC system software used to simulate ablation of the basemat by a melted reactor core

MELODIE ▪ Model for the long-term assessment of buried radioactive waste

MELOX ▪ MOX fuel manufacturing plant (COGEMA Marcoule – France)

Mesenchymal ▪ Relating to embryonic connective tissue

mGy ▪ Milli Gray – unit of absorbed radiation dose of the International System of Units

MIMAUSA ▪ Memory and IMpact of urAniUm mines: Summary and Archives

MLLL ▪ Medium-Level Long-Lived

MORET ▪ Monte-Carlo code for simulation of neutron transport (multi-group approximation) to calculate the effective multiplication factor (Keff) of 3-D complex systems

MOX ▪ Fuel of uranium (natural or depleted) and plutonium oxides

MOZART ▪ Analytic tests to study the oxidation kinetics of clads under air

MRI ▪ Magnetic Resonance Imaging

mSv ▪ Milli Sievert – unit derived from dose equivalent of the International System of Units

MWe ▪ MegaWatt electric

[N]

N4 ▪ N4 series – series of 1,450-MWe pressurised water reactors operated by EDF

NAIMORI ▪ Novel Approaches in the Management Of the Radiation Injury - European project

NEA ▪ OECD Nuclear Energy Agency

NF-PRO ▪ Near Field Processes

NNC ▪ National Nuclear Corporation - Firm of nuclear services consultants (United Kingdom)

NNSA-NSC ▪ National Nuclear Safety Administration (United States) – Nuclear safety centre (China)

NOD-SCID ▪ Line of immunodeficient mice (non obese-diabetic/severe combined immunodeficiency)

NRC ▪ Nuclear Regulatory Commission (United States)

NRG ▪ Nuclear Research and consultancy Group (The Netherlands)

NRPB ▪ National Radiological Protection Board (United Kingdom)

NSA ▪ Nuclear Security Agency (United States)

NSRR ▪ Nuclear Safety Research Reactor (Japan)

Nuclear fuel ▪ Fissile material (capable of undergoing a fission reaction) used in a reactor to develop a nuclear chain reaction. After being used in a nuclear reactor, this is referred to as irradiated fuel

Nuclear island ▪ Assembly comprising the nuclear boiler, the installations relating to the fuel and the equipment needed to operate and ensure the security of this assembly

Nuclear materials ▪ Materials which could be used to manufacture a nuclear explosive device. They are defined according to their fissile (for a fission device), fusible (for a thermonuclear bomb), or fertile (capacity to produce fissile or fusible materials) characteristics. French legislation covers six nuclear materials: plutonium, uranium, thorium, tritium, deuterium and lithium 6 (deuterium and lithium 6 are not radioactive)

Nuclear safety ▪ Set of measures taken at all levels of design, construction, operation and decommissioning of the nuclear installations to prevent accidents and limit their effects

NUPEC ▪ Nuclear Power Engineering Corporation – Japanese nuclear safety organisation

[O]

OECD ▪ Organisation for Economic Cooperation and Development

OECD/CSNI ▪ Organisation for Economic Cooperation and Development/Committee on the Safety of Nuclear Installations

OECD/NEA ▪ OECD Nuclear Energy Agency

OEDIPE ▪ Tool for assessment of personalised internal dose

OJ ▪ Official Journal

OPCW ▪ Organisation for the Prohibition of Chemical Weapons

OPERA ▪ IRSN permanent environmental radioactivity observatory

OPRI ▪ Office de Protection contre les Rayonnements Ionisants (French office for protection against ionising radiation)

ORME ▪ Observatoire Régional Méditerranéen de l'Environnement (French mediterranean environment observatory)

ORPHEE ▪ Experimental, pool-type nuclear reactor with a rated power of 14 MWth (CEA Saclay – France)

[P]

P4 ▪ Plant series comprising eight, 1,300-MWe, water-pressurised reactors at Paluel, Flamanville and Saint-Alban

P'4 ▪ Plant series comprising twelve, 1,300-MWe, water-pressurised reactors – the most recent French reactors

PACA ▪ Provence-Alpes-Côte-d'Azur region (France)

PANAME ▪ Method developed by IRSN to quantify the reliability of operating actions

PASEPRI ▪ Action plans for the monitoring of patient exposure to ionising radiation

PATRAM ▪ International symposium on PAckaging and Transportation of RAdioactive Materials

PCO ▪ Operational control centre

PCRDT ▪ Framework Programme for Technological Research and Development

PHARE ▪ Poland-Hungary Assistance for Reconstruction of the Economy – European assistance programme for reconstruction of polish and hungarian economies

PHEBUS FPT3 ▪ FPT-3 test of the PHEBUS-FP programme

PHEBUS-FP ▪ IRSN experimental programme on the degradation of a nuclear reactor core and the release of Fission Products (FP)

