the materials ageing institute

SUPPORTING LONG-TERM PLANT OPERATIONS

The Materials Ageing Institute (MAI) was founded based on the belief that sharing research, experimental results, feedback and scientific information on materials degradation can contribute significantly to the long term operability and life extension of power plants and, more specifically, nuclear plants. Management of nuclear power plant ageing is increasingly considered to be a key energy challenge worldwide. By 2020, one third of the world's nuclear fleet will be 40 or more years old. In 2030, this figure will increase to 80%. Since short term replacement of current generation capacity without a massive increase in CO2 emission is not technically feasible, ensuring the safety of nuclear plant operations beyond 40 years is currently considered to be the best option.

The MAI addresses this crucial issue from an applied research and development (R&D) perspective. By teaming up with utilities and related industries as well as academic partners, the MAI is able to combine operational expertise and theoretical knowledge, and to apply experiments and computer modeling to the understanding of the ageing process in materials and components. Since establishment of the MAI in 2008 by the world's largest nuclear power plant operator, EDF, other nuclear plant operators and organizations have joined the Institute. In 2010, full members include the Tokyo Electric Power Company (TEPCO, Japan), Kansai Electric Power Company (KEPCO, Japan) as well as the US Electric Power Research Institute (EPRI).

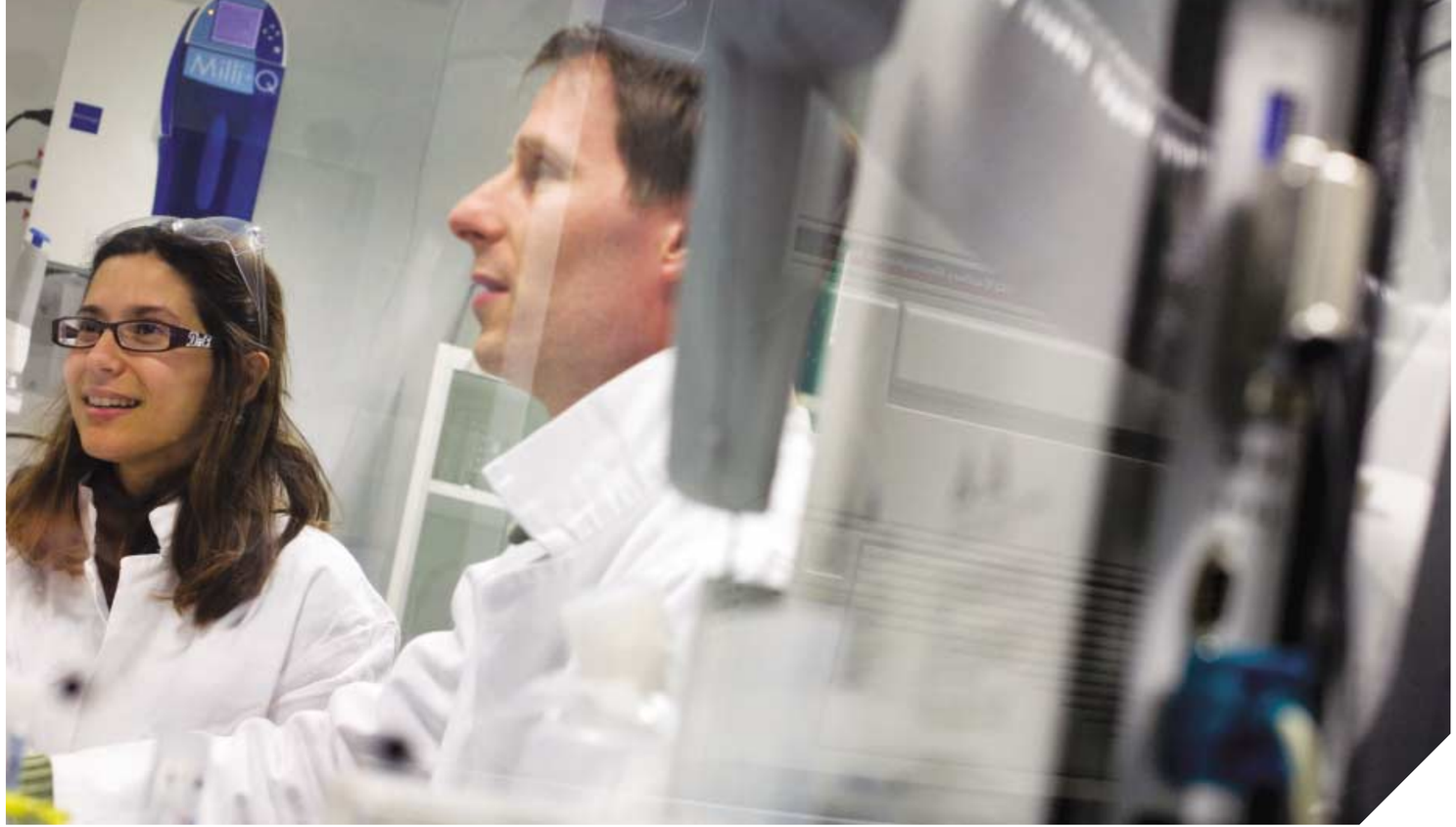
A unique research and training institute

