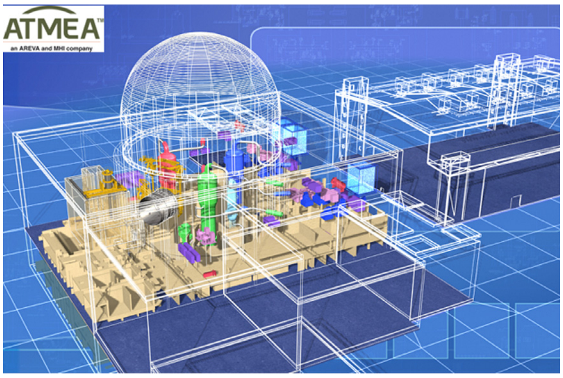
Concepts and Features of ATMEA1™ as the latest 1100 MWe-class 3-Loop PWR Plant



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ATMEA1™ is a 3-loop 1100 MWe-class of the latest Generation III+ PWR plant under development by ATMEA™, which is a joint venture established by MHI (Mitsubishi Heavy Industries, Ltd.) and AREVA, two world-leading nuclear plant suppliers. ATMEA1™'s high reliability is ensured by proven technologies superior operating performance, top-level safety features, flexible operability in response to customer needs, high adaptability to various site conditions, and high licensing certainty. ATMEA™ will complete the basic design by the end of 2009 and will deploy design certification activities, detailed design, and marketing activities hereafter.

1. Introduction

Many countries that plan to introduce nuclear power plants (NPPs) in the near future strongly need 1100 MWe-class PWRs from the viewpoint of power demand and/or grid capacity. To meet these requirements, MHI and AREVA that are 2 world-leading nuclear suppliers established the joint venture ATMEA™. This new joint venture is promoting the development of ATMEA1™, which is a 3-loop Generation III+ PWR, by combining the latest technologies held by the 2 companies.

ATMEA™ is responsible for development, marketing, sales, licensing, and all technical and business operations of ATMEA1™. To complete the development within a short period, it has introduced a new approach, i.e., effective utilization of both companies' facilities and designers, as well as the utilization of their latest technologies and experience in construction and licensing. ATMEA™ is planning to complete the basic design by the end of this year.

2. Concepts of the ATMEA1™ plant

ATMEA1™ generates a net electric power of 1100 MWe with a 3-loop configuration, which is the same output level as Japanese existing 4-loop PWRs. Fuel assemblies are 4200 mm long type, and 157 assemblies are installed in the core. The safety system features 3 trains that fit the 3-loop design and these trains are independent, each train being connected to 1 loop. Each train has sufficient capacity to ensure the required safety functions for a whole plant and consists of highly reliable active components and is partially complemented by passive components such as advanced accumulators.

ATMEA1™ incorporates a pre-stressed concrete containment vessel (PCCV) whose construction design has been proven in 4-loop PWRs. The PCCV is also designed for protecting the reactor from large commercial aircraft crash accidents. In addition, the latest full digital I&C design is introduced to reduce human errors and improve the operational reliability. **Table 1** lists the main features of ATMEA1™.

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Table 1 ATMEA1™ Main Features

	ATMEA1™	Remarks
Electrical output (Net)	1 100 to 1 150 MWe	Obtain electric output with 10% less thermal output, which results in less generation cost and less spent fuel.
Thermal output	3 150 MWth	
No. of fuel assemblies / effective length of fuel assembly	157 / 4.2 m	Standard specifications
Primary system loop configuration	3 loops	The output per loop is similar to that of the latest plants (APWR and EPR™).
Safety system configuration	3 trains	Each train mainly consists of reliable active components and partially complemented by passive components.
Steam generator	with axial economizer	A proven high-efficiency design is used.
Main steam pressure	7.3 MPa	World top-level pressure is achieved.
Thermal efficiency (Net)	35 to 37%	The thermal efficiency depends on the site conditions.
CV design	Pre-stressed concrete CV	The CV design endures the impact of an aircraft.

3. Features of ATMEA1™

The features of ATMEA1™ are summarized as follows:

(i) established reliability supported by proven technologies;

(ii) superior operation performance; and

(iii) top-level safety as Generation III+ plant.

Described below are these advantages :

3.1 Established reliability supported by proven technologies

MHI and AREVA have a large experience in the design and construction of more than 130 nuclear power plants. To design ATMEA1™, ATMEA™ utilizes these technologies, systems, and components that were validated through such experience, as well as those technologies of APWR/EPR™ that are latest PWR plants of MHI and AREVA.

