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How Quality and Safety Contribute to Fuel Performance

Abstract

In a context of increasing demand for competitive energy generation, nuclear power plants must operate safely, reliably and provide the highest possible level of availability. Fuel performance and reliability are more than ever key points for all players in nuclear fuel activities. After a brief presentation of fuel activities, this paper will illustrate how AREVA's focus on quality and safety contributes to its in-reactor fuel performance.

Fuel activities within AREVA

The Fuel Sector of AREVA designs, manufactures and supplies fuel assemblies for PWR, BWR and research reactors throughout the world. It provides roughly 40% of worldwide fuel needs for PWR (VVER excluded), BWR-type and research reactors. Moreover, AREVA supplies 52% of the zirconium semi-finished product market. These activities represent approximately 1.248 billion Euros in annual sales (2006).

AREVA has supplied more than 155 000 PWR and BWR fuel assemblies worldwide to more than 47% of the world's 303 operating PWRs and BWRs. More than 1000 enriched reprocessed uranium fuel assemblies have been manufactured to date and AREVA's MOX product line designs, manufactures and supplies MOX fuel assemblies, meeting the most stringent plutonium content and discharge burnup requirements.

The Fuel Sector is organized into three lines: the Design and Sales line teams up the engineering sites and offers customer site inspection and assistance services; the Zirconium line is the world leader in supplying nuclear-grade zirconium-containing products; and the Fuel Manufacturing line, fabricating components and fuel assemblies in four countries, provides customers with flexibility and security of supply. The Fuel Sector is distributed among 16 locations, with 5000 employees. Fourteen manufacturing sites, five laboratories and four design offices are located from the USA across Europe. All fuel sites are certified to ISO and OHSAS quality, safety and environmental standards, indicative of AREVA's commitment to sustainable development.

The synergies within the entire AREVA Group, from the front end to the back end of the fuel cycle, are indicative of its mastery of the full range of nuclear fuel know-how.

AREVA governance principles: The AREVA way

As a key player in the nuclear industry and a reliable long-term supplier of the entire fuel cycle of nuclear products and services, AREVA plays an essential role in the great economic, social and environmental challenges of our time. Based on the three domains of Financial, Social, and Environmental responsibilities, these three axes have many interactions with one another, as seen in *Figure 1*. At the intersection of all three, we find Sustainable Development, which is the foundation of the AREVA corporate values.

Ten principles support these values in a tangible way; together, they compose the 'AREVA Way'. These principles encompass our responsibilities toward each of our stakeholders, including employees, the community, shareholders, customers, and the nuclear industry.

One of the AREVA Way principles addresses Risk Management and Prevention. It sets expectations for each site to:

- define health and safety objectives more stringent than prevailing standards and regulations;
- systematically use formal risk analysis techniques, followed up with corrective actions;
- implement training programs;
- systematically manage communications;
- strive for zero defects/zero accidents.

To emphasize the importance of this principle to all, the statistics on Industrial Safety are the first items reviewed and discussed during each budget review with CEO Anne Lauvergeon and her staff.

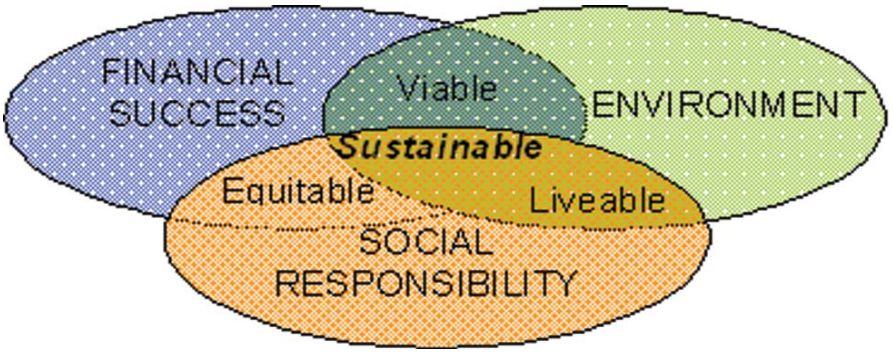


Figure 1

A second AREVA Way principle addresses Continuous Improvement. It sets expectations for each Corporate Department to:

• systematically search for best practices, and disseminate them throughout the company;

• develop, disseminate, and maintain group tools (methods, handbooks, models, etc.) to support policy implementation.

