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NEW ENERGY EFFORTS

INTEGRAL FAST REACTOR
A FUTURE SOURCE OF NUCLEAR ENERGY

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ABSTRACT

Argonne National Laboratory is developing a reactor concept that would be an important part of the world's energy future. The Integral Fast Reactor (IFR) concept provides significant improvements over current generation reactors in reactor safety, plant complexity, nuclear proliferation, and waste generation. Two major facilities, a reactor and a fuel cycle facility, make up the IFR concept. The reactor uses fast neutrons and metal fuel in a sodium coolant at atmospheric pressure that relies on laws of physics to keep it safe. The fuel cycle facility is a hot cell using remote handling techniques for fabricating reactor fuel. The fuel feed stock includes spent fuel from the reactor, and potentially, spent light water reactor fuel and plutonium from weapons. This paper discusses the unique features of the IFR concept and the differences the quality assurance program has from current commercial practices. The IFR concept provides an opportunity to design a quality assurance program that makes use of the best contemporary ideas on management and quality.

INTEGRAL FAST REACTOR

A FUTURE SOURCE OF NUCLEAR ENERGY

The Integral Fast Reactor (IFR) has the promise to be a significant part of the world's energy future. The IFR concept, as being developed by Argonne National Laboratory for the Department of Energy, has the potential to resolve many of the issues being debated concerning current nuclear power plants. The IFR differs substantially from current commercial nuclear power plants. Its design differences along with the additional facilities needed to accomplish the "integral" fuel cycle manufacturing process require rethinking the application of quality assurance. This paper briefly describes the IFR and suggests where and how quality assurance should be applied to a commercial IFR facility.

Many features make the IFR important to our national interests. The more significant of these features are:

Inherent safety

- Safety based on laws of physics
- Significantly reduced need for complex safety systems and human intervention

Resource utilization and environmental benefits

- Recycles its own fuel for energy production
- High level waste is much reduced in volume and has shorter half life
- Can use weapons plutonium and spent Light Water Reactor fuel for fuel
- Consumes long half life actinides as fuel (actinides include plutonium, neptunium, americium, californium)
- Reduces transportation of new fuel and waste
- Uses nearly 100% of uranium resources
- Emits few airborne pollutants
- Eliminates need for mining new uranium for 500 years

Weapons proliferation

- IFR fuel has proliferation resistant characteristics
- Can convert weapons plutonium to a form unsuitable for weapons

Economics

- A United States technology with export potential
- IFR has a 60 year design life

As envisioned by Argonne, the IFR consists of two major facilities, a reactor with electrical power generating equipment and a facility for manufacturing and recycling of fuel. The fuel manufacturing facility is small and one could service several reactors.

The reactor is a fast neutron reactor using a metal alloy fuel of Uranium, Plutonium and Zirconium. The fuel core sits in a pool of sodium coolant maintained at near atmospheric pressure. The primary coolant pumps and the primary to secondary heat exchanger(s) are all located in the reactor vessel. The sodium coolant is covered with inert argon gas that is contained by the primary vessel lid. Only the secondary sodium which is not radioactive leaves the reactor. A second tank around the primary reactor vessel is designed to contain the sodium and maintain the coolant level if the primary vessel were to rupture. A containment vessel similar to current U.S. commercial reactor designs is also utilized. Both the normal operating and accident pressures for an IFR are much lower than those for a Light Water Reactor since there is no high pressure steam or water within the containment vessel.

IFR reactor fuel behavior in off normal conditions is a fundamental element of reactor safety. In 1986, two special tests were run in the Experimental Breeder Reactor II (EBR-II). The first simulated a loss of station electrical power so power was lost to all cooling systems. In the actual test the primary cooling pumps were shut off with the reactor at full power. There was no operator intervention, nor were normal shut down systems allowed to interfere. The reactor power dropped to near zero within about 300 seconds. There was no damage to the reactor or its fuel. This test demonstrated that with the loss of all electrical power and reactor shutdown capability, the reactor will simply itself shut down without danger or damage.

In the second test, also with the reactor at full power, the secondary coolant flow was stopped with a total loss of heat sink. The primary coolant temperature of the reactor started to increase. As the temperature increased, the fuel, sodium coolant, and the reactor structure expanded. This reduced the nuclear reactivity, due to increased neutron leakage, and resulted in the shutdown of the reactor. This test showed that an IFR type reactor shuts down using inherent features such as thermal expansion even if the ability to remove heat from the reactor primary system is lost.

As a result of these design characteristics, fewer active safety systems are needed for the IFR Reactor. Passive features such as reactor internal design that promotes natural convective flow upon pump shutdown and design allowance for thermal expansion are the primary safety systems. There is no need for a large safety grade emergency power system, emergency coolant feed systems to replenish the coolant and containment spray systems or hydrogen recombiners to control the post accident containment atmosphere. There are some systems in the IFR reactor that are not found in a LWR such as non safety systems to purify the sodium and argon cover gas. Refueling is accomplished within the reactor vessel which contains storage for new and spent fuel. Spent fuel assemblies can be exchanged from the storage location to an external fuel processing facility while the reactor is running.

The IFR fuel processing facility would dismantle spent fuel, refine it, cast it into new fuel and reassemble it into new fuel assemblies ready for further use. In the fuel processing facility portion of the IFR the primary safety concern is combustion of the fuel at elevated temperatures. An inert atmosphere of argon gas within the fuel processing hot cell prevents combustion. The massive hot cell walls and thick leaded glass windows are a formidable barrier to the entrance of outside air, even after a seismic event. A safety exhaust system is provided to assure the hot cell pressure always remains negative to the atmosphere. The exhaust system filters all hot cell exhausts to remove particulates. The significant active safety systems for the fuel cycle facility include the safety exhaust system and emergency power system. The massive hot cell boundary is the primary passive safety system for the fuel processing facility.