PHENIX ▪ 250-MWe fast neutron reactor

PIC ▪ Common interest program

PICSEL ▪ Propagation of solid fuel fire in a laboratory and plant environment

PIV ▪ Particule Image Velocimetry

PKL ▪ Primar KreisLauf – test loop used for inherent dilution phenomena

Plant unit ▪ Power production unit including a boiler and a turbo-generator set. A nuclear plant unit is mainly defined by its type of reactor and the power of its turbo-generator

Plutonium ▪ (Pu, atomic number 94). Transuranic chemical element. The isotope 239 has a half life of 24,110 years

PN3 ▪ "Trace detector" dosimeter for neutrons

PNNL ▪ Pacific Northwest National Laboratory (United States)

POLLUTEC ▪ International trade fair for environment-related equipment, technologies and services for industry

PPI ▪ Special response plan

Primary system ▪ Reactor coolant system operating in a closed loop, comprising a series of components ensuring the coolant fluid circulation used to extract the heat given off by the reactor core

PRISME ▪ Propagation of a fire for elementary, multi-premises scenarios

PSA ▪ Probabilistic Safety Assessment

PUI ▪ Internal emergency plan

PWR ▪ Pressurised Water Reactor

[Q]

QUENCH ▪ German experimental programme aimed at studying hydrogen production during the degradation of a reactor core

[R]

Radiation protection ▪ Set of measures intended to ensure health protection of the population and workers using ionising radiation sources

Radioactivity ▪ Property of certain chemical elements whose nuclei spontaneously disintegrate into other elements emitting ionising radiation

Radioelement ▪ Natural or artificial radioactive element

Radionuclide ▪ Radioactive isotope of an element

RASSC ▪ Radiological Safety Standards Committee (IAEA)

RBMK ▪ Graphite reactors from the ex-Soviet Union

RECI ▪ RECombiner of Iodine – experimental system used to assess the influence of recombiners on the chemistry of iodine in the containment (IRSN, Saclay – France)

REMOTRANS ▪ REMObilisation, long distance TRANsport and bioavailability of radionuclides in marine sediments

REP-Na ▪ Experimental programme in the sodium loop of the CABRI reactor aimed at studying the behaviour of fuel during a power transient

RES ▪ Test reactor

RHF ▪ Laüe Langevin Institute's high-flux reactor (France)

RIA ▪ Reactivity Insertion Accident

RNG ▪ New generation reactor

RNIPP ▪ *Répertoire National Individuel des Personnes Physiques* (National register of persons)

RPO ▪ Radiation Protection Officer

[S]

SAE ▪ Annual statistics for public and private health establishments

SARA ▪ Automated monitoring of aerosol radioactivity

SARNET ▪ Severe Accident Research NETwork of excellence – a European network of excellence on water reactor core meltdown accidents – 6th FPRD project

SATURNE ▪ Experimental installation with an extractor hood aimed at studying the progress of a fire

SC 45B ▪ "SECNUC exercise" – "Nuclear Safety" exercise

SCANAIR ▪ Software used to calculate an RIA-type transient developed by IRSN

SDMV ▪ Synchronised Distributed Mapped Values

SEBIM ▪ Brand of valves

SECNUC ▪ Nuclear safety

SEVESO ▪ The Seveso accident, that happened in Italy in 1976, gave its name to a European directive on industrial accident risks

SFR ▪ Société Française de Radiologie (French radiology organisation)

SFRP ▪ Société Française de RadioProtection (French society for radiation protection)

SGDN ▪ Secrétariat Général de la Défense Nationale (French general secretariat for national defence)

SICN ▪ Industrial nuclear fuel company (CEAI) (nuclear fuel fabrication plant)

SIEVERT ▪ Information and assessment system of the exposure to cosmic radiation during flights

SIGIS ▪ Information and management system for the national inventory of ionising radiation sources

SIGMA ▪ Graphite block containing radioactive sources, producing a "realistic" field of mainly thermal neutrons (IRSN, Cadarache – France)

SILOE ▪ Pool-type reactor (CEA/Grenoble)

SILOETTE ▪ Pool-type teaching reactor (CEA/Grenoble)

SIMEVENT ▪ Software simulating aeraulics in a ventilation system developed as part of a joint project between IRSN, SGN and COGEMA

SIMO ▪ Mining company in western France (CEA)

SIPA ▪ Pressurised water reactor accident simulator developed and used by IRSN

SIPA/SCAR ▪ "Simulator CATHARE Release" – a joint project conducted by IRSN and EDF aimed at integrating the thermal-hydraulic code CATHARE 2 into IRSN's SIPA 2 simulator

SISERI ▪ Ionising radiation exposure monitoring information system

SKI ▪ Swedish nuclear power inspectorate

SNA ▪ Nuclear attack submarine

SNCF ▪ Société Nationale des Chemins de Fer français (French national railway company)

SNLE ▪ Nuclear-powered ballistic missile submarine

SNM ▪ Military nuclear system

SNR ▪ Fast breeder reactor

SNRCU ▪ State Nuclear Regulatory Commitee of Ukraine

SSD ▪ Department for the safety of radioactive waste (IRSN)

SSI ▪ Swedish radiation protection authority

SSTC ▪ State Scientific and Technical Centre (Ukraine)

