GETTING THE BEST OF WHAT MATERIALS CAN GIVE

materials ageing institute

Supporting long term operation

The Materials Ageing Institute (MAI) is an international research institute founded in 2008. Sharing research, experimental results and operating experience on materials degradation significantly contribute to the safe long term operation of nuclear power plants all over the world.

By 2020, one third of the world's nuclear fleet will be 40 years old or more. In 2030, this figure will increase to 80%. Management of nuclear power plant ageing is increasingly considered to be a key energy challenge worldwide. Short term replacement of current generation capacity without a massive increase in CO_2 emission is not technically feasible at an affordable cost. 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 driven by utility needs. By teaming up with utilities and related industries as well as academic partners, the MAI is able to combine operational expertise and theoretical knowledge, striving for the understanding of the ageing processes in materials and components. Since its establishment in 2008 by EDF, EPRI and TEPCO, 8 other organizations have joined the MAI.

The major objectives of the MAI are to understand, model, predict and anticipate the ageing of materials used in the electricity generating plants to capitalize on shared resources, maintain and share knowledge and skills to help plant operators incorporate the highest standards of safety.

A core mission of the MAI is education and training. Courses on materials ageing are developed and offered to graduate and postgraduate students as well as to working engineers in the nuclear industry. In addition, technical seminars and workshops are organized by the MAI to promote discussions and knowledge sharing.

A CENTRE OF EXCELLENCE

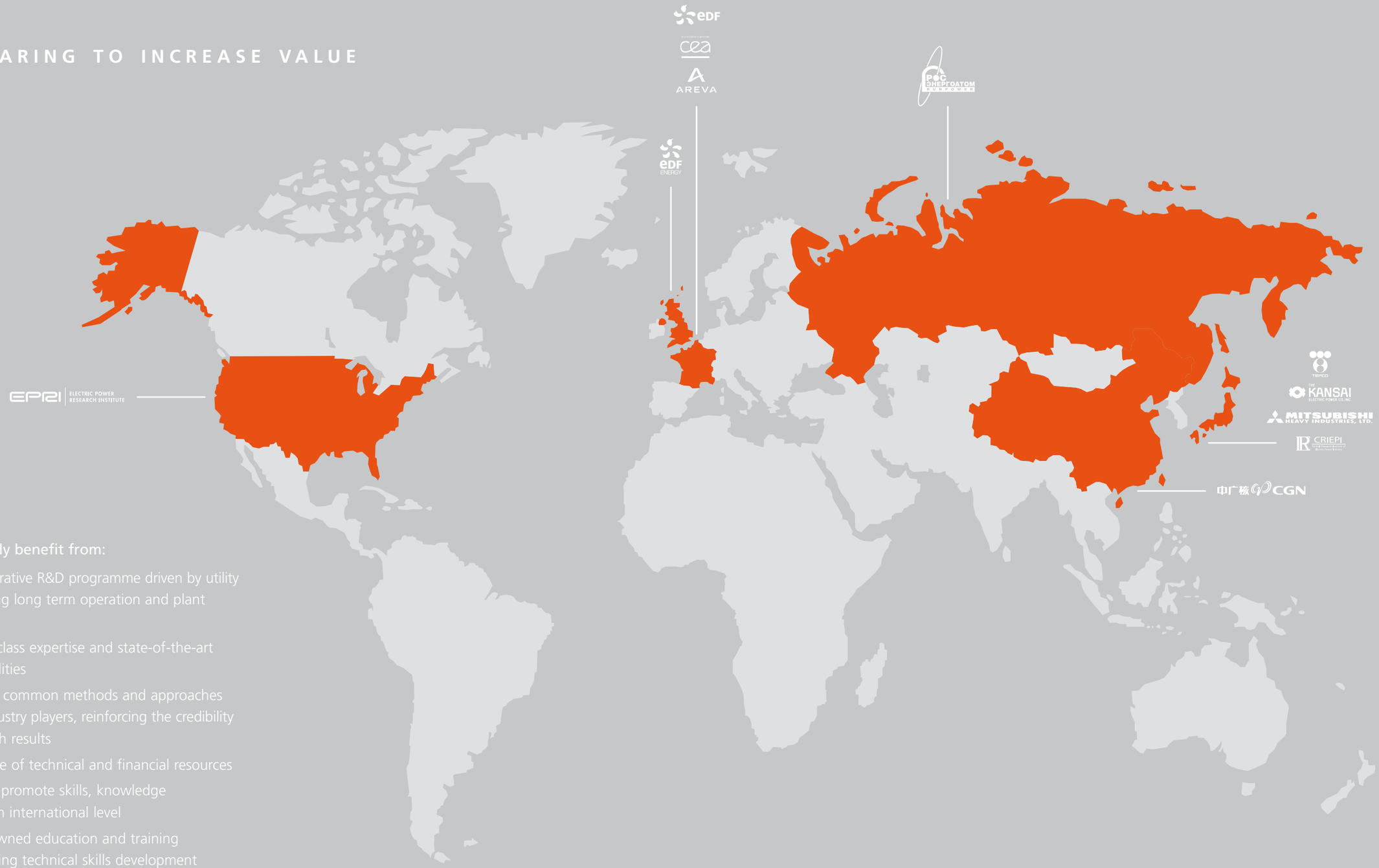
The MAI is led by EDF, which continuously invests in dedicated experimental facilities. The Institute includes state-of-the-art laboratories, teaching facilities and offices to house both permanent staff and guest researchers from members. The MAI also greatly benefits from members' complementary experimental capabilities. The Institute promotes a collaborative research approach between members through benchmarks and joint experimental programmes. Currently, around 100 researchers and technicians are working on MAI projects.

