Orano transforms nuclear materials so that they can be used to support the development of society, first and foremost in the field of energy.

The group offers products and services with high added value throughout the entire nuclear fuel cycle, from raw materials to waste treatment. Its activities, from mining to dismantling, as well as in conversion, enrichment, recycling, logistics and engineering, contribute to the production of low carbon electricity.

Orano and its 16,000 employees bring to bear their expertise and their mastery of cutting-edge technology, as well as their permanent search for innovation and unwavering dedication to safety, to serve their customers in France and abroad.

Orano, giving nuclear its full value.

Let's talk more about it; join us on

orano
Giving nuclear energy its full value

Business corporation with a Board Directors. Capital of 118,868,750 euros
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Energy is our future. Don't waste it!

Cementation in waste management

Comprehensive range of solutions

Waste management

orano
Giving nuclear energy its full value

orano

As our common industrial mission, effective management of nuclear waste is a complex combination of meeting requirements for safety, conformity, sustainability, modularity, acceptance alongside constraints such as volumes, toxicity levels, costs, risks, and maintenance requirements. Helping nuclear operators achieve equilibrium in their waste management activities has been Orano's worldwide mission for decades, whether this is for our clients or for our own nuclear facilities.

We share your objectives and visions for managing nuclear waste and our experience and solutions are yours : strategy, engineering, project management, characterisation, R&D, conditioning, treatment, transport, storage, we also have significant experience in interacting with safety authorities and disposal agencies. Orano delivers a comprehensive range of solutions tailor-made to your requirements and helping you to achieve your ambitions.

With a proven track record, simple implementation and versatility, time and experience have proved the benefits of cementation for low and intermediate-level waste confinement. Owing to the wide variety of physical states waste can have, including bulk waste, powders and sludge, cementation is the easiest and most efficient immobilisation process for all types of waste. Among the many factors for its success, the use of an appropriate mixing technology is key in achieving a heterogeneous cementation in the case of bulky waste grouting, or homogenous cementation, which includes the intermixing of the powder or sludge with the cementitious material.

Nuclear waste management also needs to accommodate a wide range of chemical and radiological variables. Expertise in all kinds of nuclear waste is essential, and that is exactly what Orano commits to deliver from its wide-ranging experience across the nuclear fuel cycle.

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Orano has cutting-edge expertise in the management of all types of radioactive waste, from low, medium to high-level radioactivity, solid or liquid, conventional or exotic, with a predefined or pending disposal route.
This ensures that Orano's customers benefit from end-to-end management of their waste management issues, and the development of technical and technological solutions that work within their constraints.

1 Waste Management Strategy

2 Waste Characterization

3 Waste Conditioning Solutions

4 Engineering & Project Management

5 Waste Management Operations

6 Waste Packaging Services

7 Waste Packages

8 Waste Transport to Disposal

1 Waste Management Strategy

Strategic approach for best global solutions in waste management

Managing waste routes in a sustainable, innovative and cost-effective manner to provide peace of mind to our customers and communities

Orano offers a unique integrated range of management solutions for all type of wastes, from technology bricks to turnkey projects. Orano's Dismantling and Waste Management Division was established with the aim of providing an integrated view on the entirety of waste types to be treated as part of Orano's multi-site projects.

Nuclear operators can therefore benefit from a catalogue of experience that has been developed over more than 40 years of waste management activities.

We put waste in its place!

Our teams will accompany you throughout the entire waste lifecycle in order to:

- Reduce costs
- Enable space from earlier site clearance to be reused
- Foster compactness, standardization, modularity and incremental investments
- Provide solutions for simplified design & implementation of scarce storage and disposal facilities
- Minimize the environmental footprint through volume and toxicity reduction
- Increase stakeholder acceptance

80% waste
sent to the French Ground Disposal facility conditioned by Orano

~ 300,000+ m^3
VLLW-SL-LILW conditioned, transported by Orano and disposed of in France

40 Nuclear sites
benefiting from Orano waste solutions

Support to decisions at every stage to provide solutions from scenario to risk management through safety analysis, licensing and strategic planning.

Benefiting from 40 years of nuclear operator experience, we aim at:

MINIMISE
costs, volumes, toxicity and incremental investments

INCREASE
safety, modularity, sustainability and acceptance

Each year, in France, for disposal in operation, Orano is responsible for conditioning more than:

Did you know

70% LLW | **30%** ILW | **10 000m^3** of Waste

2 Waste Characterization

Upstream and downstream waste evaluation

Radiological Characterization is critical for optimized waste management from retrieval through to conditioning and disposal

Characterisation is a crucial step in waste management as it provides the information used for the appropriate definition of waste routes, and optimisation of routes for sustainable landfill disposal and environmental protection.

