2010 LWR Fuel Performance Meeting / Top Fuel / WRFPM
September 26-29, 2010
Orlando, Florida Hyatt Regency Grand Cypress

ZERO

Presented by Eric P. Loewen, Ph.D.
September 27, 2010
Vice President/President Elect American Nuclear Society

On behalf of the American Nuclear Society – Welcome! Thank you to our sponsors, AREVA, GE Hitachi Nuclear Energy, Global Nuclear Fuel, Studsvik Scandpower, and Westinghouse Electric Company.

You're going to hear a lot about the idea of "zero defects" in nuclear fuel performance in the days ahead. Let's take pause to review the concept of zero itself, and whether we are looking at this idea from a reasonable perspective. Our culture is a little ambivalent about it. In many cases, zero is seen in a positive light, or at least as a curiosity, as in absolute zero, zero gravity or to "zero in" on a problem, or when we balance the budget or keep the building level. In many other cases, zero is seen in a dubious light, or at least an uncertain one, as in ground zero, zero based budgeting, zero hour, zero population growth, a zero sum game or zero tolerance.

A COMPLICATED IDEA

Will Durant, the prolific American historian, philosopher and writer, once said, "Most history is guessing, and the rest is prejudice." Let's take a look at history, and perhaps a little etymology. From where did the concept of zero come? Answering this question is a bit like trying to answer the question, "Who invented apple pie?" In both cases, it probably started with the Egyptians and then the English finally got it right sometime between Chaucer and Newton. In between, the guts of the idea bore fruit on the Indian subcontinent, and were spread by Arabia. Brahmagupta was the first to formalize arithmetic operations using zero; Al-Khowarizmi was the first to work on equations that equaled zero, which he called algebra, although he titled his work *The Method of the Indians*. Many other cultures contributed along the way, and some seemed to almost do without it, like the Greeks, the Romans and the Chinese, who based their numbers on the use of the abacus or on geometry. As usual, there was a parallel path in native America between the Olmec and the Maya, but no apparent communication across the oceans except to deliberately erase a large portion of native heritage from history in the quest for gold. Ultimately, a lot of higher order mathematics resulted, which made possible our modern world.

If you look at the etymology of the word "zero," a somewhat less positive picture emerges. One begins with the Egyptian *nfr*, which the pharaohs used to balance their books and ensure that the pyramids were level. But then you reach the Indian *sunya*, the Arabic *sifr*, and finally arrive at the English *cipher*, or *zero*. The *Oxford English Dictionary* tells you to look at the word cipher for a clue to the meaning of zero. There you find only three possibilities… (1) a code, used to pass secret messages, which, if intercepted, will mean nothing to an enemy; (2) a person or thing of no importance, especially a person who does the bidding of others and seems to have no will of their own; or, (3) a continuous sounding of an organ pipe, caused by a mechanical defect, which will cause the instrument to produce no music until the defect is repaired. In all cases, then, zero itself is a defect. So the idea of 'zero defects' from this perspective is nonsense.

Now, perhaps, we come closer to the view of some familiar voices and to a little humility when we so doggedly insist on a perfect zero. Einstein reminds us that, "the horizon of many people is a circle with zero radius which they call their point of view." We recall the words of science fiction writer Arthur C. Clarke that, "the best measure of a man's honesty isn't his income tax return; it's the zero adjust on his bathroom scale." To be more direct, we remember the words of former Washington State Governor, Dixie Lee Ray: "The reality is that zero defects in products plus zero pollution plus zero risk on the job is equivalent to maximum growth of government plus zero economic growth plus runaway inflation." In a natural, asymptotic world, a strict insistence on zero is what halts all progress when we agree to the fictional whimsy of politicians for the unattainable and the counterproductive. The mindless pursuit of zero risk as if it were anything more than a myth tends to paralyze science and actually leaves us less safe than before. As political scientist Aaron Wildavsky put it, "What is spent to lessen risk cannot be used to increase productivity." We gave up when we agreed to the 10,000-year standard at Yucca Mountain, never mind the 1,000,000-year requirement the lawyers finally settled on, in complete disregard for common sense, never mind engineering judgment.

ZERO BY TEN

So where does all of this leave us regarding nuclear fuel? We all know the technical scope of this meeting includes all aspects of nuclear fuel – from the rod to the core. The INPO fuel performance guidelines have had a positive impact by raising management attention to the right areas, including debris, pellet-cladding interaction (PCI), chemistry, fretting, monitoring and fabrication. On the other hand, we may now have swung the pendulum too far in the direction of endless paperwork in the final quest for zero defects. An indication of this I learned just last week in Vienna at the IAEA's 54th General Conference. Their 2010 *Review of Fuel Failures in Water Cooled Reactors* actually suggests that we change the way we count.