STARMANIA ▪ Station for the study of airborne contamination transfer and mechanical strength under incident and accident conditions (IRSN Saclay – France)

STE ▪ Technical operating specifications, effluent treatment centre

STI ▪ Scientific and Technical Information

STUK ▪ *Stäteilyturvakeskus* – Radiation and nuclear safety authority (Finland)

SUNSET ▪ Statistical calculation tool that, when combined with software that simulates physical phenomena, can be used to study the effect on chosen calculated responses of uncertainty concerning some parameters and data entered into the software

SYLVIA ▪ Software system used to study ventilation, fire and air contamination

SYMBIOSE ▪ Systemic approach for modelling the fate of chemicals in biosphere and ecosystems

[T]

TACIS ▪ Technical Assistance for Commonwealth of Independent States – European assistance programme for the reconstruction of economies in the new independent states

TID ▪ Total Indicative Dose

TONUS ▪ Code developed by the CEA on behalf of IRSN that uses models that govern the distribution of hydrogen in the containment

TOSQAN ▪ *TonuS Qualification ANalytique* – Experimental containment used to reproduce a small-scale accident scenario enacting a hydrogen risk in a nuclear reactor containment (IRSN Saclay – France)

TPO ▪ Thrombopoïetin

TranSAS ▪ Transport Safety Appraisal Service

TRG ▪ Translational Research Group

TVO ▪ *Teollisuuden Voima Oy* – Finnish electricity company

[U]

UF_6 ▪ Uranium hexafluoride

UNSCEAR ▪ United Nations Scientific Committee on the Effects of Atomic Radiation

UOX3 ▪ Fuels with an initial U^{235} content of 4.5 % and a burnup fraction of 60 GWj/t

UP1 ▪ Biggest plant for the reprocessing of spent nuclear fuels with a view to them being recycled in France (Cogema Marcoule – France)

UP2-800 ▪ Irradiated nuclear fuel reprocessing plant located at the Site in La Hague (Cogema – France)

[V]

VHE ▪ Very High Efficiency

[W]

WHO ▪ World Health Organisation

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IRSN

INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

Finance Ledger of the Annual Report 2004

Didier Demeillers,
Director in charge of Financial Matters

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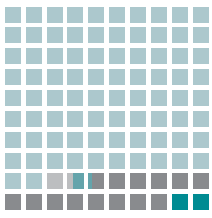
Breakdown of resources (in M€)



MEDD subsidy **201.9**
MINDEF subsidy **2.7**
Other subsidies **2**
Own resources **35.2**
Miscellaneous **3.8**

Management report

Law 2001-398 of 9 May 2001 creating the French health and environmental safety agency merged, in article 5, within a public establishment of industrial and commercial nature named IRSN, part of the Office for protection against ionising radiation and the Institute of protection and nuclear safety.

1. Evolution of the Institute

After the **2002 financial year**, limited to ten months (from 28 February to 31 December) and not incorporating the accounts of OPRI and IPSN, the **2003 financial year** really marked the accounting and financial birth of the Institute with a normal twelve-months period and incorporation in the closing balance sheet of the assets and liabilities of OPRI and IPSN. The end of 2003 also saw finalisation of the new organisation of the Institute. It was transcribed into the Institute's budget at the beginning of 2004 and was adjusted at the DM1 of June 2004. This has affected the whole financial year, more particularly certain investments whose completion was delayed.

In addition, installation of monitoring per process and launching of steps towards ISO 9001 version 2000 certification by 2007, marks a stage in the continuous improvement process involving Institute management as a whole.

Consistent with this quality orientation, major progress has been made in improving budgetary piloting of activities, both in forecasting and in realisation, with a finer monitoring of activities by using a budgetary presentation per client. This economic and financial supervision system will be completed in 2005 by implementing a decision information system, currently in the course of installation, and the launching of cost accounting revision which will enable refinement of cost price relevance.

The main features of **the 2004 financial year**, apart from extraordinary items, are:

- observance of balances presented for the approval of the Board of Directors with the EPRD 2004;
- a budget realisation rate of 97.5%, a variation of 7 M€ due, as to 2.5 M€, to delays in completing certain investments, and as to 4 M€, to a fall in costs and a smaller sales figure.

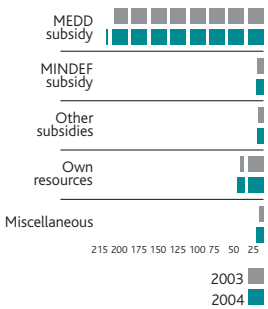
At the end of the year, extraordinary items disrupted the 2004 balances:

- non-payment by MEDD of the counterpart of the budget deficit consequent on the tax system implemented on creation of the Institute, budgeted for in EPRD at 9.2 M€ inc. VAT;
- cancellation, in the sum of 1.5 M€ inc. VAT, of the balance of receivable income, established in 2002 at an initial amount of 22.5 M€.

2. Profit & loss account analysis

2.1. Income

Operating income (in M€)



2.1.1.