AREVA's focus on Customer Satisfaction, which is a third AREVA Way principle, includes both Quality and Safety in design and manufacturing, which are strong elements to address the expectations of the nuclear industry.

Why does AREVA link Quality and Safety? The nuclear industry demands perfection in its products, its services, and its conduct of operations. Attention to Quality and attention to Safety reflect the same kind of mindsets in the corporate culture, the same attention to detail, the same questioning attitude, and the same responsibilities to stakeholders.

AREVA has demonstrated improvement trends in Quality and Safety, which are quite impressive. But the bar continues to be raised and expectations continue to be increased. It means for fuel business activities that the quality of the delivered fuel products are measured by the following criteria:

• the plant operates reliably, without fuel failures;

• there are no problems with fuel assembly handling or with debris failures;

• there are no issues with fuel to be declared to the safety authorities.

AREVA continues, more than ever, to be aggressive in its message to all employees that there must be Zero Tolerance for Failure.

AREVA's continuous improvement focus: The Zero Tolerance for Failure (ZTF) initiative

As can be seen in the logo in *Figure 2*, the ZTF initiative encompasses all aspects of the fuel business: from Design to Manufacturing, Processes to Human Factors, R&D to Product Strategy. It recognizes that even minor mistakes can have large consequences and can be seen as "failures" to meet expectations of AREVA's stakeholders - customers, employees, regulators. To achieve excellence in safety and in quality, the first and key step is to gain the commitment of each employee coming into the plant or office every day, regardless of the work area, job responsibilities, or level in the organization.

The Zero Tolerance for Failure philosophy embodies four concepts:

• Failures are avoidable.

• Zero failures is our goal.

• We will respond rapidly to any failure.

• We succeed only when we fix the root cause of failures to avoid recurrence.

So what is considered a failure?

• A "failure" is any deviation in product or services.

• The objective of the ZTF Initiative is to eliminate failures and to meet the expectations of all customers.

This Zero Tolerance for Failure initiative brings a significant contribution to the permanent commitment of the AREVA Fuel Sector to continually upgrade fuel performance and reliability, to the benefit of its customers, who are implementing ever more economically efficient and operationally demanding fuel management strategies.

Some ZTF Examples

So how does an organization take its performance to another level? Some examples of various tools which AREVA employs are discussed in the following paragraphs.

LEAN MANUFACTURING

AREVA's Fuel Manufacturing Business Unit, encompassing eight sites in four countries, is currently focussing on two "tools" of LEAN manufacturing: 5S and Value Stream Mapping. Each site has a LEAN manager, who is part of a network that receives training updates, exchanges experience feedback and provides training and support to the sites. An important aspect is that, although the LEAN manager may lead projects, the hands-on workers perform the work, suggest the improvements, and are the backbone of the success of the project. The LEAN tools of 5S and Value Stream Mapping are currently being actively implemented at all fuel manufacturing sites.

