France derives 78 per cent of its electricity from nuclear power, the highest proportion of any country in the world. A crucial role in generating all this nuclear power is played by Areva, a major player both within France and on the global stage. Curious to find out more about the application of stainless steels in nuclear recycling and waste treatment, Stainless Steel World visited Areva's nuclear reprocessing plant, Cogema-La Hague, and two of its suppliers, the fabricators Mecachimie and Mecagest.

Waste not, want not: nuclear reprocessing and stainless steel

By James Chater

It measures half a mile wide and 11/2 miles long, and it provides full-time work for 6000 people. Its vast scale can best be seen from aerial photos of the sprawling complex, located near the tip of the Lower Normandy peninsula 25km from Cherbourg in northern France. Commissioned in 1966, its construction provided work for 7000 people. The Cogema reprocessing plant at La Hague, Areva states with evident pride, was the biggest building site in Europe at the time.


Cogema-La Hague

Areva and Cogema

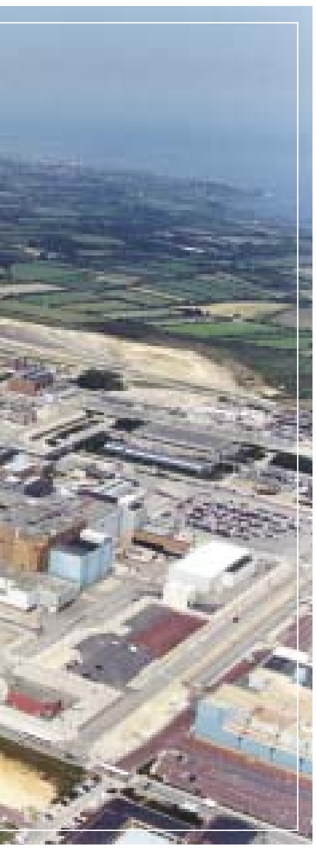
Cogema is a fully owned subsidiary of the Areva group, which dominates the nuclear industry in France and exports technology throughout the world. Areva was born on 3 September 2001 as a result of a major restructuring of the French nuclear industry. Nowadays, with manufacturing facilities in over 40 countries and a payroll of some 70,000 people worldwide, the Areva group is involved with every stage of the nuclear power generation process, and in other industries besides. To date Areva has built 98 reactors throughout the world and supplied pressurized water reactors (PWRs) to France, Brazil, Argentina, China, South Korea, South Africa and Belgium. The next ace up its sleeve promises to be the European Pressurized Water Reactor (EPR), basically a PWR with enhanced safety and efficiency features. A pilot EPR is being built in France, while Finland has already bought an EPR for commercial use.

Cogema provides a number of products and services over the whole range of the nuclear cycle, from mining to chemical processing, enrichment, recycling, MOX fuel fabrication, and others. Set up in 1976 with the specific function of supplying the French civil nuclear programme, Cogema joined the Areva group in 2000. Like its parent company, Cogema has a worldwide presence and clientele. Apart from France's EDF, it has 30 clients in countries like Germany, Switzerland, Belgium, Australia and Japan.

Cask in which the spent fuel arrives at Cogema-La Hague. Both ends are fitted with stainless steel shock absorbers (balsawood encased in 316L). In foreground (left to right): Jacqueline Vansteelant (Cogema), Laurent Junod (SGN) and James Chater (Stainless Steel World).

Security

On visiting the site, one is immediately impressed by the high level of security, both in terms of protecting people and the environment from harmful doses of radiation, and, vice versa, guarding the plant against malevolent intruders. Sharpshooters are deployed against possible attacks, and visits to the plant are strictly monitored. Before entering the buildings we had to put on special clothes, and on exiting we were screened for radiation. Employees undergo regular health checks, and monitoring of soil, sea, and air is carried out by Cogema and the French state in parallel. The processing is carried out by remote control by robots operated from a central control room. On touring the plant, one had the uncanny experience of looking through brown windows into an area, just a few metres away, that is so radioactive that access would mean certain death.