Waste characterisation is therefore the first phase of a rigorously-defined waste management strategy. Orano is a pioneer in the development of innovative waste characterisation tools to support this essential process.

MANUELA ™

COLLECTE
The next step towards Waste 4.0 management

The diversity and volume of waste on any given site raises the issue of how waste packages are physically managed.
Existing tools such as Notebook and Excel do not simplify the work of operators and complicate access to data. The COLLECTE tool digitalises the entire process and allows for the planning of operations, co-activity management, a reduction in entry-copy errors and easy location of packages in real time

Orano offers its customers a wide range of characterisation processes and technologies to ensure appropriate management and performance of activities in the field for the benefit of nuclear safety and sustainability.

MANUELA ™

Dorica™

Wide range of services and tools

- Topographical mapping: 3D scanner
- Radiological characterization MANUELA ™
  - realtime 3D mapping
  - quick & efficient time saver
- Acess to restricted and high radiation areas using robotics solutions
  - RIANA™ multi-purpose robot
  - Dorica™ easy-to-use drone
- Means of investigation; from plan definition to sampling operations

Dorica™

3

Waste conditioning solutions

Waste conditioning using hydraulic binders

We design materials that safely and durably stabilize your waste into a solid wasteform.

Our expertise:

Tailored cement formulations for your wastes

The chemical interactions between the waste and the cement matrix are carefully studied by Orano's R&D teams in order to provide comprehensive solutions by developing cement formulations which are adapted to wastes characteristics.

The aim of the studies is to obtain cement wasteforms that meet the waste acceptance criteria, the final product being thus in perfect adequacy with the disposal requirements. For over 30 years Orano has been developing cement formulations adapted to the physical and chemical specificities of the wastes accounting for constraints imposed by waste characteristics. The overall approach includes the definition of the appropriate cement composition at laboratory scale, engineering design, equipment manufacturing, testing and commissioning of the cementation facilities.

Our mission is to find conditioning solutions for a broad chemical and radiological waste spectrum and tailor the cement matrix so you can maximize waste loading by minimizing the overall volume of waste packages.

Some of our developments

- Legacy waste (sludge, magnesium, powders, ion exchange resins)
- Orphan waste (oils, mercury, asbestos)
- Plutonium contaminated waste
- Reactive metals (sodium, magnesium)
- Acid wastes (direct grouting of H_2SO_4, HNO_3 without prior neutralization)

Main research themes

- Novel cementing binders for nuclear wastes: alkali activated slags, geopolymers, magnesium phosphate and sulfoaluminate cements
- Durability prediction and transport properties for cemented wasteforms
- Pretreatment before cementation in order to maximize the waste loading in cemented packages

Case study: Mercury treatment and conditioning

Mercury is a highly toxic volatile metal and one of the most difficult contaminants to stabilise within hazardous wastes. Mercury is easily leached and readily forms organic methylmercury. Orano has developed a decontamination and conditioning method for mercury in its wet phase so that the mercury can be separated from the bulk waste and disposed of in a safe manner, whilst the bulk waste can be treated after decontamination as mercury-free waste.

The wet phase treatment is carried out in an alkaline solution, and results in the precipitation of insoluble cinnabar. Effluents and precipitates can be directly grouted if needed. The process offers various advantages, such as no volatilisation issues, a passive process at ambient temperature (low energy) and can be applied to various types of waste (solid and aqueous).

A dry process for metal mercury is industrially available and has already been used in Orano's SICN facility. An up-scaled version for larger volumes of metal (> 200 litres) is under development.

Mercury precipitation to cinnabar

Cinnabar filtration in the treatment solution

Filtered cinnabar

Cinnabar grouting

3 Waste conditioning solutions

R&D Project management: an integrated approach for legacy waste conditionning

Delivering state-of-the-art expertise fed by complex integrated R&D waste management projects to meet client needs with rigorous care on regulations and industrial constraints
.