A UNIQUE COLLABORATIVE MODEL

The Institute operates through agreements with international industry leaders to contribute to a collaborative research programme by sharing human and financial resources. Full members are typically companies owning and/or operating energy generation facilities or organizations formally representing such companies. Current members are EDF (France), EDF Energy (UK), Kansai (Japan), EPRI (USA), CGN (China) and REA (Russia). As such, the MAI represents over two-third of the World's installed nuclear power and benefits from more than 5000 combined years of reactor operating experience.

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), TEPCO and Central Research Institute of Electric Power Industry (CRIEPI) from Japan, and CEA and AREVA from France. All members contribute technically to the MAI research programme according to their key areas of expertise.

SHARING TO INCREASE VALUE



MAI members greatly benefit from:

- A worldwide collaborative R&D programme driven by utility needs and supporting long term operation and plant performance
- An access to world class expertise and state-of-the-art experimental capabilities
- The development of common methods and approaches with key nuclear industry players, reinforcing the credibility of their own research results
- A significant leverage of technical and financial resources
- An excellent way to promote skills, knowledge and know-how at an international level
- An access to a renowned education and training programme supporting technical skills development

Scientific and academic partners allow the MAI to benefit also from fundamental scientific studies and provide expertise and support to improve the quality and credibility of its research results. Scientific partners are brought together through the MAI Scientific Network (MAI-SN). This network consists of approximately 25 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 to address scientific questions on ageing. Fields involved include metallurgy, mechanical properties, chemistry, applied mathematics and numerical modelling, to name a few. Scientific seminars and workshops are organized on a regular basis to share perspectives, information on new developments and innovations in the field of materials degradation.

Getting the best of what materials can give

Research areas of the MAI cover a wide range of materials: stainless steels and alloys (reactor vessel internal structures, primary and secondary circuits), polymer materials (electric cables, coatings and insulator materials) and concrete structures such as reactor containment and spent fuel pools. Key processes studied are stress-corrosion cracking, thermal and irradiation induced embrittlement, fatigue, chemical corrosion, flow assisted corrosion, fouling and wear. The MAI also addresses the demonstration of new Non Destructive Examination techniques. Experiments, modelling and operational feedback are the 3 pillars of the MAI research programme.

Experimental facilities

Experimental research is based on observation and testing methods on specimens specifically developed by and for the MAI. The MAI cannot handle in-house 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. **Members** extend MAI's capabilities by providing access to hot cell laboratories for studying irradiation-induced ageing of materials.

The **Microstructural Laboratory** allows for metallographic analysis and observation down to the atomic scale which are necessary to study ageing mechanisms. The MAI holds 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. The ultrahigh resolution TITAN transmission electron microscope is the flagship technology of the microstructural laboratory with a resolution of 70 pm, below the atomic scale. The MAI also holds Atom Probe Tomography capabilities via some members.

