


HTGR Technology Course for the Nuclear Regulatory Commission

May 24 – 27, 2010

Module 10d Reactor Cavity Cooling System

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Outline

- 
- **RCCS functions and requirements**
 - **Passive heat removal in modular HTGRs**
 - **RCCS configuration**
 - **RCCS design concepts**
 - **RCCS performance**

RCCS System Functions and Requirements

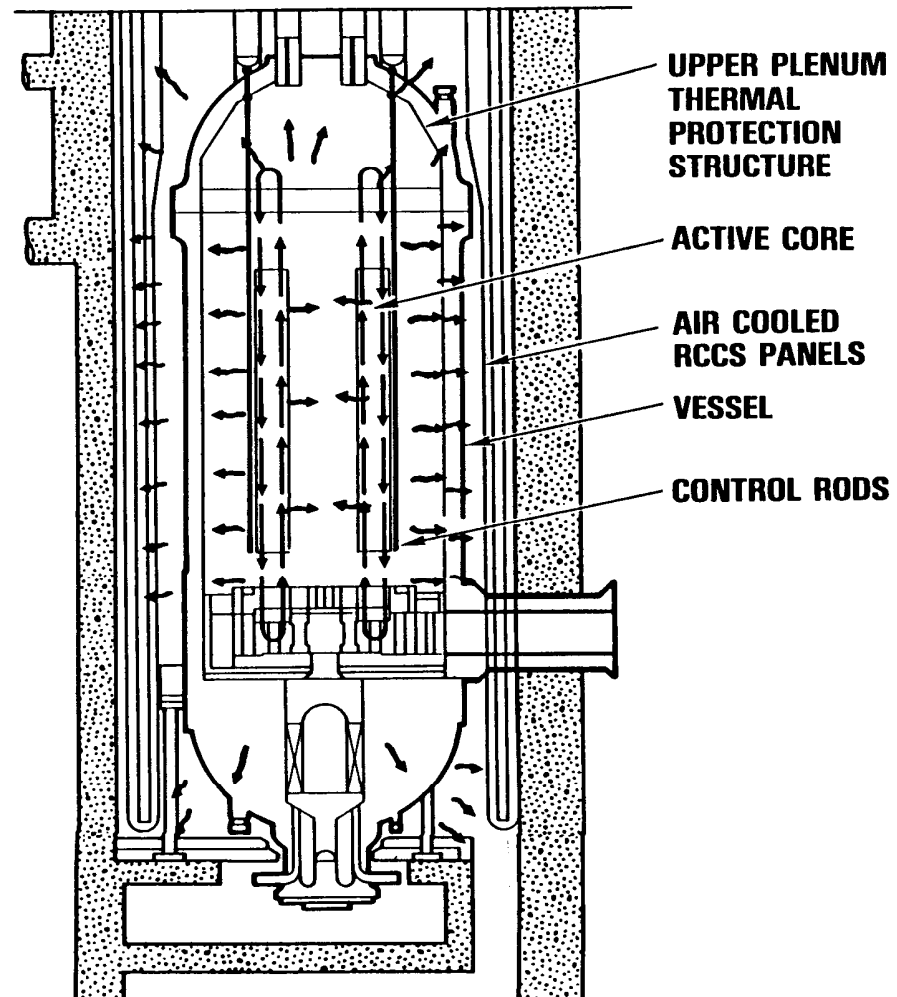
- **Normal operation**
 - Control cavity concrete temperatures
 - Cool reactor vessel (for some concepts)
- **Accident conditions**
 - Control cavity concrete temperatures
 - Control reactor vessel temperatures
 - Residual heat removal
- **Passive operation during accidents (typical)**
- **Safety-related heat removal system (typical)**
- **Redundant loops (typical)**

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Overview of Passive Decay Heat Removal in Modular HTGRs

- **In reactor vessel**
 - Conduction
 - Radiation
 - Convection (pressurized)
 - Heat capacity
- **In reactor cavity**
 - Radiation
 - Convection
- **In RCCS**
 - Conduction
 - Convection
 - Evaporation



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General RCCS Configuration Considerations