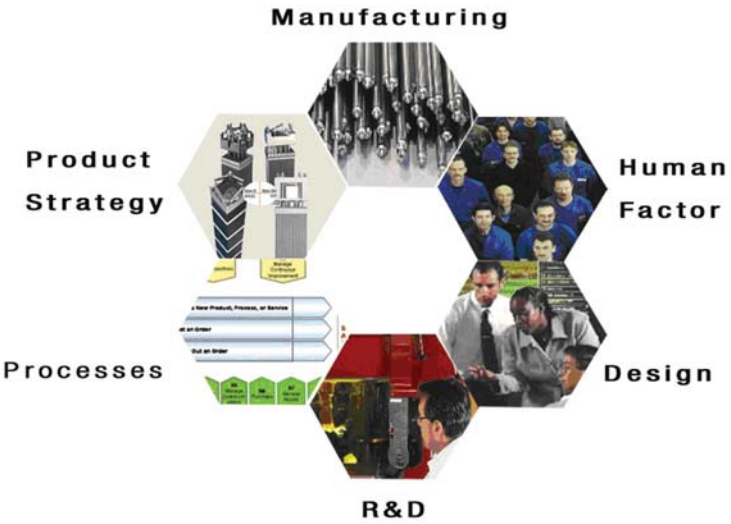


Figure 2

5S

The 5S tool is a very visible and often an excellent "quick hit" way to profit from the advantages of a well-organized work place.

- **S**ort - Eliminate what is not needed.
- **S**traighten - A place for everything and everything in its place.
- **S**hine - Cleaning and looking for ways to keep it clean.
- **S**tandardize - Maintain and monitor the first 3 S's.
- **S**ustain - Stick to the rules - practice and develop good habits.

When these five simple steps are completed, the operator can reliably find his necessary tools, and distracting clutter disappears - providing a cleaner, safer, and more efficient working environment.

For the visual impact of a 5S campaign, see the "before" and "after" photos of one of the gauge calibration workshops in *Figure 3*.

Value Stream Mapping

The Value Stream consists of the process steps the customer finds value in, and is willing to pay for. Value Stream Mapping begins with charting the flow of the manufacturing process for a given component. This mapping is a project performed by the operators themselves. The first step is to walk physically through the process and to create a flow diagram of each step of the process as it currently exists. Following this "current state map", the operators then brainstorm to identify those steps which actually add value for the customer, normally those which change the form, fit, or function of the product; or assure the quality and performance of the products. Following the mapping, an analysis of the non-value-added steps identifies those which can be performed more efficiently, performed in parallel, or eliminated altogether. Often this process also enables the organization to reduce complexity of information flows, which creates fewer opportunities for errors.

Industry experience is that the value-added steps comprise between 15% and 40% of the time taken to manufacture a component. So often, an organization tries to reduce cycle time or reduce costs by doing necessary things more quickly and more efficiently. But by just reducing or eliminating those steps which add no value, a huge saving in cycle time is achievable.

ROOT CAUSE ANALYSES

If there is any value in making a mistake, it is in learning from the experience. But to learn, one must truly understand the root cause: the barriers which failed and the systems which failed, but also the generic implications which can be learned from the incident.

The AREVA Fuel Sector process for handling quality events has been developed with a tiered approach. Three levels of events are identified:

Level 1: Significant Events

Level 2: Important Events

Level 3: Watch/Trend Events

This tiered system enables an organization to "lower the threshold" for recording quality and safety events, while maintaining proper focus where needed.

Level 3 events may require few or no corrective/preventive actions, but can give good weak signal indications. This can be particularly effective when "near misses" are included in the system. Both quality and safety near misses are important tools for risk management, and point up the need to put certain barriers in place to prevent a real event.

Level 2 events require an "apparent cause analysis", which is an investigation typically performed by one subject matter expert. Generally, these events do require

Gauge Calibration Room before 5S

Figure 3 - Gauge Calibration Room after 5S

corrective/preventive actions, and they can have generic implications.

Level I events require a Root Cause Analysis. The RCA process requires a written charter, which identifies the RCA team and its leader, a management sponsor responsible for providing resource support, and defines the scope of the investigation and approximate time schedule for completion. It also describes internal and external communication paths.

By operating on such a tiered system, the organization can give priority and resources to serious problems, while still being able to track less important events which on their own are not so important, but, taken together, may give an indication of weaknesses or "weak signals" before they actually create an event. In fields of both quality and safety, this helps to assess risks and put barriers in place before serious incidents take place.

HUMAN PERFORMANCE

The philosophy behind Human Performance training starts with the recognition that, as humans, we all make mistakes. However, errors can be avoided by identifying and eliminating error-likely situations. By reinforcing good human performance practices and by eliminating bad ones, the level of human performance can be raised. By learning from mistakes, one can avoid making them again.