The ATMEA1™ design fully complies with U.S. regulations, codes, standards, and ICRP (International Commission on Radiological Protection) requirements. Japanese and European regulations are also considered in this design. The IAEA (International Atomic Energy Agency) completed its review of ATMEA1™'s safety features in June 2008 and concluded that the new plant's design adequately addresses the IAEA's fundamental safety principles as well as key design and safety requirements.

The ATMEA1™ design also addresses the latest regulatory trends in, for example, severe accident (core melt-down accident) and aircraft crash protection that will be required for future plants mainly in the U.S. and European countries, based on proven and validated technologies.

Therefore, ATMEA1™ has high reliability and licensing certainty by applying the latest and fully validated technologies. We describe the main characteristics as follows :

(1) Heavy neutron reflector

The heavy neutron reflector is a proven design applied to MHI's APWR plants and AREVA's EPR™ plants. Stainless steel ring blocks surround the core to reduce neutron irradiation toward the RV to extend the life of the plant, increase reliability, and improve fuel economy through the effective utilization of neutrons. Also, each ring block is bound by a tie rod to remove fixation bolts within the high irradiation area, contributing to reduction in maintenance workload and achievement of high plant reliability and availability factor.

(2) Steam generator with axial economizer

The steam generator with axial economizer is a proven design employed in France. The feedwater to the steam generator is delivered to the cold leg side and flows down in parallel to these tubes to ensure sufficient temperature exchange between primary and secondary systems and thus increase the heat transfer efficiency of the steam generator and the main steam pressure, achieving improved plant thermal efficiency. **Figure 1** shows the steam generator with axial economizer.

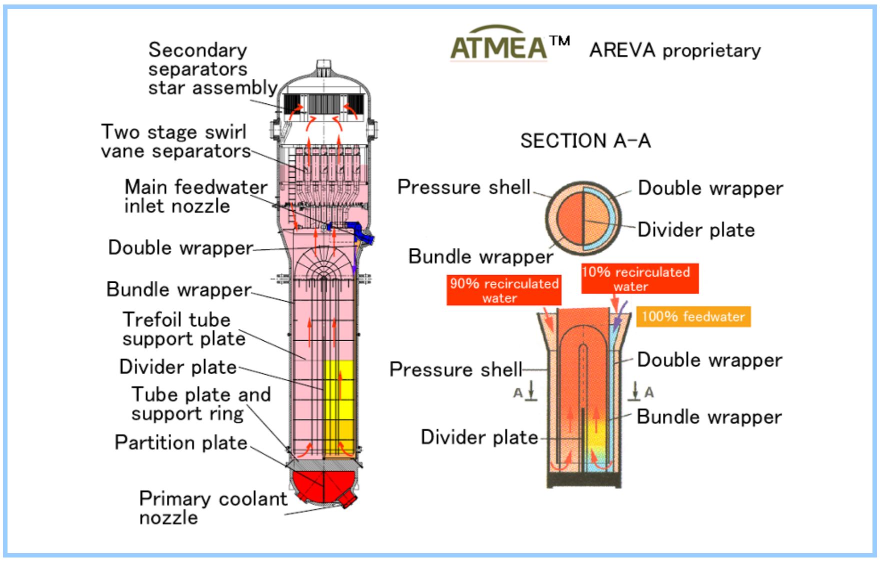

Figure 1 Steam generator with axial economizer
This figure shows the steam generator with axial economizer and the temperature distribution in the steam generator.

(3) Top-mounted in-core instrumentation

The in-core instrumentation is inserted into the RV from the top in order to remove the bottom RV penetration nozzles thus improving the reliability of the plant. This design has been applied to AREVA's plants as well as to MHI's latest plant to be exported to foreign countries. Accurately measuring the in-core power distribution can address diversified operational requirements while maintaining the proper operational margin. A proven structural design (lance-yoke structure) is used for detector guides to minimize maintenance workload.

(4) Emergency power source equipment

Diesel generators, which we have a lot of experience with, are used as the standard design of ATMEA1™ for emergency power source. On the other hand, gas turbine generators that contribute to reduce maintenance costs and building volume and that will be used for the MHI's latest foreign plants are under planning as an alternative design.

(5) Digitalized I&C at the MCR

Proven full digital technologies improve man-machine interfaces, achieve automatic operation, and reduce human error probability through advanced signal processing.

3.2 Superior operation performance

ATMEA1™ allows economical operation of the NPP through achievement of high thermal efficiency and plant availability. Also, ATMEA1™ has sophisticated load-follow and frequency control capabilities, as well as flexible adaptation to utilities' requirements such as long operation cycles and MOX (mixed oxide) fuel loading.

