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PASCAR - a Small Modular Reactor for PEACER Demonstration

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1. Introduction

The proliferation-resistant, environment-friendly accident tolerant continual & economical reactors (PEACER's) have been developed at NUTRECK, aiming at avoiding spent nuclear fuel disposal in geological formations by recycling and burning while assuring proliferation-resistance, safety, overall fuel cycle economy. Based on PEACER developments, a proliferation-resistant accident-tolerant self-supported, capsular and assured reactor (PASCAR) has been designed to have a representative rating of 100MW (thermal), relying entirely on outstanding natural circulation capability of LBE. Applications of PASCAR are two-fold: 1) demonstration of high level waste transmutation capability with inherent proliferation-resitance and safety, and 2) development as a robust modular reactor for remote or harsh environments.

Like PEACER design, PASCAR designs have achieved unparalleled proliferation resistance, accident tolerance and economical viability, as described herein.

2. PASCAR Design

The PASCAR reactor design proposed by NUTRECK, is for a small, modular, pool-type, lead-bismuth liquid metal cooled reactor producing maximum 100MW (thermal) power. Fig. 1. is a cut-away view of the reactor module. PASCAR module is located in its own below-grade silo and is connected to pyro-processing plant by fuel transporter. The steam generator and secondary system hardware are also in below-grade silo. The PASCAR was proposed a 60-year design life time. The main plant characteristics are provided in Table I.

The reactor module is approximately 8m high and about 5m in diameter. The reactor module and its associated components are seismically isolated. The reactor module is enclosed by reactor vessel enclosure, reactor vessel, and guard vessel. Reactor vessel is surrounded by reactor vessel auxiliary cooling system (RVACS) to remove decay heat during accident. Two RVACS stacks on the ground inhale cool air and exhaust heated air. Chemical and volume control system (CVCS) located on the reactor module removes radiation toxicity gas, store coolant, control coolant level and manage cover gas.

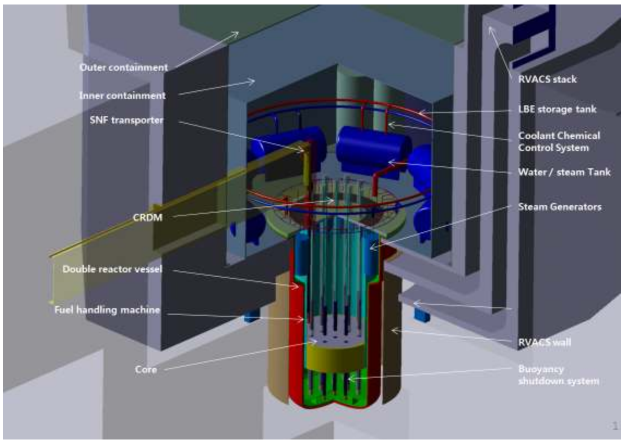

Fig. 1. PASCAR reactor module

Table I
Main Design Parameters of PASCAR

Parameter	Value
Power (Mwe/MWt/Efficiency)	35/100/35
Fuel	U(70%)-Zr(30%)
Fuel Assembly Type	Metallic fuel Square open
Coolant	Pb(44.5%), Bi(55.5%)
Core lifetime(year)	~20
Fuel Pin Diameter (cm)	0.83
Fuel Pin Pitch Pin to Diameter Ratio	1.3
Active Core Dimensions Height / Diameter (m)	1.1 / 3.3
Control Rods Material	B_4C
# of Control Rod Assemblies	12
Reactor Vessel Diameter / Height (m)	4.94 / 9.12
Core Temperature(℃)	383(outlet) 306(inlet)
# of Steam Generators	20
Primary Coolant Flow Rate (kg/sec)	8,985
Secondary Coolant	Water-Steam

2.1 Core Design

The main goal in core designs was to achieve a 20 year lifetime with no refueling. The PASCAR core (Fig. 2) is designed to use metallic fuel. Fuel rod consists of 70% U and 30% Zr, fuel assembly type is open square type. There are 320 fuel assemblies in the active core, each fuel assembly has 188 fuel rods. Reactivity and power are controlled by eight independent control rod assemblies made of B_4C. The reactor core is designed to utilize passive reactivity feedback mechanisms to give a negative reactivity coefficient for all design-basis transients. A buoyancy shutdown system is located on the bottom of the reactor vessel, the poisoning materials would rise and be inserted in the active core by buoyancy if the accidents break out.

After 20 years operation or if necessary, fuel can be replaced by fresh fuel by fuel handling machine.

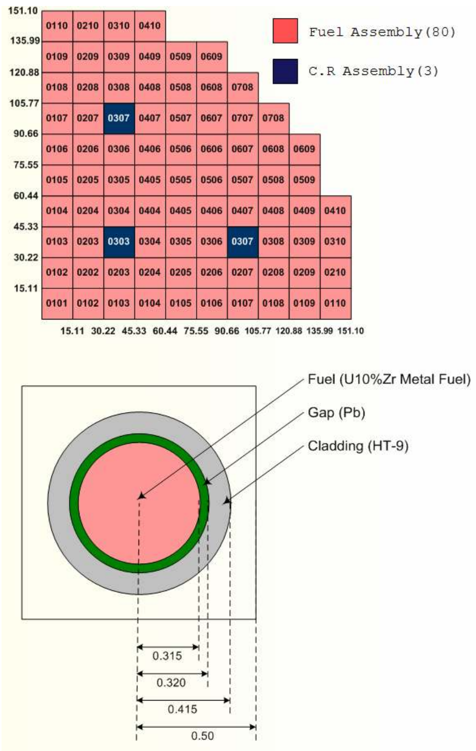

Fig. 2. PASCAR core.

2.2 Thermo-hydraulic analysis

PASCAR's coolant is liquid LBE which removes the heat generated by the core and transport the energy to the steam generators. LBE is harnessed by natural circulation, and the LBE's natural circulation ability was tested by LBE test loop, HELIOS. Table II shows the result of natural circulation ability of PASCAR with hand calculation and MARS code simulation. As a result, the operation temperatures does not exceed 400°C which is not tough environment for PASCAR's materials.

TABLE II
The result of hand calculation and MARS code predicting natural circulation

Parameter	Hand Calculation	MARS Code
Total Pressure Drop (Pa)	5209.4	4972.2
Mass Flow rate (kg/s)	8396.5	8985.2
Fluid velocity in Core (m/s)	0.1214	0.1309
ΔT (K)	81.71	76.53
(Core outlet T – Core Inlet T)		
Core outlet T (° C)	Not calculated	382.15
Core inlet T (° C)		306.32

3. Conclusions

PASCAR design is expected to be suitable for a small modular reactor by assessment of following features.

- Proliferation-resistant
  - Once fuel has been inserted in reactor initially, there is no need to take it out from reactor for 20 years.
  - From manufacturing to withdrawal, whole process is under UN's surveillance.
- Accident-tolerant
  - LBE is chemically stable. Therefore, there is no worry if there is coolant leakage.
  - Pool type reactor has little loss of flow risk.
  - Guard vessel surrounding reactor vessel can prevent coolant leakage though there is rupture on the reactor vessel.
  - Passive cooling system by primary coolant and RVACS can remove decay heat if there is accident.
  - No pressurization can protect reactor from some problems come from high pressure.
- Economical-viability
  - Because of PASCAR modularization, whole components can be produced in large quantities under same processes.
  - Simple reactor structure makes the construction and maintenance cost low.

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