Operating income net of tax rose 10.1 M€ in comparison with 2003 (+ 4.3%).

It totalled 245.6 M€, including:

- 201.9 M€ for the MEDD subsidy, representing, after deduction of VAT, the entire allowance shown in LFI, up by 3.8 M€ in comparison with the preceding accounting period in which a cancellation was effected during the year;
- 2.7 M€ in respect of the agreement with the ministry of Defence, as against 2 M€ in 2003;
- 2 M€ for other subsidies, in particular from local authorities, the level of which stays much the same from year to year;
- 35.2 M€ of own resources from expert activities or co-financing of research programmes. The fall in such resources in relation to DM1, balanced by a reduction in expenditure of the same amount, is explained mostly by disruption, linked on the one hand to the reorganisation adjustment for the whole of 2004, and on the other hand to uncertainties resulting from the ending on 27 February 2005, of the option period fixed for operators seconded from CEA. However, this financing source rose by 3.7 M€ in comparison with

that of the previous year, consistent with the orientation adopted for diversification of resources;

■ 3.8 M€ sundry income, including 3.3 M€ from cancellation of accruals established in previous financial years, 0.1 M€ for industrial property royalties and 0.4 M€, sundry income on current management.

2.1.2.

Total **financial income** was 1.4 M€, as against 1 M€ in 2003. The DM1 provided for 0.4 M€. The strong increase in this income is explained by the imbalance between the regular payment of subsidies, which accounts for 85% of IRSN resources, and the concentration of payments at the end of the financial year, resulting in particular from the difficulties encountered in separating the activities of the Institute from those of CEA. The stated increase in income, 1 M€, has been posted completely to working capital consolidation.

2.1.3.

Extraordinary income, particularly high in 2003 (25.2 M€), came down to 6.7 M€ in 2004. 6.5 M€ relates to the portion of investment subsidies transferred to the Profit & loss account. The balance, 0.2 M€, corresponds to sundry current management transactions.

Total income for the 2004 financial year is therefore 253.8 M€, as against 261.7 M€ the previous year, the reduction resulting exclusively from extraordinary operations.

2.2. Charges

2.2.1.

Financial year operating charges fell by 15 M€ in comparison with 2003 (-5.8%), to 246 M€.

They are broken down as follows:

■ overall personnel charges, including employees seconded from CEA: 102.3 M€, against a DM1 forecast of 104.5 M€. This reduction of 2.2 M€ is explained by the deferring of recruitment plans and is to be reconciled with the non-realisation of 4 M€ of services sold;

■ taxes: 4.1 M€ as against 4.8 M€ in 2003, including 1.6 M€ tax on remuneration, and 1.3 M€ made up by a provision for contingencies as the method for determining business tax is not yet known. This valuation has been revised downwards and justifies the reduction in this item from one year to the next;

■ **depreciation** of 13.6 M€ is lower than the DM1 forecast taking into account the delay in certain operations, and a particularly **large reduction in comparison with the 2003 provision, due to the ageing of equipment whose replacement financing has not been ensured**.

The provision allowance represents a total of 2.9 M€ including 1 M€ for the dispute following the fuel pollution of the Le Vésinet site and 1.9 M€ for waste treatment costs;

■ purchases of goods and services was 121.9 M€, as against 125 M€ in 2003. This variation is not very significant. It simply reflects fluctuations in activities;

■ other charges were 1.2 M€, including 0.9 M€ for cancellation of accruals established in previous financial years.

2.2.2.

The **financial charge** and the charge paid for profits tax (fixed annual taxation) are cited as a reminder. The cancellation of the balance of accruals (10.7 M€ inc. VAT) made up by the MEDD subsidy for the 2002 financial year constitutes the main portion of **extraordinary charges** of 13.7 M€. For information, a comparable cancellation of 2.9 M€ was applied in 2003.

Total charges for 2004 were therefore 259.8 M€, as against 261.3 M€ for the preceding financial year.

2.3. Result and financing

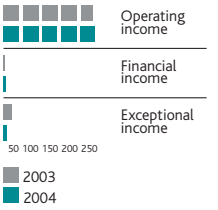
2.3.1.

The financial year resulted in a loss of 6 M€, as against a forecast profit of 1 M€ according to the revised decision of EPRD, and a profit of 0.4 M€ in 2003. The variation with the DM1 results from the taking over of an OPRI VAT adjustment of 2.2 M€ and especially the non-payment by MEDD of 9.2 M€ of the tax deficit. These extraordinary charges have been partly compensated by a higher level of financial income, a reduced depreciation charge for the financial year and the balance of 2003 accruals unused in 2004.

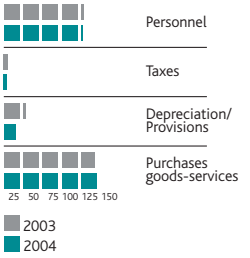
2.3.2.

