All the organisations involved in nuclear power development and generation continue to give increasing attention to the safety and economics of the current and future nuclear power plants. In particular, enormous efforts are being devoted to this subject world-wide by designers, utilities and regulatory bodies as applied to advanced water-cooled reactors. In many future reactor concepts a reasonable coupling of traditional safety systems and new passive means is adopted as the possible way to improve the safety, economics, and the public acceptability of the nuclear power.

Strictly speaking, a reactor system cannot, in general, be rigidly classified only by the two terms “active” and “passive” - we often find both passive and active features existing together in a single system occurring in an existing plant or in an advanced concept. In several IAEA Technical Committee meetings the general definitions, descriptions and explanations of passive/active systems were given. Usually a system should be classified as passive one if no external input is needed to perform its functions; this definition allows the use of instrumentation and the one-time repositioning of valves if adequate passive power supplies (e.g., batteries) are available. One may also ascribe the “degree of passivity” to the system depending on the existence and necessity of the moving fluids, moving mechanical parts and external initiating signals. Otherwise a system is considered as the active one and again the “degree of activity” varies depending on the necessity of human actions and external input to initiate or to operate the system.

A reasonable balance between the passive and active systems is to be established on the basis of a detailed consideration of their advantages and disadvantages as applied to their effect on the overall plant safety and total cost. One of the most essential advantages of a passive system is the independence from external energy supply. The passive systems may be more reliable than the active ones for some design functions. Besides, the use of passive systems decreases the possibility of human errors and makes the plant less sensitive to the plant equipment malfunctions and erroneous operator actions. The main drawbacks of passive systems include the lower driving forces and less possibility to alter the course of an accident if something undesirable happens (i.e., less operational flexibility). The lower driving forces might lead to quite large equipment, and this factor may reduce the cost savings projected from elimination or downsizing of active components. In many cases, there are neither reliable analytical tools nor sufficient operating experience of the passive systems to evaluate their performance under the real plant conditions. So, time- and money-consuming research and development works may be needed individually for each advanced reactor concept. The design decisions in relation of the balancing active/passive features may also depend upon the functions assigned to the given system. In particular, the system having an important role in the mitigation of severe accident consequences in potentially polluted areas (e.g., the part of the containment cooling system which is located inside the containment) could be designed as passive as reasonably achievable. This is because of the difficulty or even impossibility of access to such areas and because of highly reduced or even zero requirement for maintenance of passive components even during long term operation.

Both novel and more or less proven passive systems and features are proposed in many advanced water cooled reactor designs. Some designs have only implemented a few passive features to the traditional systems, and some other designs make widely use of the passive systems to ensure or to back up a number of safety functions, such as reactor shutdown, core cooling, residual heat removal, and confinement of radioactive substances. The Russian advanced WWER-1000/W-392 reactor has the
increased number of gravity-driven scram rods to maintain shutdown margin even in the absence of boron supply. Besides, special quick boron supply system driven by the main coolant pump coastdown has been designed and tested as a diverse system to the gravity-driven scram system for this reactor. A rapid emergency boration system is also implemented in the Sizewell PWR for diverse reactor shutdown (it is operated by the inertia of the main coolant pumps as well). The emergency core cooling in the most of the water cooled reactors (both current and future ones) is ensured by a combination of passive (hydroaccumulators) and active (pumps) features. The tendency for some advanced designs in comparison with the existing plants is to widen the primary pressure range for passive injection and to make it more controllable. American AP-600, Russian W-392 and W-407, Mitsubishi APWR designs could be mentioned as the examples of this tendency. In particular, Mitsubishi APWR designs make use of the advanced accumulator system to ensure the safety functions of core cooling. It has function both the accumulator tank and low pressure injection pump of the conventional plant. So the low pressure injection pumps are eliminated and the safety injection system configuration is simplified. All the advanced concepts imply substantial improvement of the containment functions with respect to the radioactivity confinement in case of a core melt accident. Such functions as containment heat removal, hydrogen management, core debris cooldown and prevention of basement melt-through are probably among the most proper areas for passive systems usage. Many advanced water cooled reactor concepts have implemented or considered different passive means to ensure these functions. For example, the EPR concept with large power while preferring mainly active means for the prevention of core melt accidents also makes largely use of passive systems and components to ensure the containment of radioactivity after such an accident.

The utilisation of passive systems in a reasonable combination with or instead of traditional active systems is being considered as the important measure to enhance the safety in many concepts of the next generation plants. The right balance of active and passive systems can be found only for each advanced concept separately, but the basic criteria for decision-making are the same for the most of the concepts. These criteria are mainly based on the weighing of passive and active system's advantages and disadvantages with regard to the designated functions, overall plant safety and cost. There are some aspects in this area which are very plant specific, e.g. the validation of passive systems for plant conditions, integration of passive features in the overall safety systems, in-service inspection of passive components, etc. These problems have to be addressed by each plant designer to propose the optimal combination of active and passive systems and components. Nevertheless, one can conclude that passive systems/components have clear potential advantages in some applications. This conclusion is particularly true for beyond design basis accidents, and the passive means (systems) are being designed in many advanced reactors for severe accident mitigation. The design basis for these passive means (systems) is to be established with account for probabilistic safety criteria.