La Hague's waste retrievals and waste packages production is addressed throughout **a global integrated approach:**

- From laboratory studies to final process and package qualification (TRL 1 to 8)
- Leveraging operational Lessons Learned at plants such as La Hague and Melox
- Comprehensive programmes to address R&D, engineering and operational requirements with tailor-made solutions
- Fundamental and comprehensive studies
- Cold and hot laboratories available, lab scale and full scale pilots facilities
- Qualification of improvement on various scale inactive pilots, including product formulation and final product quality

Key metrics

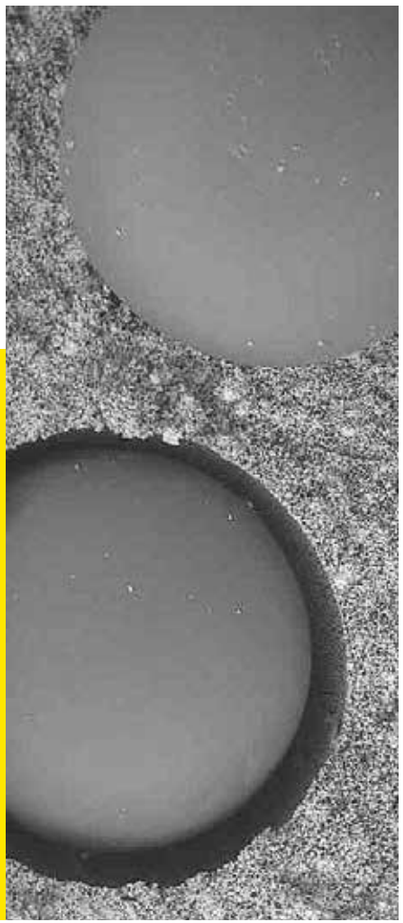
18 R&D technical lead managers

4 Cross-linked competence centers

200 R&D programs through partnerships (CEA, IRSN...) and suppliers

Main expertise

- Radiolysis - available tool for gas production evaluation
- Long term behavior (corrosion, leaching, stability)
- Hulls characterization
- Longevity case studies for geological disposal
- Conditioning process such as cementation
- Supporting our customers and their own Safety Authorities for waste package acceptation

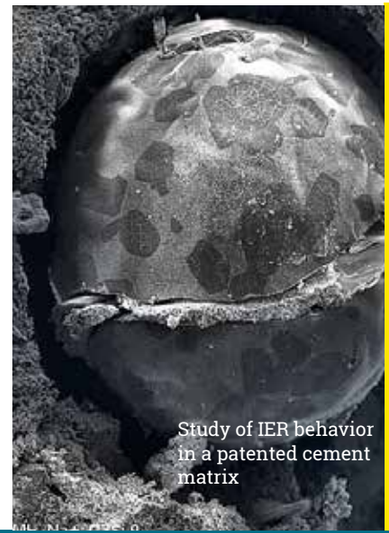


IER embedded in a cement matrix

Case study – legacy wastes : La Hague's HAO resin sludge

Some of our developments

- Cemented hulls and end-pieces
- ILW packages containing organic wastes
- Radiolysis studies for foreign costumers (Fukushima)
- New process and package developed for Legacy waste exchange resins



Study of IER behavior in a patented cement matrix

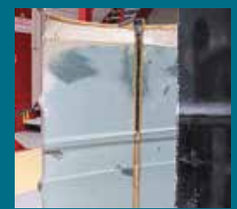
From comprehension studies ...

Ion exchange resins (IERs) are widely used in the nuclear industry to decontaminate radioactive effluents. Spent products have to be conditioned. However, the solidified waste form can exhibit strong expansion, possibly leading to cracking, if the appropriate binder is not used.
Orano successfully conditions IER in cemented packages at ACR facility in La Hague. The ACR facility has been in service since 2001, with more than 1000 packages sent to disposal.

...to industrialization of new solutions

HAO Silo in La Hague contains IER mixed with highly active dissolution and shearing fines. The cement formulation developed enhances waste loading in the cemented package*.

- The cemented formulation was developed in compliance with production, storage, transportation and final disposal constraints
- The Waste package Specification was prepared (the package is to be sent to geological disposal).
- Special challenges linked to the high activity of the waste were addressed (extensive radiolysis program)



4 Engineering and Project Management

Definition and formulation of containment matrix

At HRB – Beaumont Research Hall, we develop and qualify processes or equipment for the nuclear industry using inactive surrogates on full scale mockups to obtain quick answers in a cheaper way.