The self-financing capacity of the Institute, which was 10 M€ in EPRD, has reduced, due to extraordinary operations, to 5.1 M€ as against 10.3 M€ in 2003. Consequently, financing of investments at 16 M€ is balanced by a large debit of 10.8 M€ on working

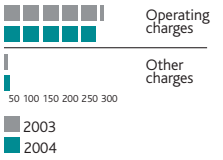
Details of income (in M€)



Operating charges (in M€)



Details of charges (in M€)



capital, whereas the debit was already 3.2 M€ in 2003. It should be noted that the ex-OPRI investments of 1.5 M€, and loans to personnel of 1.2 M€, which EPRD envisaged financing by debit from working capital, were not entirely realised and will be deferred to the next financial year for an amount of 0.73 M€. In the same spirit, certain investments whose financing appeared in EPRD 2004 and for which a delay in realisation did not enable the expenditure to be made in its entirety, will be deferred to the next financial year and will therefore be financed in 2005 by a debit on working capital, excessive in relation to 2004.

2.3.3.

Despite the fact that IRSN has maintained, apart from extraordinary items, the equilibrium forecast by EPRD, **the financial year shows a new debit from working capital of 10.8 M€**.

3. Balance sheet analysis

3.1. Liabilities

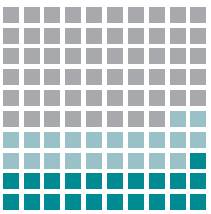
3.1.1.

After taking into account the loss recorded in 2004, **invested capital** comprises a net balance of 34.6 M€, 12.3 M€ of investment subsidies and 12.4 M€ of provisions, namely a total of 59.3 M€, as against 67.9 M€ at the end of the previous financial year.

3.1.2.

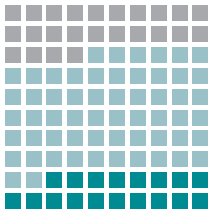
Short-term debts of 62.6 M€, as against 100.7 M€ the previous year, comprise 16.6 M€ tax and social debts, 2.4 M€ advances on pending orders, 40.6 M€ debts to suppliers and 3 M€ sundry debts. The "suppliers" item has returned to an acceptable level in comparison with 2003, which finished with accruals of more than 70 M€. IRSN indeed achieved an honourable level in the period taken to pay suppliers in 2004 and has progressively regularised its mode of operation with CEA, allowing a more natural pace of payment. This situation will reduce the cash reserves of the Institute, the weakness of which now requires early payment of the subsidy or recourse to external financing (bank overdraft).

Invested capital in M€



- Net balance **34.6 (58%)**
- Investment subsidies **12.3 (21%)**
- Provisions **12.4 (21%)**

Analysis of short-term debts in M€



- Tax and social debts **16.6 (27%)**
- Debts to suppliers **40.6 (64%)**
- Sundry debts **5.4 (9%)**

3.2. Assets

3.2.1.

Tied-up assets at 50.1 M€, as against 47.9 M€ the previous year, are itemised as a gross amount of 88.8 M€ and depreciation of 39.7 M€.

This weak variation in tied-up assets represents ageing equipment of the Institute and weakness in the current level of investments. As a reminder, the research reactors, which remain the property of CEA in accordance with the Institute incorporation decree, therefore do not appear in the balance sheet, but are directly taken by the Institute as operating charges.

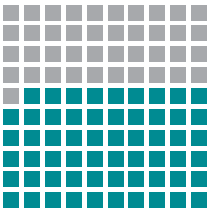
3.2.2.

Current assets are 71.8 M€, as against 120.7 M€ the previous financial year, and are made up as to 13.5 M€ cash, 9.8 M€ advances on orders; client receivables are stable at 29.8 M€ and finally the balance of 18.7 M€ being sundry receivables, mostly VAT. There was a significant fall in cash reserves from 44.1 M€ at the end of 2003 to 13.5 M€ at the end of 2004 *(see opposite)*. This is explained, apart from the financial year deficit, by the progressive regularisation of the relationship with CEA, of whom IRSN is one of its major customers. The 2004 financial year therefore finished with working capital reduced to approximately 9 M€ as against 20 M€ on 1 January.

Current assets in M€

Cash **13.5 (19%)**
Advances **9.8 (13,5%)**
Receivables **29.8 (41,5%)**
Sundry receivables **18.7 (26%)**

Details of assets in M€



Fixed assets **50.1 (41%)**
Current assets **71.8 (59%)**

Conclusion

Apart from extraordinary items, 2004 was in strict conformity with the commitments undertaken by IRSN before the Board of Directors in observing fundamental equilibrium in terms of results and effects on working capital.

The evolution of the balance sheet is contrasting **while the head of the balance sheet has worsened due to the strong dip in working capital, there is nonetheless a marked improvement at the end of the balance sheet**, with the reduction in time taken to pay suppliers, the result of progressive standardisation of the operation of the Institute.