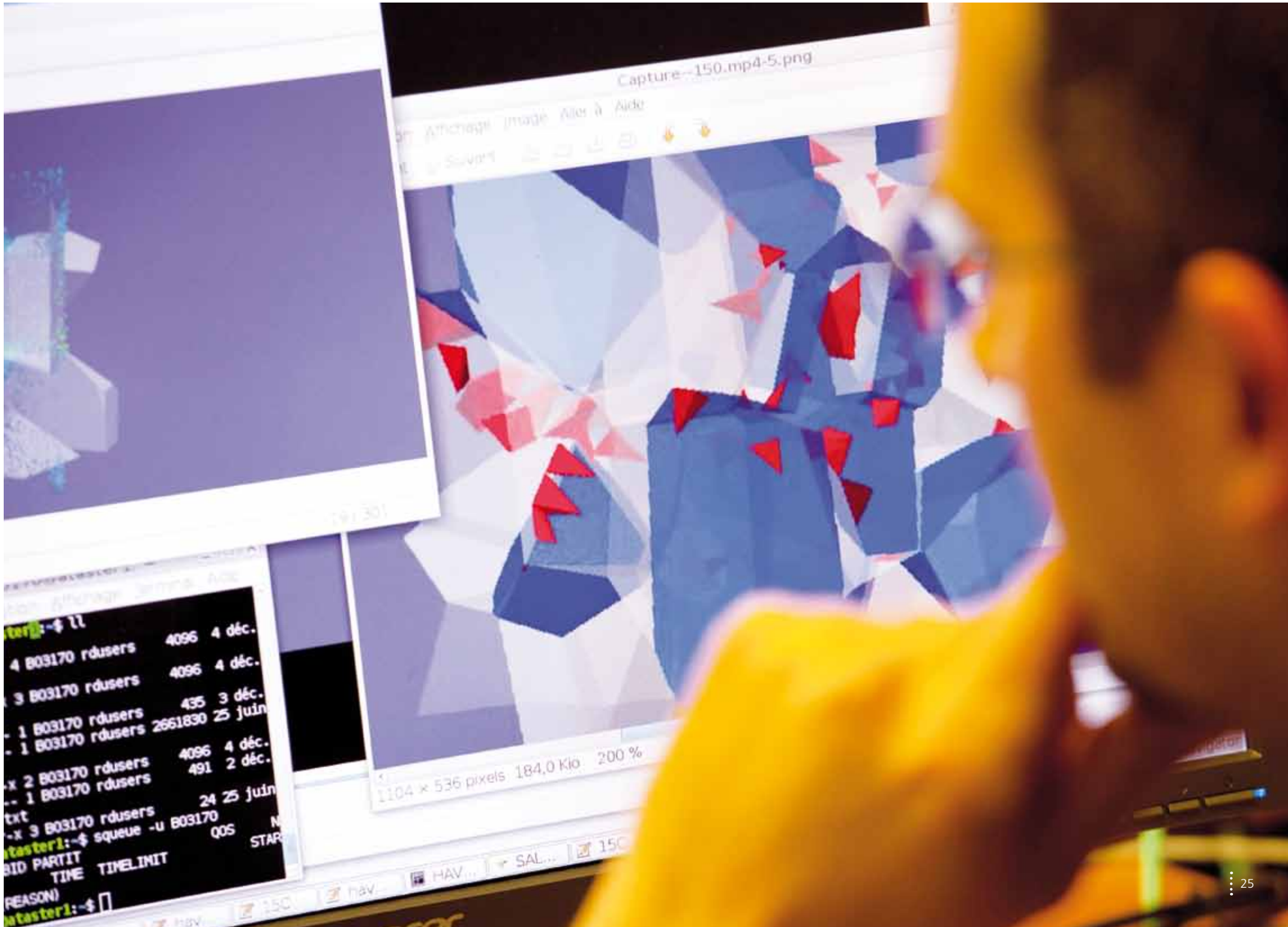
The **Chemistry and Corrosion Laboratories** provide equipment which contributes to the fundamental understanding of chemically induced ageing mechanisms and therefore to safety, availability, radioprotection, and environmental impacts. There are several experimental loops to study corrosion under primary 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 components and material integrity, mechanical degradation, fatigue and creep. Specific constitutive laws of materials are established to feed numerical models to simulate micro-mechanical behaviour at the crystalline scale.

Modelling and operating experience data

Modelling is one of the central activities of the MAI. Numerical models enable researchers to achieve a physically-based understanding of material degradation mechanisms. Once validated by experimental and operating experience data, the models enable utilities to predict and anticipate component degradation to optimize lifetime management. The MAI performs complex numerical simulations, including dislocation dynamics, molecular dynamics, ab initio modelling, Monte Carlo simulations, as well as simulation of complex 3D structures of materials.

The 40 years operating experience and plant life management expertise represented by the MAI members constitute 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 replacement of specific components.



Education and Training

Education and training is also a key focus for the Institute. The MAI organizes events, 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 MAI collaborates with universities in an international educational programme supporting members' needs. This programme provides participants with a deeper understanding of solid mechanics and material engineering applied to challenges faced by ageing nuclear components. The programme is organized into specific modules given by MAI members.

www.themai.org

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