Recycling and waste processing

Cogema-La Hague is where Areva handles the back end of the nuclear cycle: in-take of the spent fuel, fuel recycling and processing the waste, and providing interim storage for its clients. Recyclable fuels are uranium (95-96% of the spent fuel) and plutonium (1%); the rest (3-4%) is fissionable materials or other waste that must be disposed of. The fuel and the waste are separated through a chemical process using nitric acid (the hydrometallurgical Purex process, developed in the USA). The fission waste is heated and dried in a calciner, a revolving tube heated to about 800°C, before being incorporated into a glass-like substance. This vitrified waste is then poured into refractory SS 309 canisters and eventually returned to the client.

Materials specification

Before touring the plant I met Laurent Junod, head of R & D (engineering materials comportment) at the SGN (Société Générale pour les Techniques Nouvelles), the engineering department within Areva that works with Cogema on materials selection and other technical issues. "The process entails the use of huge amounts of austenitic stainless steels," explained Mr. Junod. "Hundreds of tons of the low-carbon grades, 304L and 316L, are used for the vessels and confinement cells. Stainless steel is used in hundreds of kilometres of stainless steel pipes and several tons of large mechanical equipment. All the big cells are totally lined with stainless steel."
On visiting the plant, one has the impression of being led through a stainless steel jungle: on every side a tangle of tubes and pipes, a cluster of sheets, bars and cast products, used in both in low- and high-corrosion applications in vessels, pipes, tanks, canisters, robots, chimneys and other mechanical equipment.
"The more aggressive the medium, the nobler the metal used," Mr. Junod continued. "Stainless steel 304L is used for 85% of the process components, while 316L is used mainly for concentrated fission product storage. More aggressive corrosion conditions require Uranus 65 (for instance, the calciner), while Uranus S 1 is used in the

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Christian Bécot of Mecagest demonstrates a waste treatment vessel made of Ni-Cr-Fe (Ni>50%)

apparatus that handles the concentration of fission products. For still more aggressive applications, zirconium is used when there is no problem with fluoride or chloride corrosion; for instance, it is used for the dust cleaner and gas treatment in the dissolver, to handle nitric 4N boiling acid. Titanium is reserved for the most extreme applications. It is not only useful in resisting heat, but is also applied because of its low density. For example, some of the chimneys employ titanium as part of their seismic design."

I asked Mr. Junod what factors have to be taken into account in determining the right material for the application. Mr. Junod: "Several factors must be considered: for instance, the level of corrosives ions concentration in process media and the process temperature, the chemical conditions in process, the nature of the process unit (e.g. dissolution vessels, where only liquids are used, or gas treatment), the kind of raw material used in the fabrication (whether rolled sheet, forged or cast alloys, etc.), what filler metals to use for which welding operations, mechanical stresses, and so on. Also, we must continually take account of the results of corrosion R&D testing from the CEA [the Atomic Energy Commission, which supervises the French nuclear industry]."

Only very small thicknesses of materials are required, because there is no pressure in the process: 90% of the fluid circulation is effected by gravity rather than pressure. There are only a few mechanical transfers (such as pumps), which helps keep maintenance costs low.