Focus on research and training. The MAI is led by EDF, which from the start invested heavily in dedicated experimental facilities, IT systems and a new building to house the MAI at EDF's Les Renardières Research Center, southeast of Paris, France. The Institute includes a state-of-the-art microscopy laboratory, video conferencing capability enabling global coverage, teaching facilities and offices to house both permanent staff and guest researchers. One of the core missions of the MAI is education and training. Courses on materials ageing are being developed and offered to graduate and postgraduate students as well as to working engineers in the nuclear industry. In addition, seminars and workshops are organized by the MAI to promote discussions and knowledge sharing on technical subjects. Currently, around 80 researchers and technicians are working on MAI projects, most of them permanent EDF employees.
The MAI building was built in line with EDF's commitment to sustainable industrial growth and in compliance with the highest environmental quality standards. It features high performance heat pumps using geothermal technology, double air flow with variable flow recovery, CO2 sensors to automatically adjust air recycling, rainwater recycling and low luminance lighting with detectors for the presence of people… all of which bringing an almost 80% reduction in overall energy consumption.

Understand, **develop**, capitalize

Major objectives of the MAI and its members are:

- To understand, model, predict and anticipate the ageing of materials used in the electricity generating plants, whether nuclear, fossil or hydro
- To develop knowledge about the behavior of materials to be used in future plants in order to make recommendations to the members of the institute as to the choices offered by the manufacturers
- To capitalize on shared resources, maintain and share knowledge and skills to help plant operators, throughout the world, incorporate the highest standards of safety and thus reinforce the community of stakeholders
- To contribute to the training of students and engineers on materials ageing in nuclear power plants.



An international network

Partnership as the basis

The Institute operates through agreements with international industry leaders to contribute and share human and financial resources to a collaborative research program. Members are typically companies owning and/or operating energy generation facilities or organizations formally representing such companies. Current members are EDF (France and UK), TEPCO (Japan), KEPCO (Japan) and EPRI (USA) representing all US nuclear operators. As such, the MAI represents over 50% of the World's installed nuclear power and benefits from close to 5000 combined years of reactor operating experience, feedback and skills relating to the materials used in nuclear power plants. Industrial organizations involved in nuclear engineering and specifically in the maintenance of components or materials research also participate in MAI activities as associate members. Current Associate Members are Mitsubishi Heavy Industries (MHI) and Central Research Institute of Electric Power Industry (CRIEPI), both of Japan.

Associate Members and labor atories

Scientific and academic partners allow the MAI to carry out fundamental scientific studies and provide expertise and help to improve the quality and credibility of the research results. Scientific partners are brought together through the MAI Scientific Network, MAI-SN. They join the MAI via an agreement based on the MAI-SN Charter which can be found on the MAI website along with the full list of scientific partners. This network consists of 15 partners, including prominent universities from the USA, Japan, UK and France as well as several research institutes.

The purpose of the MAI-SN is to create a strong and permanent link between academic researchers and the MAI. This link fosters the development of a shared knowledge base with a focus on methods and approaches required to address the scientific questions on ageing involving metallurgy, mechanical properties, chemistry, applied mathematics and numerical modeling, to name a few. Scientific seminars and workshops are organized on a regular basis allowing partners to share perspectives, information on new developments and innovations in the field of materials behavior.

Understanding materials behavior

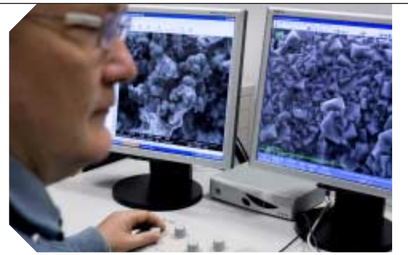
An ambitious research program

Most current efforts focus on **predicting the remaining life of nuclear power plants** as this topic is a major international issue. Research areas are stainless steels and alloys (reactor vessel internal structures, primary and secondary circuits), polymer material (electric cables, coatings and insulator materials) and the concrete structures such as reactor containment Key processes studied are stress-corrosion cracking, thermal and irradiation induced embrittlement, fatigue, chemical corrosion and erosion.