(1) High thermal efficiency y

As a standard design, ATMEA1™ can achieve an electrical output of 1150 MWe (Net) and 37% thermal efficiency under a thermal output of 3150 MW. This high electrical output and efficiency are accomplished by a high steam pressure of 7.3 MPa through the optimization of the primary circuit temperature and flow rate, and introduction of a steam generator with axial economizer, as well as the latest turbine generator technologies. ATMEA1™ offers 10% more electrical output with the same thermal output in comparison with operating NPPs.

(2) High design availability

ATMEA1™ is designed to achieve a very high availability through 60-year total plant design life. To this end, the duration of normal refueling outage is 16 days or shorter by applying the following design features:

(i) On-power maintenance ensured by redundant design of support systems

Since the maintenance of the component cooling system, the essential service water system, and the emergency power source equipment becomes a critical path in the periodic inspection schedule, a design is introduced whereby, in addition to 3-train configuration, 1 additional backup train (division X) will be activated in case of maintenance activities so that these systems can be serviced even during plant operation. Switching the load from the normal train to division X allows preventive and corrective maintenance during plant operation.

(ii) Accessible reactor building design during plant operation

In this design, the inside of the reactor building is divided into 2 areas. Allowing maintenance staff to access the operation floor and the outside area of the secondary shield wall enables pre- and post-outage work inside the reactor building. This design can reduce the duration of periodic inspection. **Figure 2** shows accessible areas inside the reactor building during plant operation.

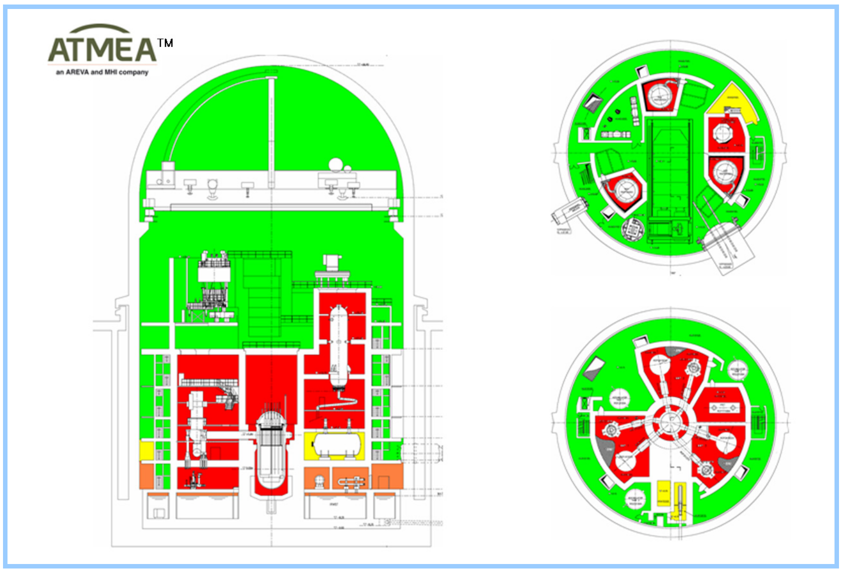

Figure 2 Accessible areas inside the reactor building during plant operation
Maintenance staff can access the green areas (operation floor and outside of the secondary shield) during plant operation.

(3) Flexible adaptation to operational and site conditions

ATMEA1™ can flexibly address the following operational and site conditions based on customer needs.

- The operation cycle can be set between 12 and 24 months.
- Sophisticated load-follow and frequency control capabilities can be achieved.
- Up to 100% (full) MOX fuel loading is acceptable.
- Grid frequencies of 50 and 60 Hz are acceptable.
- Various heat sink conditions are acceptable without drastic change in the plant design.
- The standard seismic design condition is 0.3g-SSE (based on the U.S. NRC Regulatory Guide), and the plant design can adapt to conditions of high-seismicity sites.
- The plant design can address hard, medium, and soft soil conditions. (The design is consistent with EUR (European Utilities Requirement.)

3.3 Top-level safety as Generation III+ plant

The probability of core damage and large radiological release in ATMEA1™ is 10 times lower than that in existing PWRs since the well-considered redundancy design and clear segregation of safety-related systems and components achieve higher plant safety and reliability. In addition, ATMEA1™ can continuously ensure the integrity of the containment vessel for longer periods after a severe accident (core melt-down accident) or large commercial aircraft crash impact in response to the latest regulatory trends required for future plants mainly in the U.S. and European countries.