Corrosion

In specifying and selecting materials, two types of corrosion have to be dealt with: uniform and localized. The rate of uniform corrosion will affect the thickness of vessels. This thickness can be fine-tuned, adjusted a few millimetres more or less, to make it last the lifetime of the vessel concerned. Localized corrosion, such as pitting or intergranular corrosion, is especially a problem in chromium carbides in grain boundaries – whether in low-chromium content areas in passive conditions or in-high chromium content areas in transpassive conditions (carbides dissolution in nitric acid). This means that the carbon content of stainless steels must be limited to 0.03 per cent, especially in the welding joints. Ferritic corrosion is another problem: this occurs in the transpassive condition of higher chromium content ferritic areas, with anodic behaviour in austenitic areas; in the dissolution of anodic ferritic alignment, as a result of crack corrosion; and in sigma phase formation in high-temperature applications. Ferrite content is limited to a maximum of 3 per cent, the minimum necessary to get a decent quality of weld (and avoid hot-cracking). Crack corrosion can occur by dissolution of the non-metallic inclusion alignment, especially with regard to sulphur, aluminates, silicates and oxides. Sulphur content is therefore limited to 0.015 per cent. Other chemicals whose content has to be limited in nitric acid media are silicium (<0.75%), molybdenum (<0.50%, in X2 Cr Ni 19 11 only) and titanium (<0.02%). Titanium carbides are especially vulnerable to corrosion in nitric acid, so no grade with titanium stabilisation is used in the welding joints. Also, austenitics containing Mo and low Si additions have low corrosion resistance in nitric acid solutions: thus 316L SS is less resistant to nitric acid than 304L SS. Mo is better for pitting corrosion but not for intergranular and oxidising media like nitric acid for concentration >4N and temperature >60°C in the chemical applications.

Other important factors in forming and manufacturing are roughness (surface delivery conditions) and grain size. In specifying grain size, ductility and corrosion behaviour are important: therefore a fine grain structure is preferred, with a small distribution around the average size.

Economic challenge

In conclusion, Mr. Junod stressed the high quality of the materials provided, but laments the fact that it is difficult nowadays to obtain small quantities of these materials cost-effectively. “We face an economic challenge in obtaining small quantities of materials for optimisation or modification,” says Mr. Junod. “The suppliers ask: ‘Are you ok for ten tonnes?’, when all we need is ten metres of a pipe, which is a very small quantity! That is why we are carrying out a lot of technical and background analysis on older facilities to optimize alloys choice and delivery conditions. I don’t think it’s true that we have specified too high a quality in the past; but in

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Nuclear waste canisters at Mecagest being dye penetrant tested for surface defects

Vitrification workshop at Cogema-La Hague, with cylindrical calciner made of Uranus 65

Remote tele-operator at Mecachimie, made of 304L (left) and carbon steel (right)

some cases, after trials have been carried out, it turns out that the corrosion is less aggressive than we anticipated, or the process has changed, so it may be possible to rethink our material choice and specify the right stainless steel grade at the right place for new fabrications at the La Hague plant or for customers in other countries, such as Japan and the USA."

Mecachimie and Megagest

Two important suppliers to Cogema-La Hague are located conveniently nearby: Mecachimie (at Beaumont-Hague) and Mecagest (at Valognes). Both these stainless steel fabricators are subsidiaries of Areva. Mecachimie supplies mechanical engineering and pneumatic conveying to several industries, including nuclear. For Cogema-La Hague it manufactures robots, vital in ensuring safe working conditions. "Our robots often use a mixture of painted carbon steel and stainless steel," explained Véronique Vonfeld, Operational Director at the Beaumont-Hague facility, as she showed me round the factory. "The components that come into contact with corrosive substances have to be made from SS 304L."

Down the road, Mecagest manufactures a wide array of components for the nuclear industry, using stainless steels, titanium, tantalum, zirconium and aluminium. These include waste canisters, waste treatment vessels condensers, glove boxes, calciners, dust separators, melting pots, electrolysers, MOX transportation baskets, as well as numerous small components.

Commitment to nuclear power

France's commitment to nuclear power is total. Whereas a few years ago this commitment was deemed controversial, now this choice seems far-sighted in view of the looming danger of power scarcity in much of Europe. Nor is France about to make the mistake everybody has been making with fossil fuels, over-speedy consumption of a finite resource.

If France continues to recycle nuclear fuels (and its excellent safety record suggests that it probably will), there will be enough uranium to last for many decades, if not centuries. ■