Low operating pressures in the nuclear portions of the reactor and fuel processing facility contribute to an overall reduction of safety concerns; both the reactor primary system and the hot cell operate at near atmospheric pressure. Robust design practices should be used to minimize operating failures. The EBR-II reactor at Argonne National Laboratory - West near Idaho Falls, Idaho, has safely and reliably operated for nearly 30 years. An existing hot cell facility in Idaho is being modified to demonstrate the IFR fuel cycle. The hot cell was successfully used for five years to recycle EBR-II fuel using a predecessor to the IFR fuel cycle process. More than 30,000 fuel elements were processed and used to refuel EBR-II.

The IFR could use as its fuel plutonium from nuclear weapons, spent fuel from Light Water Reactors, stocks of depleted uranium, as well as spent fuel from the IFR reactor. It is estimated that enough of this fuel is currently available to provide the U. S. with all its electricity for hundreds of years without mining any new uranium.

The QA program, for a commercial IFR facility, should focus on those processes which result in safe configuration, reliability and availability.

New to a conventional nuclear power plant would be a QA system to assure that the process for remanufacturing fuel is producing fuel of the requisite quality. Past experience has shown a similar process to produce fuel elements (pins) to have breach failures in the range of 1 in 100,000 or 10 ppm. Even with fuel failure, however, the sodium coolant reaction with the fuel would be minimal such that the reactor could continue to operate with some breached fuel.

The fuel manufacturing facility would utilize sophisticated computer systems to control the process, assure accountability of nuclear materials and as one element in the multilayered criticality control program. Development, validation, verification, and configuration control of computer programs needs to be covered in the QA program. While computer control is a useful tool, it cannot replace the skill and knowledge of the operating personnel. The technicians really control the process providing input, monitoring the process and taking action in off normal situations. Periodically during the fuel manufacturing process product samples should be randomly selected, inspected, and tested to assure process controls are functioning. Statistical process control should also be used to optimize the process and make product improvements. These and other quality assurance practices typical of a well run manufacturing process will need to be included in the QA program for the fuel processing operation.

Variations in composition of the fuel recycled back into the reactor creates a challenge to the physicist and the analytical chemist. The chemist must accurately analyze the constituents in metal fuel at several points in the recycling process to maintain on-line control and to evaluate acceptability of fuel for use in the reactor. Effective sampling and calibration programs would be necessary to assure accurate fuel assay. Each fuel assembly could have a unique fuel composition that the physicist must consider in core neutronic calculation. Every new core load requires, as part of its restart, confirmation of the chemists and physicists work during approach to criticality.

At ANL-W, the analytical chemistry laboratory has been upgraded with state of the art equipment to analyze IFR fuel. The quality program for the IFR must assure the accuracy of the fuel analysis. Procedures must be verified and validated, chemists trained and certified, and a program of checks and balances implemented to provide the required confidence in analytical test results. The quality program for the analytical chemistry should be based upon a standard similar to ANSI/ASME E4, Quality Assurance Program Requirements for Environmental Programs.

The extremely high radiation field from the fuel during the fuel cycle process makes the fuel highly theft resistant. However, the fact that the fuel cycle process must be done in a heavily shielded hot cell facility significantly complicates process control, operation, and maintenance. Process equipment design, manufacturing, checkout, and testing must be done with maximum attention to factors affecting operation and maintenance. For example, when designing a component that is likely to fail, the design must consider remote removal and replacement of the component. Interchangeability is critical, special bolt head configuration may be required to facilitate removal and reinstallation, electrical leads must be capable of remote connection and special features provided for handling the components. Another design consideration is the reduced cooling provided by argon gas cell atmosphere as compared to air. Motors may need derating or additional features added to assist in cooling. Cross-functional design teams should be used to assure designs meet requirements and the design is capable of being manufactured.

With the inherent safety features of the reactor placing less reliance on the skills of operating and maintenance personnel, an attempt might be made to relax the qualifications of the staff. This would be a major mistake. Operator "ownership" of the quality of reactor and the fuel processing facility is key to success of the IFR. Operator/maintenance personnel system knowledge is essential to maximizing plant efficiency and availability. This knowledge must be used in developing procedures and training programs. The improving trend in current nuclear plant availability is at least partly attributable to progressive management techniques that place responsibility for quality on the operating organization management. Self assessment to identify areas for improved performance is one part of a continuous improvement program.

While the focus of a quality assurance program for an Integral Fast Reactor that includes both a reactor and an accompanying fuel processing facility may be changed, there is still a critical need for effective quality assurance programs. The TQM approach is the preferred method for assuring IFR quality. Getting everyone involved in achieving quality from design through to operation is essential. Facility operation, both in the reactor and fuel processing facility, must strive for continuous process improvement. Programs to measure performance against expected standards must be established. Team approach methods for design, procurement, construction, and operation are needed to assure the best approaches are selected and to reduce communication errors.

In summary, the IFR could be an important part of the world's energy future. It provides solutions to many of the technical and societal issues facing nuclear power. For the IFR to perform up to its expectations, the hardware must be effectively operated and managed. The best management system to achieve the promise of the IFR is Total Quality Management.