Presentation

Certifications ISO: 14001

Utilities **Electricity 800 kVA compressed air, chilled water, nitrogen**

3000 m² **4 pits, 1 pool (100m²), 7m depth) 3 bridges cranes, 1 workshop**

Our lab at a glance

- **Since 2014 a new dedicated cementation laboratory has been online** with the last standard and apparatus used in cementation.
- Limited and full scale industrial process.
- Analytical equipment as spectro photometer, gas chromatography, potentiometric.
- Multi-skills integrated team used to deal with cementation topics from theory to on site tests.

Capabilities

- Development and industrial qualification for cement recipe from lab scale to industrial process, using non-active surrogates.
- Capability to compare and adjust the non-active surrogate with the real waste in active laboratory.
- Manage project from feasibility to final qualification of a cement recipe with an industrial approach.
- Capability to manage full projects from waste characterization, chemical design to full qualification of the process using all Orano Projects engineering support.
- Bring expertise and support to operation during active tests or facility operation.

Orano's most significant projects

- La Hague site HAO facility – D&Q of cement recipe from lab scale to industrial process for ILW resins and fines coming from La Hague D&D activities. (under construction on LH site)
- La Hague NUGG waste – various D&Q cement recipe from lab scale to industrial process to encapsulate graphite, magnesium and various other waste, mixed or not. Reactive metals issues for magnesium metal.
- Taishan resin encapsulation – D&Q of various cement recipe using customer's standard and binding materials.
- Sludge encapsulation feasibility at lab scale for Fukushima, SOGIN, Hanford ..
- Developed and qualified processes and equipment for international projects (Rokkasho Mura plant in Japan, MOX plant in USA, ...)
- NPP wastes cementation by continuous flow mixer: NPP Bohunice, Slovakia; NPP Trillo, Spain; NPP Ignalina, Lithuania; NPP Kola, Russia; NPP Taishan, China (under construction), as well as for the Hahn Meitner Institut in Germany

In-drum mixer technology

Safe and simple process with no rinsing effluent generation and simple mechanical conception. It is well suited for homogeneous Cementation (liquid effluent or small-particle waste). Adapted for package volumes from 100L to more than 1 m³.

Operational facilities : NPP Vandellos, Spain

Under construction : HAO Facility, La Hague, France

Batch reactor system (cone mixer)

This innovative mixing process for nuclear waste conditioning presents numerous advantages. This high energy mixing system, proven in the civil engineering field, minimizes retention due to its conic shape and its ceramic coating. It is available in different tank volumes (from 100 L to 3m³).

We follow your waste from lab scale to industrialization

Did you know

HRB was created to support the design, building, testing and commissioning of the UP3 La Hague plant.

Ever since, HRB has developed strong expertise in the nuclear fuel cycle and in large scale projects. HRB represents 90 people, 8 senior scientists, over 100 suppliers in support.

4 Engineering and Project Management

The path to containment reliability and sustainability

Orano CIME provides and develops new processes of treatment, from tests in laboratories to the deployment of industrial pilots.

Benefits

Active testing within Orano laboratory, equipped with advanced and sophisticated materials evaluation facilities, provides testing and consultancy services in the areas of materials engineering*.

Some of our current studies: Cementation of sludge, exchange resins, mercury sulfide, formulation of sulfoaluminate cements, alkali activated slag, ordinary cement...

CIME also represents: 40 000 samples analyzed per year, 3 pilot test workshops (> 1000m²) and 30-year experience in extractive metallurgy.

*4 ICP-OES, 3 ICP-MS, AA Flame and Oven, FX , mobile FX, DRX, MEB with ion probe, Chromatographies : HPLi, HPLC, CPG-MS, CPG, UV automated, 3 gamma spectrometry chains, 8 alpha spectrometers, Proportional meters(α, β), liquid Scintillation(14C, tritium ...), Solid Scintillation(émanométrie, dosage 226Ra), UV, IRTF, Potentiometers, Specific analyzers, Carbon / sulfur analyzer (liquid / solid), Preparation systems: microwaves, melters, hot plates, ovens, incubators, centrifuges ....

Our LAB at a glance

ICPE — **Authorization to manage radioactive materials 10t Ur / 600 kg thorium**

Accreditation — **COFRAC laboratory**

Certification — **ISO 9001, 14001 OHSES 18001**

Capabilities

- R&D studies, technical developments and innovation (new processes);
- Support to projects and design of pilot units;
- Onsite assistance to operators during plant operations;
- Participation in the plant's start-up and industrial adaptations;
- Environmental analyses, new analytical techniques;
- Cementation lab and studies on innovative materials for waste confinement.

sulfoaluminate cements

5 Waste Management Operations

The path to containment reliability and sustainability

A turnkey solution of waste cementation from onsite management 'til removal, Triade is a proven global service to a large scope nuclear waste.