The objectives of Human Performance training are to reduce the occurrence of human error and to minimize the consequences of mistakes. Each employee must expect himself and his fellow workers to anticipate the potential for error, to use error prevention tools taught with the training, to raise and address issues which give weak signals, and thereby to avoid preventable errors.

In this age of rapid change and need for efficiency, there is an increased emphasis on *doing more with less*. However, the biggest factor to be considered is how each individual can impact the process. Personal behaviour is paramount. Each person must beware of letting complacency infiltrate his work habits. What he does, how he works, and the standards he sets for himself, makes the difference between success and failure.

Some tools are effective in improving Human Performance in the engineering domain. They are easy to teach, easy to use, and are intuitively effective (therefore being easy to show added value):

- An informal peer review: ask a peer to check over one's work before passing it on.
- Control interruptions while performing a task which requires concentration: finish a task before answering the telephone, reading an email message, responding to a request for help.
- Think about the expected results of a calculation, a laboratory analysis, a process response to a change. Then compare the results with those which were expected: if there is a difference, be sure to understand why.

These kinds of tools can be easily implemented by everyone; it is a matter of work habit. When higher performance standards are set by each individual for himself, he can make a difference.

Failure to do things correctly can also jeopardize the health and safety of an individual, as well as those around him.

Safety-related behaviour, like quality-related behaviour, is strongly related to Human Performance factors.

This concept points out that one's mental state can create a mental error, which can lead to bad consequences. Although these same weaknesses can result in a Quality problem, the focus of this initiative is to link Human Performance to Safety.

Always enlarging and deepening safety culture

IMPROVING SAFETY AWARENESS

"A picture is worth a thousand words" is the old saying; this is especially true for making employees aware of accident risks. The example in *Figure 4* of how to communicate visually on Safety makes operators aware of where they are especially vulnerable to injury. Although these statistics over the entire year 2006 include minor injuries where only first aid was required, this view point presents a message on the "weak signals", as well as on more serious injuries. This poster creates an eye-catching "visual management" tool, which employees tend to notice when passing.

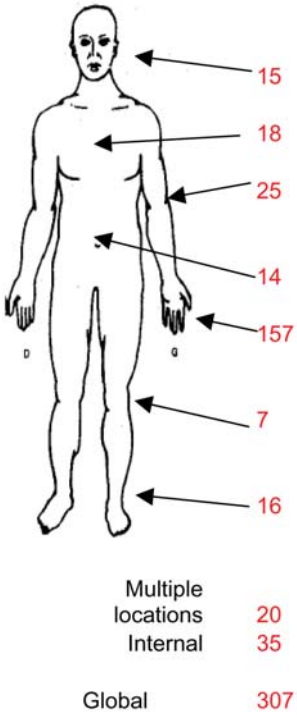


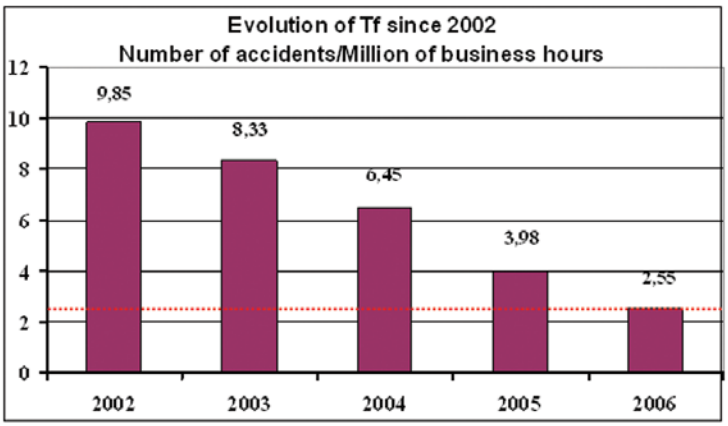
Figure 4

It clearly appears that the main location of accidents (first aid included) is the hands: the consequence has been an action plan to make everybody aware of safe handling rules.