- **RCCS heat absorber structures shield cavity wall surrounding reactor vessel active core height**
 - Air ducts
 - Panels
 - Stand pipes
- **RCCS fluid circulates through heat absorber structures to remove heat from cavity**
- **RCCS fluid**
 - Air
 - Water
- **RCCS isolation from atmosphere**
 - Open to atmosphere
 - Separated by HX
- **Passive and/or active operation**

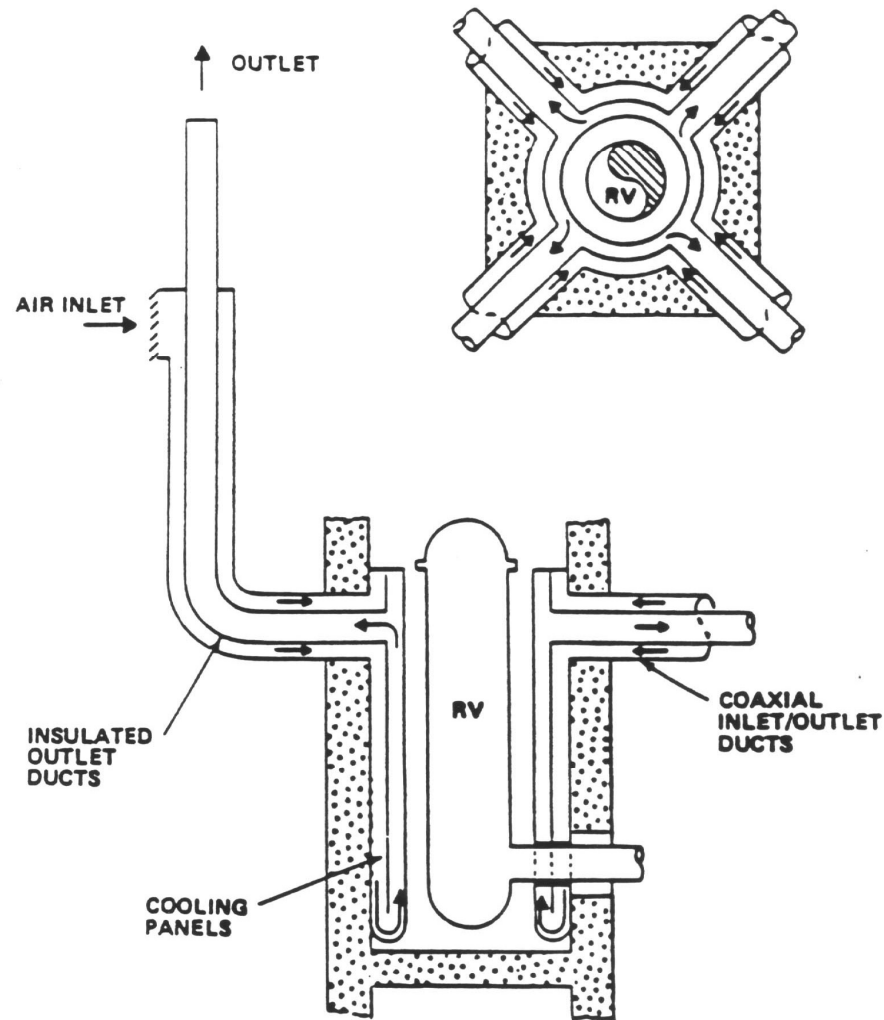
Outline

- **RCCS functions and requirements**
- **Passive heat removal in modular HTGRs**
- **RCCS configuration**
- ➔ • **RCCS design concepts**
 - MHTGR
 - NP-MHTGR
 - PBMR-DPP
 - AREVA
- **RCCS performance**

