Chapter 9
Safety in Nuclear Power: A Proposal

Maurizio Cumo

Abstract. MARS is a fission nuclear reactor developed at the Department of Nuclear Engineering and Energy Conversion of the University of Rome “La Sapienza”. The design was aimed at a multipurpose, modular reactor to be used in high population density areas not only for electricity generation, but also for industrial heat production and, in particular, for water desalination or district heating. This objective, not common for nuclear power plants, required the adoption of very high safety standards not achievable by the use of conventional systems; the only viable approach was the extensive use of “passive” safety. The whole plant is assembled with special flanged connections and even major components of the primary loop, such as the reactor vessel and the steam generator, may be easily substituted or repaired. The cost of KWh is competitive with that of large reactors.

Key words: Nuclear power plant, nuclear safety, generation III+, inherent safety, passive safety, decommissioning.

9.1 Introduction

Modern nuclear power plants, in order to be accepted and widely used, must be based on new safety targets and design criteria, with the principle rule that the overall safety is not impaired by component failures or malfunctioning, nor by human errors: the most reliable approach is to utilise incontrovertible natural laws to perform any protection action needed. This philosophy leads to the identification of plant and component solutions relying on “inherent safety” and generally utilising passive components instead of active ones and static components instead of moving ones. Inherent safety concepts must be applied not only to the functional design of circuits, but also to the structural design of components, structures and buildings.

The MARS (Multipurpose Advanced Reactor, inherently Safe) nuclear reactor, developed at the Department of Nuclear Engineering and Energy Conversions of the

University of Rome “La Sapienza?, belongs to the generation of “inherently safe” nuclear reactors and may be classified as a “Generation III+” reactor. Its concept emphasises the “prevention approach” up to extreme consequences, making any component relevant to safety practically free from primary stresses, thus highly reducing the probability of their failure. These results are achieved thanks to the new design of the primary loop, of its auxiliaries and of the whole primary building.

The MARS design was originally conceived with the purpose to adopt only passive safety systems, so as to reach the condition of an inherently safe reactor. However, the removal of residual decay heat with natural circulation of water, together with the economic competitiveness of the plant, imposes a limit on the size of the plant. In this sense, 600 thermal MW power represents an optimal compromise. So, looking for a proper market niche, the small-medium size is particularly fit for countries which have a limited electric network for transmission. Some of these countries have also a shortage of desalinated water and the MARS plant has also been studied in a cogenerative version, electricity plus heat for desalination of water.

Other characteristics have been progressively developed along the design line: the modularity of the plant to facilitate a chain production in factories, which was possible only with the introduction of flanged connections by means of an external steel envelope which practically annuls the pressure difference in the primary loop confinement. The possibility to assemble the reactor from pieces on the site, while all the construction work is done in factories ensuring all the necessary quality controls in clean environment, thus reducing construction times and costs. The reactor life is prolonged to over a century through easy substitutions and, all the plant structures being made of steel, at the end the decommissioning costs are greatly reduced. A small part of the total steel used that is radio-activate, can be melted and frozen directly in the form of final waste, while its largest part can be recycled.

The huge increase in oil (and gas) prices has recently drawn attention to the competitiveness of nuclear energy and a greater interest, worldwide, has been focussed on small-to-medium size plants. For instance, a recent initiative of the US DOE (Department of Energy), called Global Nuclear Energy Partnership (GNEP), which received attention in France, Russia, Japan, and other countries, is applicable also to countries that are interested in building small-medium size plants. These countries will have the possibility to employ such reactors, even in co-generation of electricity-heat, receiving fuel from countries that have enrichment and reprocessing plants at a pre-defined, convenient cost equal to that of the selling countries. The only condition to subscribe is that, to avoid risks of proliferation, all the irradiated fuel must be given back when receiving new, fresh fuel. In this case, for instance, the MARS reactor might be employed. Recent developments in the MARS nuclear design, devised jointly with CEA researchers, have held out the possibility of raising enrichment and burn-up, thus prolonging fuel life up to five years, and in the meantime neutralising the boric acid content (and the complication of the related systems) through its substitution with burnable poisons.