IMPROVED SAFETY RESULTS

Efforts made to improve safety awareness and culture seem to have been effective considering the positive trend of the statistics presented hereafter.

The graphs in *Figure 5* show the evolution of Safety Statistics within the Fuel Sector, for frequency of accidents (Tf) and gravity of accidents (TG).



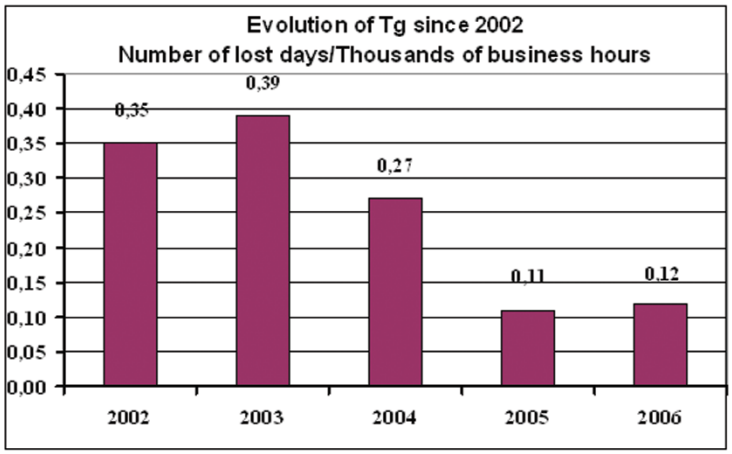


Figure 5

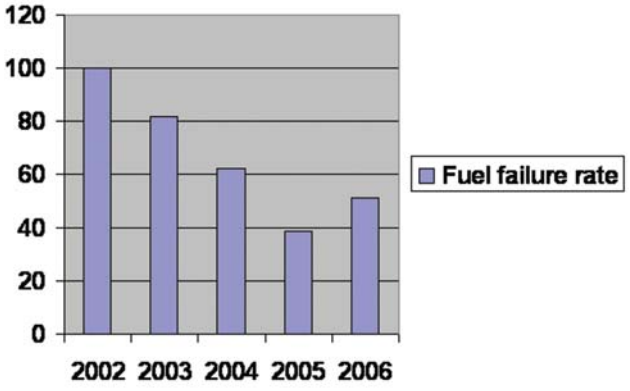


Figure 6

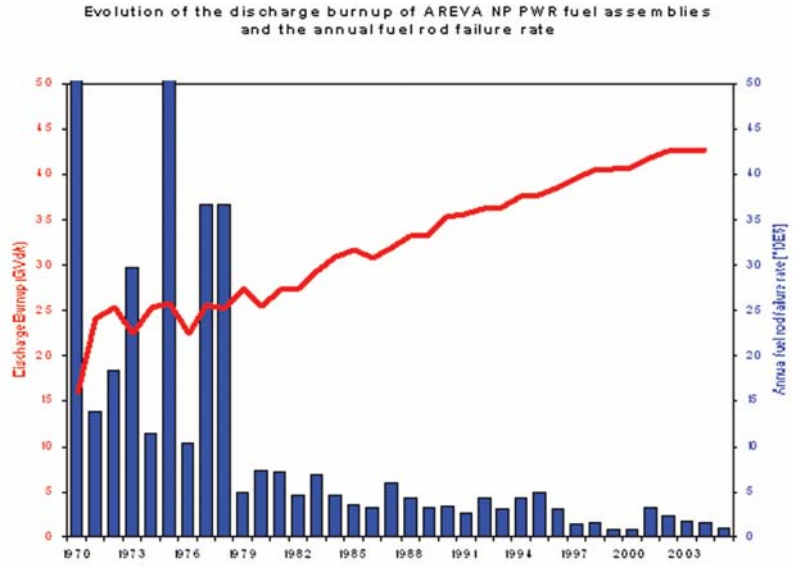


Figure 7

Although it is difficult to precisely benchmark Fuel Sector activities with those in other industries, some general safety studies performed in 2005 with ten other companies in similar scopes of activity and size rank AREVA in fifth position. This positioning is somewhat better if the comparison is made at the level of the Fuel Sector. This position will certainly be improved in the future, with the fulfillment of the AREVA safety targets for 2010. Placing emphasis on individual site performance, the target to meet is for each site to be below a frequency rate of 3.0 by 2010; and below a gravity rate of 0.15.