Research at the MAI is divided into three areas: experiments, modeling and operational feedback. Experimental research is based on observation and tests on specimens specifically developed by and for the MAI. The tests include thermal ageing (months or years of thermal stress) for which the Institute has multiple furnaces that can generate temperatures of up to 650 °C. Modeling is one of the central activities of the MAI. Mathematical models not only allow us to test our understanding of fundamental processes such as stress corrosion cracking, corrosion fatigue and creep – they also enable us to capitalize on our databases through parametric studies. Operational feedback data are obtained using samples of material that are made available by utilities after replacement of specific components.

Research Facilities

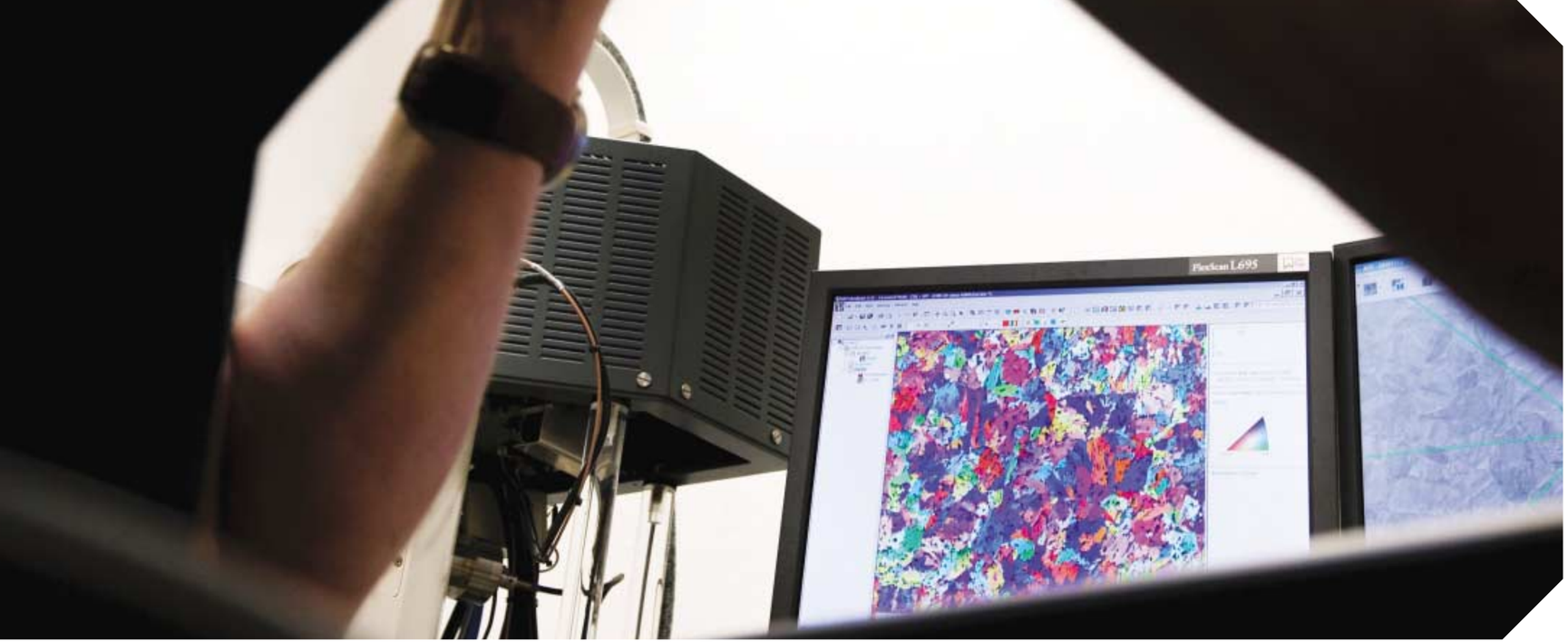
The **Microstructural Laboratory** allows for metallographic analysis and observation down to the atomic scale which are necessary to study ageing mechanisms. The MAI has the latest generation of scanning electron microscopes (SEM, ESEM) and a dual-beam nanolab, providing two or three dimensional images of damaged areas down to the nanoscopic scale. In collaboration with universities within its Scientific Network, the MAI has also access to tomographic atom probe analysis.