Extraordinary items have been partially compensated by the improvement in financial income and a lower than forecast depreciation allowance, **but the debit from working capital weakens the Institute's capitalisation, and discussions are in progress with the authorities in order to determine the procedure to be implemented for reinforcing the financial standing of the Institute on a long-term basis.**

The change of tax system, with the application of a prorata VAT regime on 1 January 2005, will eliminate as from that date, all other things being equal, the budget deficit resulting from the tax system set up during the creation of the Institute.

Profit & loss account

Income

Income (excluding tax)	2004	2003	2002 (10 months)
Operating income	**245,598,908.63**	**235,482,280.96**	**213,374,879.80**
Net total turnover	35,164,526.17	35,590,211.96	34,611,537.36
Operating subsidies	206,681,399.76	198,098,871.94	178,524,198.90
Write-backs on depreciation and provisions	80,417.64	20,504.32	
Transfers of charges	36,839.37	25,349.47	130,164.47
Other income	3,635,725.69	1,747,343.27	108,979.07
Financial income	**1,446,579.93**	**1,018,763.58**	**1,203,877.45**
Other interest and equivalent income	8,710.77	0.00	31.94
Financial write-backs on provisions and transfer of charges			
Positive exchange differences	19,953.00	38,568.13	29,626.39
Net income on sale of negotiable investment securities	1,417,916.16	980,195.45	1,174,219.12
Extraordinary income	**6,721,564.71**	**25,211,622.50**	**5,446.82**
Investment subsidies transferred to financial year profit & loss account	6,554,482.13	18,742,326.22	5,446.82
Management operations	167,082.58	6,469,296.28	0.00
TOTAL INCOME	253,767,053.27	261,712,667.04	214,584,204.07
Debit balance = loss	**6,045,350.60**		
OVERALL TOTAL	259,812,403.87	261,712,667.04	214,584,204.07

In euros (€)

Charges

Charges **(excluding tax)**	**2004**	**2003**	**2002 (10 months)**
Operating charges	**245,997,066.23**	**261,015,076.71**	**200,437,180.89**
Third-party consumption for financial year	158,454,902.47	182,831,266.23	171,834,080.29
Tax, rates and equivalent payments	2,776,145.74	1,381,124.89	3,454,953.91
Personnel charges	65,805,418.98	45,440,248.53	25,120,486.08
Depreciation and provision allowances	17,771,491.98	28,404,363.46	0.00
Other charges	1,189,107.06	2,958,073.60	27,660.61
Financial charges	**33,456.39**	**21,155.29**	**46,546.63**
Interest and equivalent charges	9,805.48	1,881.88	27,264.98
Negative exchange differences	13,650.91	19,199.31	19,281.65
Net charges on sale of negotiable investment securities	10,000.00	74.10	
Extraordinary charges	**13,763,131.25**	**260,535.00**	**3,822.36**
Management operations	13,763,131.25	35.00	3,822.36
Capital operations		500.00	
Depreciation and provision allowances		260,000.00	
Tax on profit	**18,750.00**	**0.00**	**0.00**
Fixed annual taxation	18,750.00		
TOTAL CHARGES	259,812,403.87	261,296,767.00	200,487,549.88
Credit balance = profit		**415,900.04**	**14,096,654.19**
OVERALL TOTAL	259,812,403.87	261,712,667.04	214,584,204.07

In euros (€)

N.B.: The "personnel charges" item varies with the arrival of CEA employees opting for IRSN. This increase is compensated for by a decrease in "third-party consumption".

Balance sheet

Assets

	2004			2003	2002
	Gross	Depreciation and provisions	Net	Net	Net
Intangible fixed assets	7,217,293.11	5,475,146.01	1,742,147.10	1,845,335.08	1,470,315.23
Tangible fixed assets	80,366,590.83	33,176,186.78	47,190,404.05	45,435,018.48	13,251,907.41
Financial fixed assets	1,196,078.27		1,196,078.27	635,212.81	- 7,092.29
TIED-UP ASSETS	**88,779,962.21**	**38,651,332.79**	**50,128,629.42**	**47,915,566.37**	**14,715,130.35**
Stock and work-in-progress				34,943.08	
Advances and deposits paid	9,824,069.06		9,824,069.06	7,758,726.96	27,572,585.76
Operating receivables					
Client receivables	*29,970,112.77*	*143,207.83*	*29,826,904.94*	*28,178,006.45*	*35,551,849.76*
Other receivables	*18,533,312.85*		*18,533,312.85*	*79,899,947.86*	*54,839,848.14*
	48,503,425.62	**143,207.83**	**48,360,217.79**	**108,077,954.31**	**90,391,697.90**
Sundry receivables	1,069.28		1,069.28	1,069.28	
Negotiable investment securities	10,938,217.44		10,938,217.44	33,680,806.20	47,177,335.17
Liquid assets	2,565,411.71		2,565,411.71	10,370,525.94	348,995.30
Prepaid charges	72,469.00		72,469.00	241,517.33	
CURRENT ASSETS	**71,904,662.11**	**143,207.83**	**71,761,454.28**	**160,165,543.10**	**165,490,614.13**
OVERALL TOTAL	**160,684,624.32**	**38,794,540.62**	**121,890,083.70**	**208,081,109.47**	**180,205,744.48**

In euros (€)

N.B.: The 2002 balance sheet does not incorporate transfer of accounts from OPRI and IPSN.