So what has actually been achieved? Debris and corrosion have essentially been conquered. PCI is diminished. Clad collapse, baffle jetting and hydriding have essentially been eliminated. Most outliers can be attributed to late adoption of industry standards like debris filters. Fuel design, however, is not static, since reliability is not the only consideration. Continuous advancements occur to address not only reliability, but also longer cycles, better fuel economy and power uprates. Despite this, fuel failure rates worldwide have steadily reduced to what we see today, which has leveled off at between one and two percent. Japan is the exception, where reported fuel failure rates are very low and steady at less than one tenth of one percent, due primarily to the longstanding practice of specified, standard short cycles and the very slow adoption of changes to the fuel lattice that others already take for granted.

CAN WE REACH ZERO?

So, can we reach zero? Should we try? Is this really a worthy, practical goal?

Please don't misunderstand me. I'm not saying we should throw statistical process control out the window or ignore fuel duty or preconditioning guidelines. But I am saying we should have a more balanced view of things. Just look at the third track of this meeting, "Advances in Water Reactor Nuclear Fuel Technology," specifically water chemistry. We started with the idea of pure water with zero impurities, and then realized we needed to add a few things (impurities) like lithium, zinc and noble metals to keep the system reliable. Sounds an awful lot like bottled water, where we purified it and then realized how terrible it tastes without a few minerals. Some might object that the Japanese have already reached the goal and I should stop talking and we should move on. OK, maybe … but let's not fall into the trap of unintended consequences, the infinite expenditure of resources to the detriment of more important priorities.

What are the ramifications of a leak? We are really talking about the integrity of fuel cladding. When the cladding is compromised, we increase the background radiation of the plant environment, extending outages and increasing worker exposure. This can also increase exposure outside the plant, however small, which can affect public acceptance. We want to be good neighbors … better to improve housekeeping, than to be in the position of having to repeatedly explain away "a little dust." It may be acceptable to have a home that features what my spouse refers to as that "lived-in look," but a nuclear plant is a factory, a factory producing electrons to power our communities around the clock. We have to avoid the temptation to give an easy chair to the operator. On the other hand, absolute perfection is not required, nor is it possible.

Perhaps there are other, natural "zeroes" in nuclear energy that we have already achieved, and should take some time to celebrate. In 2008, the Paul Scherrer Institut surveyed over 21,000 accidents in *all* energy industry over the last 20 years for OECD countries and those of the European Union. For severe accidents, defined as having at least five fatalities, the number of events is in the hundreds for coal, oil, gas and hydro, and the total fatalities are in the thousands. For nuclear energy, both numbers are <u>zero</u>. ZERO. How about emissions? It has always been a fundamental fact of nuclear energy that emissions are <u>zero</u> as well. Because nothing is burned, there are no air emissions associated with it. ZERO.

BEYOND ZERO

So where is all of this headed? I see that some authors of papers presented in the fourth track of this meeting, the "Emerging Fuel Performance and Fuel Cycle Issues," may have some answers. Some would say that with ever increasing fuel economy and new reactors we will eventually end up with breeder reactors and metal fuel, where a breech to cladding is simply not an issue and burn-up easily reaches 100,000 or even 200,000 MWd/t. This has already been proved in EBR-II. Why not burn-ups that long in water reactors? Even in light water reactors, suppliers are developing beryllium oxide as an additive to uranium dioxide to improve thermal conductivity and make ceramic fuel behave more like metal. And other interesting alternatives are evolving to achieve the same thing, including the use of uranium nitride fuel with silicon carbide cladding. Of course, I have not even mentioned recycling, mixed oxide or the potential use of thorium.

WHAT'S LEFT?

So now it’s time to make sure the pyramid is level. As you share information at this meeting to improve our industry, let’s remember the larger audience outside these walls. Remember your neighbors. Let’s help them put fear aside and embrace the knowledge that nuclear power is the safest large-scale energy source on Earth, and it begins with nuclear fuel. Good luck, and I wish you all very successful careers.

ACKNOWLEDGEMENT
I wish to acknowledge the valuable contributions of Charles Bagnal to this address. Thank you Charles!

SUGGESTED READING

- Aaron Wildavsky, “No Risk Is the Highest Risk of All,” *American Scientist*, January-February 1979.
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- *Review of Fuel Failures in Water Cooled Reactors*, NF-T-2.1 (IAEA Pub 1445), International Atomic Energy Agency, June 2010.