The ultrahigh resolution TITAN microscope is the flagship technology of the microstructural laboratory. With a resolution of 70 pm, below the atomic scale, it is currently the most powerful transmission electron microscope in the world. Its outstanding performance is due – among other factors – to its specific placement and environment, which fully isolates it from vibrations and electromagnetic fields.

The **Chemistry and Corrosion Laboratories** provide experimental equipment which contribute to the fundamental understanding of chemically induced ageing mechanisms and therefore to safety, availability, radioprotection, and environmental impacts. There are several experimental loops to study corrosion under primary and secondary circuit conditions as well as many commonly used chemical analysis apparatus (e.g. ICP-AES, ICP-MS, CPL, etc.) and around 60 autoclaves.

The **Mechanical Laboratories** provide experimental tools and analysis to study component and material integrity, mechanical degradation, fatigue and creep. Specific constitutive laws of materials are established to feed numerical models to simulate micro-mechanical behavior at the crystaline scale. The laboratory contributes significantly to component lifetime assessments.



The MAI has many of the facilities needed for in-house studies of materials ageing, but cannot handle irradiated or contaminated materials. Irradiation is one of the most significant processes that contribute to the ageing of metals and alloys, and hence a major factor in limiting overall reactor lifespan. **Associate Laboratories** extend MAI's capabilities with access to hot facilities for studying irradiation-induced ageing of materials.

Computer Modeling is one of the central activities of the MAI. Mathematical models not only allow us to test our understanding of fundamental processes such as stress corrosion cracking, corrosion fatigue and creep – they also enable us to capitalize on our knowledge through parameter databases. Furthermore, they are of key importance in assessing the durability of components and materials for periods beyond reasonable duration and under conditions beyond experimental reach. The Institute has one of the most powerful supercomputers owned by a non-government organization. This computer power greatly speeds up complex numerical simulations, including dislocation dynamics, molecular dynamics, ab initio modeling, Monte Carlo simulations, as well as simulation of complex 3D structures of materials. Simulations which used to take about one month of computation time can now be performed in a few hours.

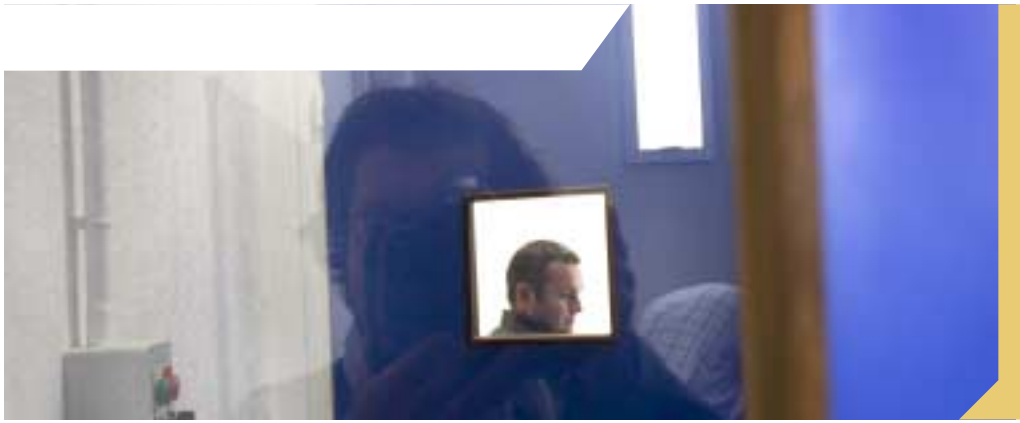
The more than 40 years operating experience and plant life management expertise represented by the members of the MAI represent a unique and valuable resource for the study of materials ageing mechanisms. **Operational feedback** data are obtained using samples of material that are made available by utilities after the replacement of specific components.

a center of excellence

The training and education

The MAI is at the forefront of collaborative R&D and training on the ageing of materials used in power plants. **Education and training** is a key focus for the Institute. The MAI organizes events, short courses, seminars, workshops and conferences for students and engineers seeking basic or advanced training in materials ageing in nuclear plant components. Some MAI courses are given by members in their countries. The Institute has conference facilities which allow us to host events.

The MAI collaborates in an international educational program with universities in France based on the needs expressed by utilities. The objectives of this program are to provide students with a deeper understanding of materials engineering science and the fundamentals of the mechanics of solids to improve their knowledge of recent developments in these fields. The focus is on advanced industrial applications and innovative processes and covers nuclear applications. The program is organized into specific modules and EDF R&D engineers are active participants in the teaching of various modules.



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