As a result, ATMEA1™ has the top-level safety in the world and provides a relief to residents around site areas.

Listed below are typical safety features :

(1) Independent 3-train safety system configuration

ATMEA1^{TM} is equipped with 3 independent ECCS train systems and 1 train alone can achieve the complete safe shutdown and residual heat removal. This system mainly consists of active components that can sufficiently mitigate accidents, complemented by passive systems, such as advanced accumulators and in-containment refueling water storage pits. Optimization of active and passive systems improves both reliability and economy. Moreover, a clear segregation design concept is applied between trains and between safety and operational systems.

These design arrangements optimize reliability and economy. **Figure 3** shows the system configuration of the ECCS.

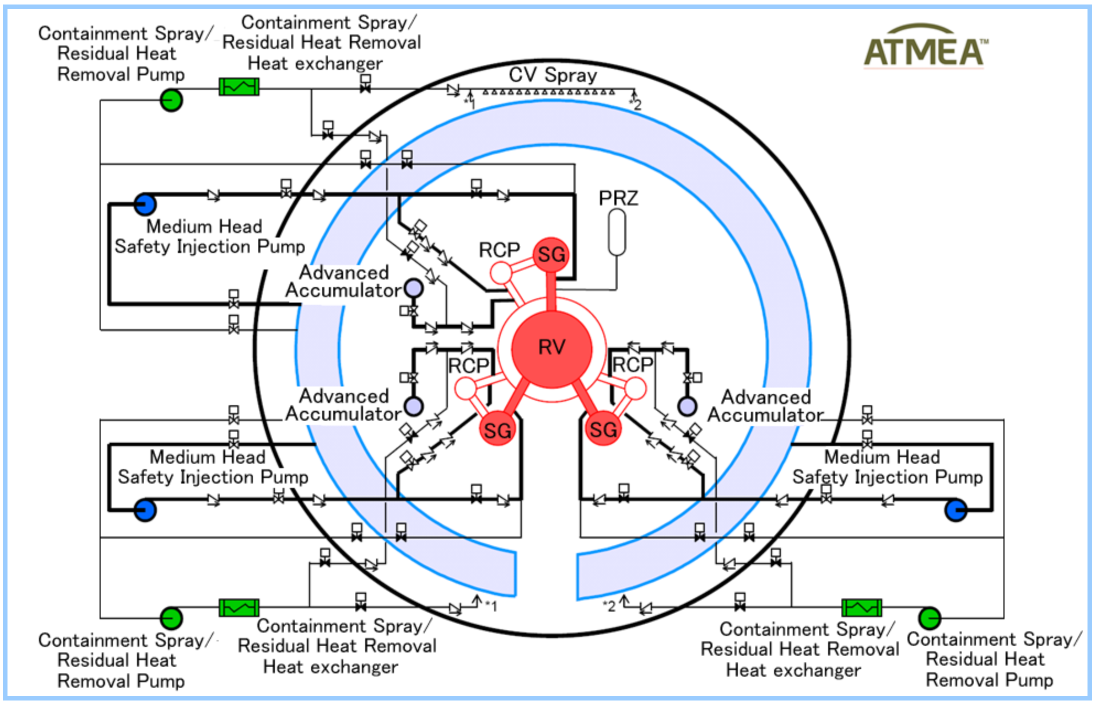

Figure 3 Independent 3-train safety system configuration
This figure shows independent safety system trains.

(2) Advanced accumulator

ATMEA1^{TM} uses advanced accumulators, similar to MHI's latest nuclear plants. The flow damper statically switches the injection flow rate from the accumulator. This design allows the accumulator to act as a low-pressure injection pump and, therefore, low-pressure injection pumps are removed to simplify the system. Since the injection time of the accumulator tank is prolonged to mitigate the requirements for startup time of the safety injection pump, it is possible to make the design requirements for EPS extensively less stringent.

(3) Core catcher

ATMEA1^{TM} is equipped with a core catcher that ensures the integrity of the containment vessel for a long period even in a severe accident. The core catcher consists of a heat-resistant floor and cooling water-supply system to keep the molten core stable and cool for a long period upon occurrence of a severe accident. This design concept is incorporated into AREVA's latest plants and is consistent with European regulations.

Figure 4 shows a schematic figure of the core catcher.

(4) Protection from large commercial aircraft crash accidents

ATMEA1^{TM} is equipped with PCCV and features thicker walls to protect the components installed in the containment from large commercial aircraft crash accidents. Facilities necessary to ensure the safety functions located in surrounding buildings are designed to be protected from the impact of an aircraft crash by means of building wall increased thicknesses and a distance-based geographical segregation design concept.