RCCS Concepts

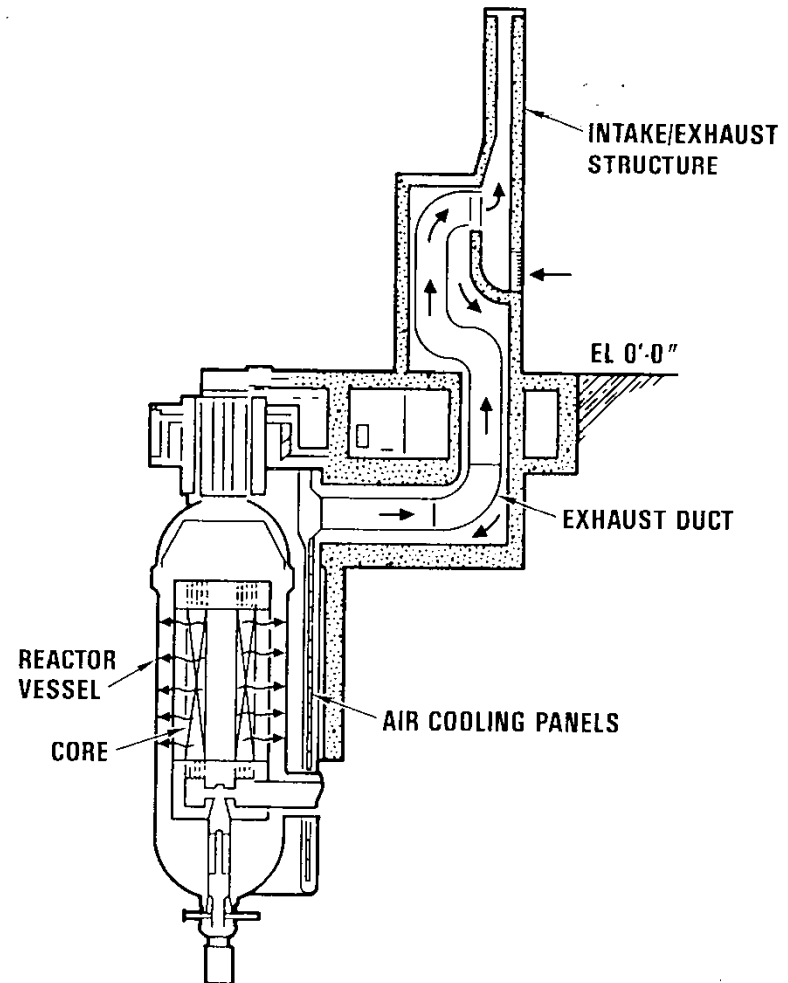
- **A large variety of possible RCCS concepts**
- **Current vendor approaches provide examples**