Pay and forget: we treat your waste

Suited for customer needs

- LLW & ILW, asbestos, electronic and electrical equipment waste management

Proven technologies

- Cutting solutions (plasma, saw, etc.)
- Sorting solutions
- Conditioning solutions (cementation, waste packages to disposal, etc.)

Innovative processes

- Mercury treatment
- Nochar (polymerization of organic wastes)
- Ask us for more!

Multi-agreements

- We work closely with stakeholders and regulators

2,600m³ of waste treated per year

300 T waste shipped per year

CDS

ANDRA CIRES - CSA

socodei GROUPE EDF

Complete and integrated solutions

Option study + scenario → Waste acceptance file realisation → Waste management → Treatment → Elimination → Waste shipment

WE DELIVER PROVEN PROCESSES

Did you know

We provide global solutions for waste From onsite management 'til removal

ICPE

Your waste can be treated in our dedicated waste treatment facility

30+

We have 30+ years of experience of serving the nuclear industry. We have a mastered industrial management process for every stage of the waste lifecycle: definition of a suitable cementation matrix, laboratory testing (validation of regulatory requirements), industrial process

Large spectrum of waste

Radiological waste (VL/LLW-SL)
Chemical waste, including special waste type such as mineral acids, base, oxidants, free organic liquids, organic liquids solidified by polymerization.

Key references

VL Waste

- **Sludge NEPTUNE - FBC - Romans-sur-isère**
  Capacity to deal with a large scope of chemical toxicities
- **Electrolytic tray – CEA – Fontenay-aux-Roses**
  Mix of corrosive chemical substances, oxidant, with viscosity constraints and alpha spectrum
- **Effluent with lead – CEA - GRENOBLE**
  Mix of corrosive chemical substances, radioactive, carcinogenic and viscous

LL-SL Waste – 4C certification

- **EDF Boron Concentrates**
  Development of a specific formulation for boron waste treatment
- **Sludge CEA GRENOBLE and CEA VALDUC**
  Alpha spectrum and homogeneity constraints
- **Radioactive organic Liquids (LOR) - CEA Fontenay-aux-Roses and Cadarache (out of 4C certification)**
  Cementation of effluents and organic sludge

cea

EDF

orano

6 Waste Packaging Services

Operations for tight containment

At La Hague, the AD2 facility has developed processes and technologies for robust and adapted confining packages. Ready to address customers' needs, proven solutions have already been certified by French ASN for our own activities.

The AD2 facility at La Hague develops and produces packages for all nuclear waste excluding HLLW. With optimized solutions, the AD2's operations aim to addresses the requirements of safety authorities and national waste agencies, **while limiting waste volume to the minimum.**

The different waste forms are confined in suitable packages further to an accurate characterisation process, which will allocate the most appropriate route and containment system and optimise the waste management process.

Key references

- Customized conditioning routes adapted to each kind of waste: cementation and compacting
- Specified and differentiated routes contributes to volume optimization for storage

Waste composition	Final treatment	Packages name
Technological by products (tools worker' equipement parts, liquid...)	Fiber-cement*	CBF-C2(Fiber-cement*) CBF-K (mortar + cement)
	Fiber-cement*	CBF-C1(Fiber-cement*) CO(compacted + mortar)
Exchange resins	Fiber-cement*	CBF-C1(Fiber-cement*)

Key metrics

60,000 Upstream waste characterization

180 Samples per year at our lab to guarantee our packages' integrity

90 Samples per year at our lab to guarantee raw material's conformity

95,000 Barrels of different purpose and formulations produced: **40,000** compacted with mortar, **35,000** compacted cement packages, **12,500 Zone 4 cement packages and 6,080 mortared blocks**

7

Waste Packages

Robust and proven solutions

Orano provides specific containers for low and intermediate radioactivity, certified by French and other nuclear authorities to ensure a safe containment for 300 years.

Key references

- Expertise in the concrete formula, conception and production of high performance concrete packaging solutions and special concrete (BHP, BTHP, BFU HP, high density concrete)
- Designed for diffusion rates com plying with radio nuclides containment requirements
- Designed to meet handling and transport requirement

Producer – Operator

Studies / R&D

Quality audit

Project management

Your waste is safe with us

Orano's containers can be used at different stages of waste treatment: on-site packaging, interim storage, transport, final storage.
Our containers are designed to provide mechanical strength and containment for 300 years.