Liabilities

	2004	2003	2002
Shareholders' equity			
Allocation	8,782,859.59	8,782,859.59	
Reserves	31,844,160.61	31,428,260.57	
Financial year result (profit or loss)	- 6,045,350.60	415,900.04	14,096,654.19
Net worth	34,581,669.60	40,627,020.20	14,096 654.19
Investment subsidies	12,297,019.86	18,851,501.99	
TOTAL I	**46,878,689.46**	**59,478,522.19**	**14,096,654.19**
Contingent liability provision			
Risk provision	1,260,000.00	260,000.00	
Taxation provision	1,300,000.00		
Provision for charges	9,882,369.57	8,150,000.00	
TOTAL II	**12,442,369.57**	**8,410,000.00**	**0.00**
Debts			
Financial debts	312.42	136,537.10	- 248,851.80
Advances and deposits received	2,426,504.71	2,426,504.71	2,426,504.71
Supplier debts	33,998,794.86	79,002,887.85	84,339,390.84
Tax and social security debts	16,649,279.72	11,409,966.28	54,797,484.67
Other		39,514,301.48	
Debts on fixed assets and related accounts	6,583,920.72	5,386,816.45	6,767,579.81
Other debts	2,792,448.24	2,197,809.41	17,909,218.06
Regularisation accounts			
Deferred income	117,764.00	117,764.00	117,764.00
TOTAL III	**62,569,024.67**	**140,192,587.28**	**166,109,090.29**
OVERALL TOTAL (I+II+III)	**121,890,083.70**	**208,081,109.47**	**180,205,744.48**

In euros (€)

N.B.: The 2002 balance sheet does not incorporate transfer of accounts from OPRI and IPSN.

Intermediate management balances

	31/12/2004	31/12/2003	Variation	%
Joint financing and own receipts	35,164,526.17	35,590,211.96	- 425,685.79	-1.20 %
Operating subsidies	206,681,399.76	198,098,871.94	8,582,527.82	4.33 %
FINANCIAL YEAR PRODUCTION	**241,845,925.93**	**233,689,083.90**	**8,156,842.03**	**3.49 %**
Third-party consumption	158,454,902.47	182,831,266.23	- 24,376,363.76	-1.33 %
ADDED VALUE	**83,391,023.46**	**50,857,817.67**	**32,533,205.79**	**63.97 %**
Taxes and rates	2,776,145.74	1,381,124.89	1,395,020.85	101.01 %
Personnel charges	65,805,418.98	45,440,248.53	20,365,170.45	44.82 %
GROSS OPERATING SURPLUS	**14,809,458.74**	**4,036,444.25**	**10,773,014.49**	**266.89 %**
Write-backs, transfers of charges	117,257.01	45,853.79	71,403.22	15.72 %
Other income	3,635,725.69	1,747,343.27	1,888,382.42	10.07 %
Depreciation and provision allowances	17,771,491.98	28,404,363.46	- 10,632,871.48	- 37.43 %
Write-backs on equipment subsidies	6,554,482.06	2,958,073.60	-1,768,966.54	- 59.80 %
OPERATING CHARGES	**6,156,324.53**	**- 6,790,469.53**	**12,946,794.06**	**-190.66 %**
Financial income	1,446,579.39	21,155.29	12,301.10	5.15 %
CURRENT PRE-TAX RESULT	**7,569,448.07**	**- 5,792,861.24**	**13,362,309.31**	**- 230.67 %**
Extraordinary income	167,082.58	6,469,296.28	-6,302,213.70	-97.42 %
Extraordinary charges	13,763,131.25	260,535.00	13,502,596.25	5,182.64 %
EXTRAORDINARY RESULT	**-13,596,048.67**	**6,208,761.28**	**-19,804,809.95**	**- 318.98 %**
Tax on profit	18,750.00		18,750.00	-
FINANCIAL YEAR RESULT	**- 6,045,350.60**	**415,900.04**	**- 6,461,250.64**	**-1,553.56 %**

In euros (€)

N.B.: The subsidy paid by MEDD has been withdrawn on financial year production.

Self-financing capacity

Calculation from GOS ***Subtraction method***	2004	2003	Variation
Gross operating surplus	14,809,458.74	4,030,431.43	10,779,027.31
+ transfer of operating charges	36,839.37	25,349.47	11,489.90
+ other operating income	3,635,725.69	1,747,343.27	1,888,382.42
- other operating charges	1,189,107.06	2,952,060.78	-1,762,953.72
+ financial income [a]	1,446,579.93	1,018,763.58	427,816.35
± proportion of result on joint operation	0.00	0.00	0.00
- financial charges [b]	33,456.39	21,155.29	12,301.10
+ extraordinary income [c]	167,082.58	6,469,296.28	-6,302,213.70
- extraordinary charges [d]	13,763,131.25	535.00	13,762,596.25
- tax on profit (if appropriate)	18,750.00	0.00	18,750.00
SFC	**5,091,241.61**	**10,317,432.96**	**-5,226,191.35**