Overview of Air-Cooled RCCS Concept



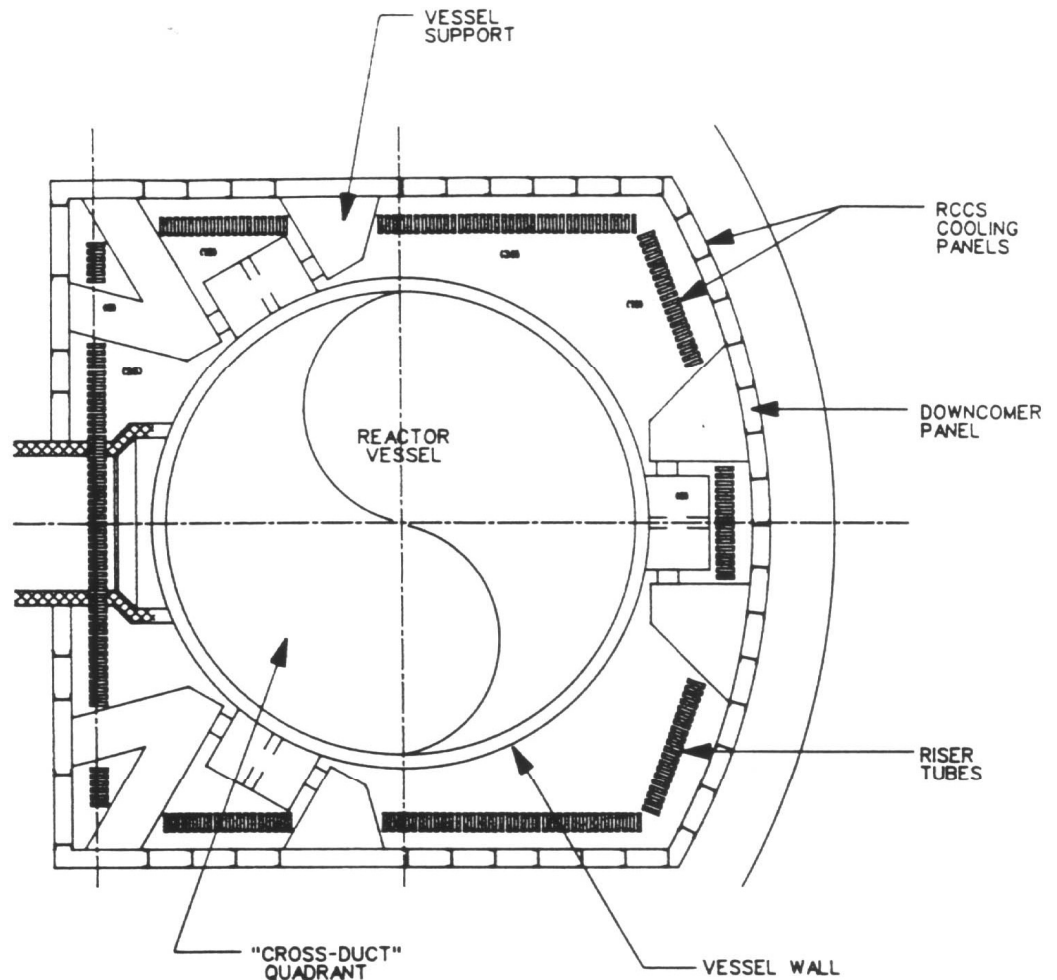
MHTGR RCCS Concept

- Air-cooled
- Natural circulation
- Multiple flow paths
- Intake/exhaust structure to mitigate external effects