Always improving fuel performance

TREND IN AREVA FUEL RELIABILITY

The graph in *Figure 6* presents the recent trend in AREVA's fuel reliability results. It represents a global figure, including both PWR and BWR fuel failure rate (2002 has been taken as the reference year, valued at 100).

The observed trend is consistent with our constant watch on fuel reliability data and with the significant efforts engaged in the framework of the ZTF initiative. We note that some specific issues can interrupt the underlying trend towards reliability, causing an increase in the failure rates during occurrence period, but followed by a return to the longer term trend as corrective actions are taken.

The graph in *Figure 7* indicates the evolution over a longer period of the annual PWR fuel rod failure rate, compared to the discharge burnup of AREVA NP PWR fuel assemblies. One can see that the burn-up sought by customers continues to grow, placing a heavier duty on the fuel.

This positive trend in fuel reliability despite the increasing trend in burnup rates confirms the need to maintain in the long term efforts in all domains in order to improve fuel reliability.

Deploying an initiative such as ZTF requires time, investment and patience. Between the occurrence of an event and the demonstration of the effectiveness of the remedy, many months may lapse. This is especially true when fuel design changes are necessary. As an example, in order to eliminate debris failures, improved debris filters are currently under development for both PWR and BWR fuel assemblies. These developments will lead to prototypes which will undergo qualification tests, be assembled onto Lead Fuel Assemblies, and performance analyzed, before being proposed as a standard feature of our designs. The development of optimized grids to

eliminate hang-ups during handling operations is another example of long lead-time design corrective actions undertaken in the frame of ZTF.

TREND IN CUSTOMERS' EXPECTATIONS ON QUALITY

In a context of increasing demand for competitive energy generation, our customers must have reliable power generation in order to satisfy the demands of their customers.

In this context, the Institute of Nuclear Power Operations (INPO) has established an industry fuel reliability goal to eliminate fuel failures by 2010, known as INPO Goal 2010, recognizing by so doing that improvements have to be made in fuel performance. INPO is an owners' group of primarily US utilities which support the US nuclear industry through plant evaluation, assistance, analysis, and training program accreditation. Its International Participant Program also involves several non-US companies.

Actions in the framework of AREVA's ZTF initiative will focus on addressing this challenge, even if it will remain a difficult task to achieve the 2010 goals, especially due to the long cycle time to assess fuel design change effects and perform in-reactor testing.

Conclusion

In a general context of increasing demand for competitive nuclear energy, nuclear power plants must operate safely, reliably and ensure the highest possible level of availability. In addition, there is increasing pressure from regulators on utilities to target the prevention of operation with failed fuel in the core. It is therefore becoming a key point for the fuel vendors to emphasize the importance of product quality in all aspects of fuel design and manufacturing. The Fuel Sector of AREVA is committed to produce more robust design and flaw-free fuel assemblies, thus supporting its customers in their challenges to produce safe, reliable and competitive power.

By setting a high priority on quality and safety, AREVA commits itself to sustainable development principles and reinforces its position as a long-term fuel supplier. Continuous improvements in both quality and safety require a specific corporate culture and employee mentality. In addition, constant management attention is vital to keep focus on these priorities. AREVA has well understood this at the highest levels. CEO Anne Lauvergeon uses the AREVA Way model as the governance model which sets the basis for sustainable development of the company. Improving safety and quality are two of the pillars of this deployment.

Within the Fuel Sector of AREVA, the ZTF initiative incorporates many different tools to enhance the safety and quality of the products: a sample has been discussed today, from 5S and Value Stream Mapping, to Human Performance. Indeed, a necessary condition for success is to focus on employee behaviour. The lesson for all is that the quality of our product and the safety of our sites are also highly dependant on the mindset of each employee as he enters the workplace each day.