Figure 5 shows a schematic figure of the protective measures against aircraft crash accidents.

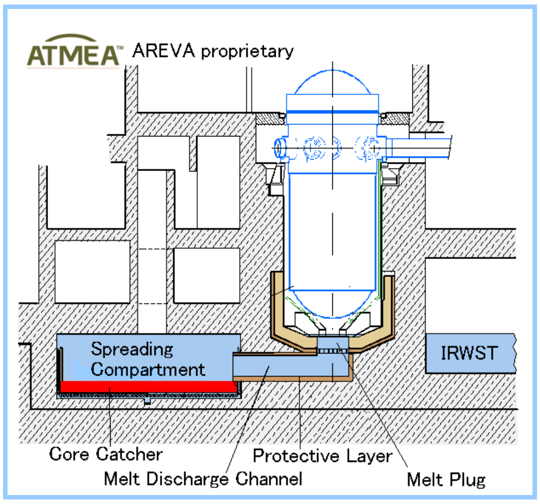

Figure 4 Core catcher (schematic)
This figure shows the structural concept of the core catcher.

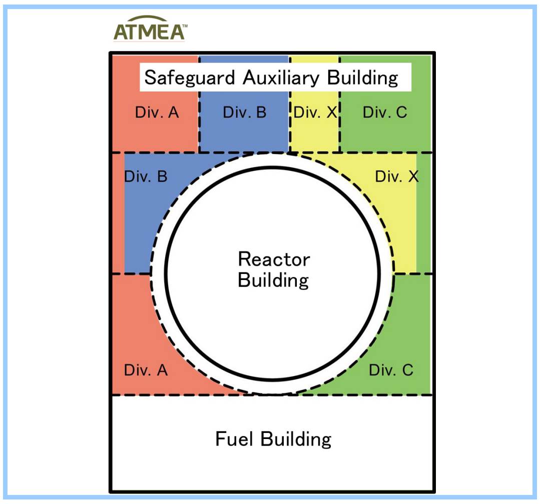

Figure 6 Area separation design concept
This figure shows the layout of each area in the safety system.

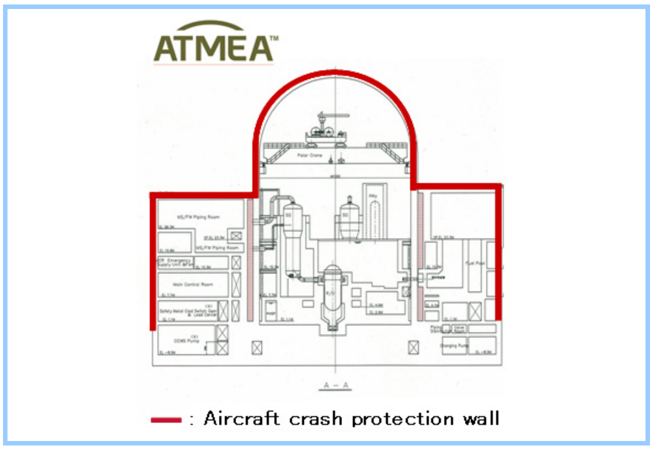

Figure 5 Aircraft crash accident protection concept
This figure shows the range where the wall thickness is increased to protect the reactor from an aircraft crash accident.

4. Layout Design of ATMEA1™

The layout design of ATMEA1™ is based on MHI's design through much experience in construction of PWRs, especially under high-seismicity like in Japan. To provide higher seismicity resistance, a rectangular shape is used for the buildings in which safety-related components are installed (reactor building, fuel-handling building, and safeguard building) so that the components can be easily installed on a common base-mat.

The train in each safety system is arranged in a completely separated area. Each area is physically separated from other areas by means of walls and floors so that an internal event (such as fire) generated in an area will not spread to other areas. **Figure 6** shows the area separation design concept.

5. Conclusion

ATMEA1™ is a 3-loop 1100 MWe-class Generation III+ PWR plant that features established reliability supported by proven technologies, higher thermal efficiency and availability, and top-level safety. It also offers flexible operability in response to customer needs, adapts to various site conditions, and assures high licensing certainty.

ATMEA1™ is being actively developed by ATMEA™, a joint venture established by MHI and AREVA, both of which are world-leading nuclear plant suppliers. The basic design will be completed by the end of this year. MHI will strongly support the design certification, detailed design, and marketing activities so that ATMEA1™ will be introduced in several countries over the world.