In France, the National Agency for the Management of Radioactive Waste (ANDRA) validated our products within the requirements of the Aube's Nuclear Wastes Storage Facility. All the products are manufactured in compliance with the requirements of our ISO 9001 and ISO 14001 environmental quality management.

8 Waste transport to disposal from management routes to roads

Leading experience by Orano in securing radioactive transport worldwide, for all levels of activity and transport modes, through to disposal

Orano is the only nuclear player to offer a comprehensive transportation service, from uranium mines to recycling plants, anywhere in the world, with the highest level of security and safety control. The group is a leader in the design and manufacture of transportation casks and in the organization and supervision of road, sea, rail or air transport

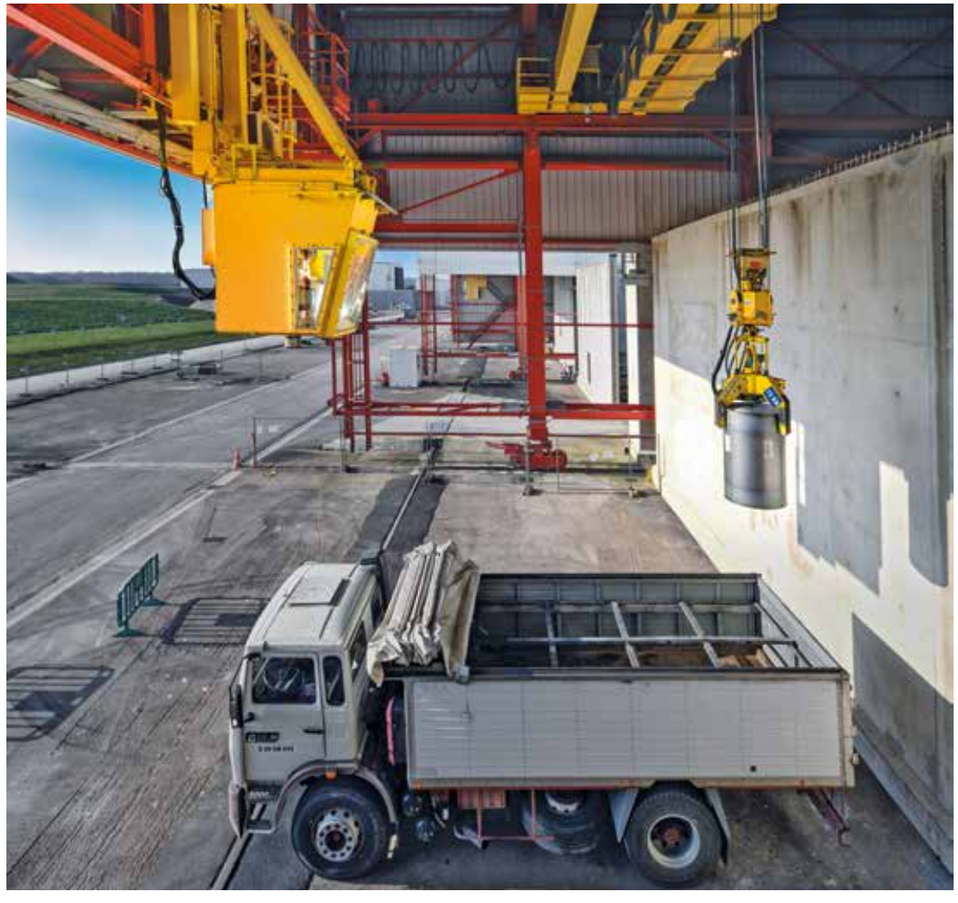
Key metrics

#1 In transport operations: about 5,000 shipments per year

#1 In dry storage solutions for utilities worldwide: over 1,200 packaging systems

1200 Employees worldwide

Unrivalled expertise in transport risk management



Capabilities

- Consulting services, expertise and logistics solutions benchmark
- Feasibility studies – identification of best transport and storage solutions
- Radiolysis risks analysis
- Cask predesign definition taking into account transport and storage regulations
- Re-use and adaptation of existing Used Fuel or Irradiated Material transport and storage packages
- Design of new packages - SAR
- Licensing process management
- Manufacture of packages, tools and ancillary equipment
- Services to operators : loading / maintenance / monitoring and control / drying
- Fleet management (documentation, compliance, design modification, repairs,...)
- Training sessions for Cask use: Cask University, Virtual Reality