In euros (€)

(a) excluding write backs on provisions
(b) excluding allowances for depreciation and financial provisions
(c) excluding - income from fixed asset sales
- proportion of investment subsidies related to financial year result
- depreciation neutralising (account 776)
- write-backs on extraordinary provisions
(d) excluding - book value of fixed assets sold
- allowances for depreciation and extraordinary provisions

Calculation from net result ***Addition method***	2004	2003	Variation
Financial year net result	-6,045,350.60	415,900.04	-6,461,250.64
+ depreciation and provision allowances	17,771,491.98	28,664,363.46	-10,892,871.48
- write-backs on provisions	80,417.64	20,504.32	59,913.32
- net result on fixed asset sales	0.00	0.00	0.00
- proportion of investment subsidies transferred to profit and loss account	6,554,482.13	18,742,326.22	-12,187,844.09
- income from neutralising	0.00	0.00	0.00
SFC	**5,091,241.61**	**10,317,432.96**	**-5,226,191.35**

In euros (€)

Variation in liquid funds

	2003	2004	Variation
CONTRIBUTIONS TO WORKING CAPITAL	-	-	-
WITHDRAWALS FROM WORKING CAPITAL	**- 3,211,987.17**	**- 10,838,704.97**	**- 7,626,717.80**
FLUCTUATIONS OVER PREVIOUS FINANCIAL YEAR	**24,283,067.65**	-	**- 24,283,067.65**
+ Variation in operational current assets	- 1,755,813.10	- 57,807,437.60	- 56,051,624.50
- Variation in operational debts	- 9,209,719.90	- 79,279,081.03	- 70,069,361.13
= Variation in operational working capital requirement	7,453,906.80	21,471,643.43	14,017,736.63
+ Variation in other debit balances			
- Variation in other credit balances	- 17,092,172.01	1,762,645.41	18,854,817.42
= Variation in non-operational working capital requirement	17,092,172.01	- 1,762,645.41	- 18,854,817.42
(1) + (2) = variation in working capital requirement or net redemption of working capital	24,546,078.81	19,708,998.02	- 4,837,080.79
VARIATION IN LIQUID FUNDS	**- 3,474,998.33**	**- 30,547,702.99**	**- 27,072,704.66**

In euros (€)

Forecast and completion reconciliation

Profit & loss account	2004 Budget	2004 Actual	Variation Actual/Budget
INCOME			
Sale of services	41,147,000.00	35,164,526.17	- 5,982,473.83
Public subsidies (c/74)	204,627,000.00	206,681,399.76	2,054,399.76
Other operating income	12,948,000.00	5,286,227.57	- 7,661,772.43
Internal transactions	6,490,000.00	6,634,899.77	144,899.77
TOTAL INCOME	**265,212,000.00**	**253,767,053.27**	**-11,444,946.73**
CHARGES			
Personnel charges	104,544,000.00	65,805,418.98	-38,738,581.02
Other operating charges	144,147,000.00	176,235,492.91	32,088,492.91
Internal transactions	15,600,000.00	17,771,491.98	2,171,491.98
TOTAL CHARGES	**264,291,000.00**	**259,812,403.87**	**- 4,478,596.13**
RESULT (PROFIT)	921,000.00		- 921,000.00
RESULT (LOSS)		6,045,350.60	6,045,350.60
TOTAL PROFIT & LOSS ACCOUNT BALANCE	**265,212,000.00**	**259,812,403.87**	**- 5,399,596.13**
Transfer of result to SFC table			
RESULT	**921,000.00**	**- 6,045,350.60**	**- 6,966,350.60**
Depreciation provision allowances	15,600,000.00	17,771,491.98	2,171,491.98
Proportion of subsidies transferred to result		- 6,554,482.13	- 6,554,482.13
Write-backs on depreciation and provisions	- 6,490,000.00	- 80,417.64	6,409,582.36
SELF-FINANCING CAPACITY	**10,031,000.00**	**5,091,241.61**	**- 4,939,758.39**
Summary financing table			
SELF-FINANCING CAPACITY	**10,031,000.00**	**5,091,241.61**	**- 4,939,758.39**
Tangible and intangible fixed asset acquisitions	- 17,165,000.00	- 15,261,954.13	1,903,045.87
Financial fixed assets	- 1,200,000.00	- 563,672.28	636,327.72
Financial debt repayment	- 132,000.00	- 136,224.68	- 4,224.68
TOTAL APPROPRIATIONS	**- 18,497,000.00**	**- 15,961,851.09**	**2,535,148.91**
Public investment subsidies			-
Other resources (excluding internal transactions)		31,904.51	31,904.51
TOTAL RESOURCES	**-**	**31,904.51**	**31,904.51**
CONTRIBUTIONS TO WORKING CAPITAL	**- 8,466,000.00**	**- 10,838,704.97**	**- 2,372,704.97**

In euros (€)

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