Similarly to the development of traditional safety systems, passive safety components (devices) shall be designed according to the essential requirements of the nuclear regulations of the Russian Federation.

Along with moving away from the traditional approach to ensuring safety, certain regulatory requirements need to be revised. Some of these have been introduced in response to the peculiarities of traditional safety system devices and are inapplicable to new devices. For example, in view of the expectedly (justified) low probability of failure, the requirement for periodic serviceability inspections of event-actuated passive devices is often needless.

ix. Slovakia

Proposal of movable reflector for fast reactor design
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Since the transient behaviour of the reactor core depends also on the fraction of neutrons that leak out of the core, the core control and reactivity management may benefit from a system of partially moveable reflector incorporated in the design. In fast reactors a larger migration area leading to a significant leak of neutrons can be observed because especially the transport cross-sections are in general smaller as compared to light water reactors. The utilization of a moveable reflector system in conjunction with dedicated safety control rods can increase the ability of accident managing due to enhanced escaping neutrons which otherwise would be reflected back into the fuel zone. The paper demonstrates the possibility of better controlling the transient reactor by additionally moving selected reflector subassemblies equipped with the neutron trap. The main purpose of the analysis of the Gas-cooled Fast Reactor (GFR) presented in the full paper is investigation of the kinetic parameters and of the control and reflector rod worth, as well as optimization of the parts used for partial reflector withdrawal. The results found in this study may serve for future design improvements of other designs such as the liquid metal cooled fast reactors are.

x. Sweden

Autonomous Reactivity Control (ARC) Systems
Staffan A. Qvist, Uppsala University

The next generation of nuclear energy systems must be licensed, constructed, and operated in a manner that will provide a competitively priced supply of energy, keeping in consideration an optimum use of natural resources, while addressing nuclear safety, waste, and proliferation resistance, and the public perception concerns of the countries in which those systems are deployed. These issues are tightly interconnected, and the implementation of passive and inherent safety features is a high priority in all modern reactor designs since it helps to tackle many of the issues at once. To this end, the Autonomous Reactivity Control (ARC) system was developed to ensure excellent inherent safety performance of Generation-IV reactors while having a minimal impact on core performance and economic viability. Properly designed, the ARC-system can act as a thermostat in the core, autonomously controlling temperature without the need for any operator action, electrical systems or indeed any moving mechanical parts. This actuation responds to temperature and relies solely on the laws of physics, and is therefore an inherent feedback mechanism (akin to the fuel Doppler feedback), rather than an engineered "safety system". This paper covers the principles for ARC system design and analysis, the problem of ensuring ARC system response stability and gives examples of the impact of installing ARC systems in well-known fast reactor core systems. It is shown that even with a relatively modest ARC installation, having a near-negligible impact on core performance during standard operation, cores such as the European Sodium Fast Reactor (ESFR) can be made to survive any postulated unprotected transient without coolant boiling or fuel melting.

xi. Ukraine

Passive shutdown of NBW fast reactor using the Autonomous Reactivity Control (ARC) system
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A great interest for the future power engineering presents the development of new concepts of nuclear fission reactors with the so-called intrinsic safety, in which the development of uncontrolled chain nuclear reaction is impossible due to the physical principles of their operation. One of such concepts, proposed by Lev Feoktistov in 1988, is based on the self-sustained nonlinear regime of the nuclear burning wave (NBW) in a fast reactor. The critical state in such a reactor is kept automatically without external control due to a special kind of the negative reactivity feedback inherent to this regime. However, this mechanism does not protect the reactor core from overheating at several types of accidents. For this purpose we intend to use the autonomous reactivity control (ARC) system that is actuated by the inherent physical property of thermal expansion, and does not have an identified failure mode that can introduce positive reactivity in to the core.

We present the results of computer simulation of the ARC system performance in the NBW reactor at the loss of flow accident in the second cooling circuit and during the restart of reactor operation after the accident. The problem is studied by means of numerical simulation of the NBW propagation in such a reactor with the depleted uranium metallic fuel and sodium as a coolant. For the neutronics simulation we use the deterministic approach based on solving the non-stationary neutron diffusion equation using the effective multi-group approximation together with a set of burn-up equations for fuel components and equations of nuclear kinetics for precursor nuclei of delayed neutrons. These calculations are complemented with the thermal-hydraulics simulation of the first sodium coolant circuit in the interaction with ARC system.

Our simulation shows that ARC system shutdowns the reactor in a few minutes without fuel and coolant overheating. We analysed also the interference between two negative reactivity feedback mechanisms inherent to the NBW reactor and ARC system, which appears in the form of certain oscillations of the flux in a few days after the reactor shutdown. As a result of this interference, the system stabilizes automatically at the acceptable temperature (below 550 ºC) when almost all intermediate isotope neptunium decays into plutonium.