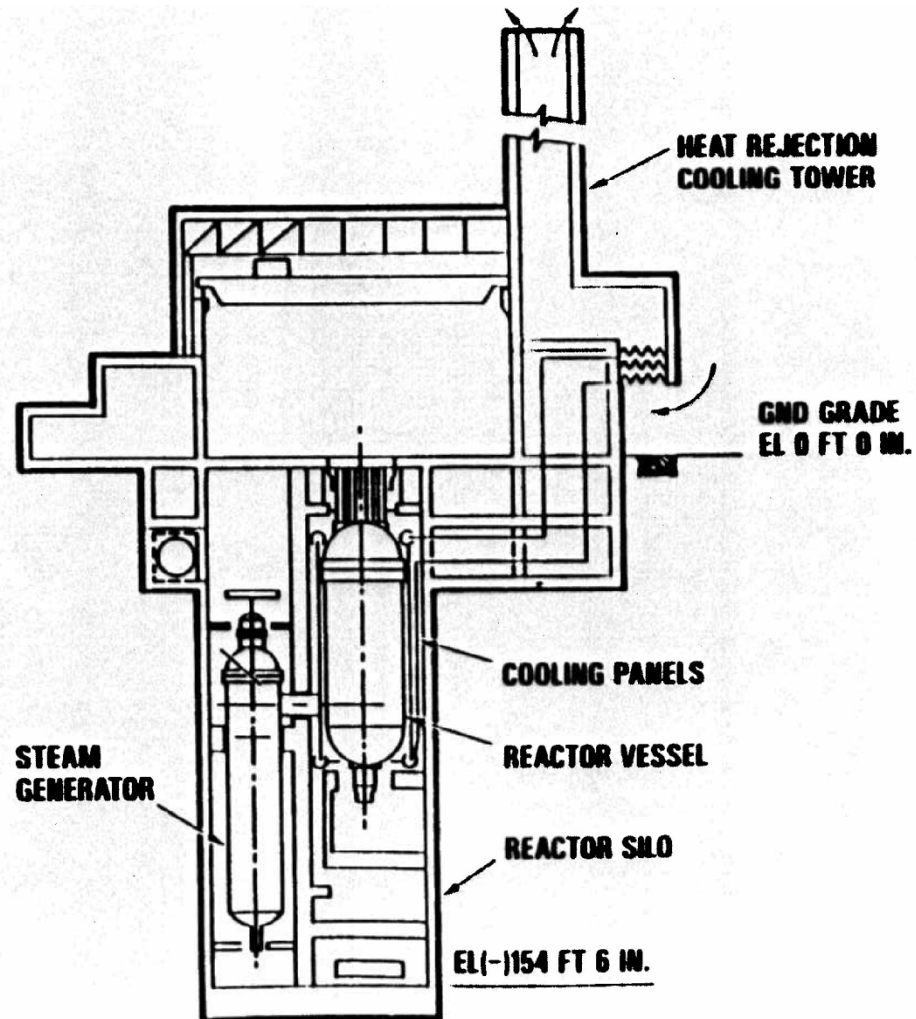
MHTGR RCCS Arrangement

- Staggered riser channels create “black” surface
- Riser channels form part of cavity boundary
- Leaks provide escape path
- No loss of coolant
- Activation of air impurities considered during design



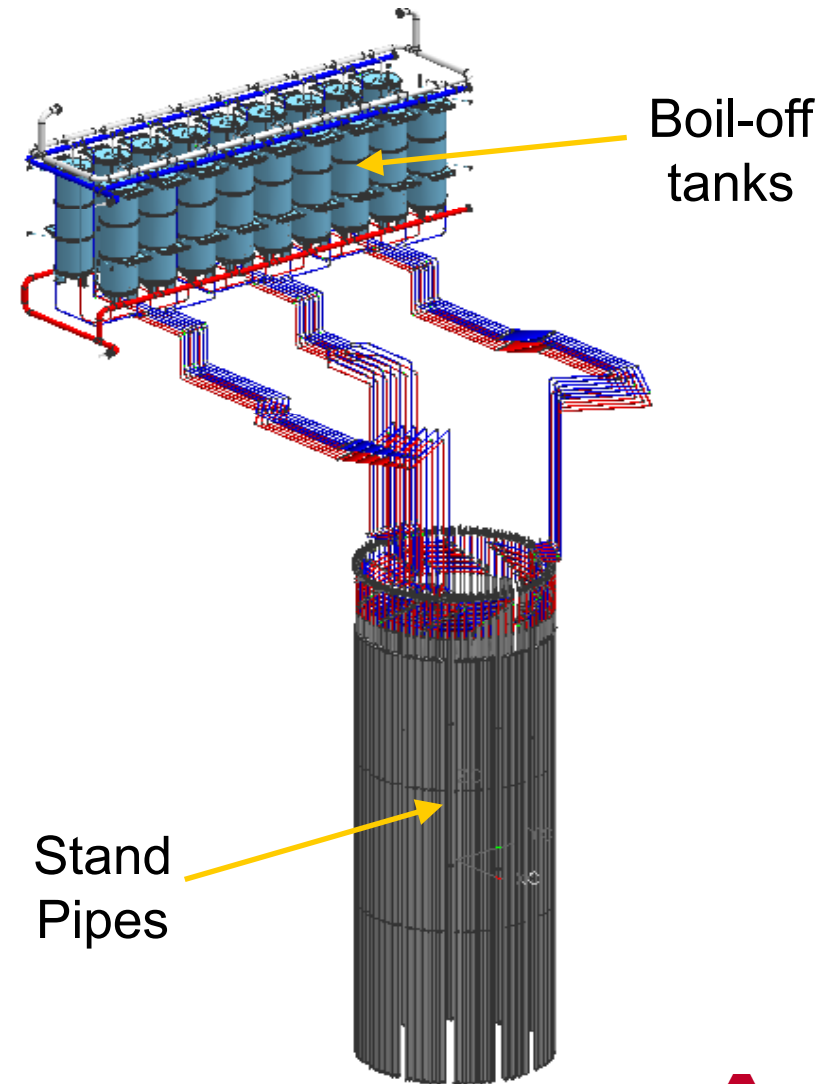
NP-MHTGR RCCS Concept

- Water loop in cavity
- Heat pipes transfer heat to air in chimney
- Redundant loops
- All natural circulation
- Head requirements for water and air loops leads to tall structure

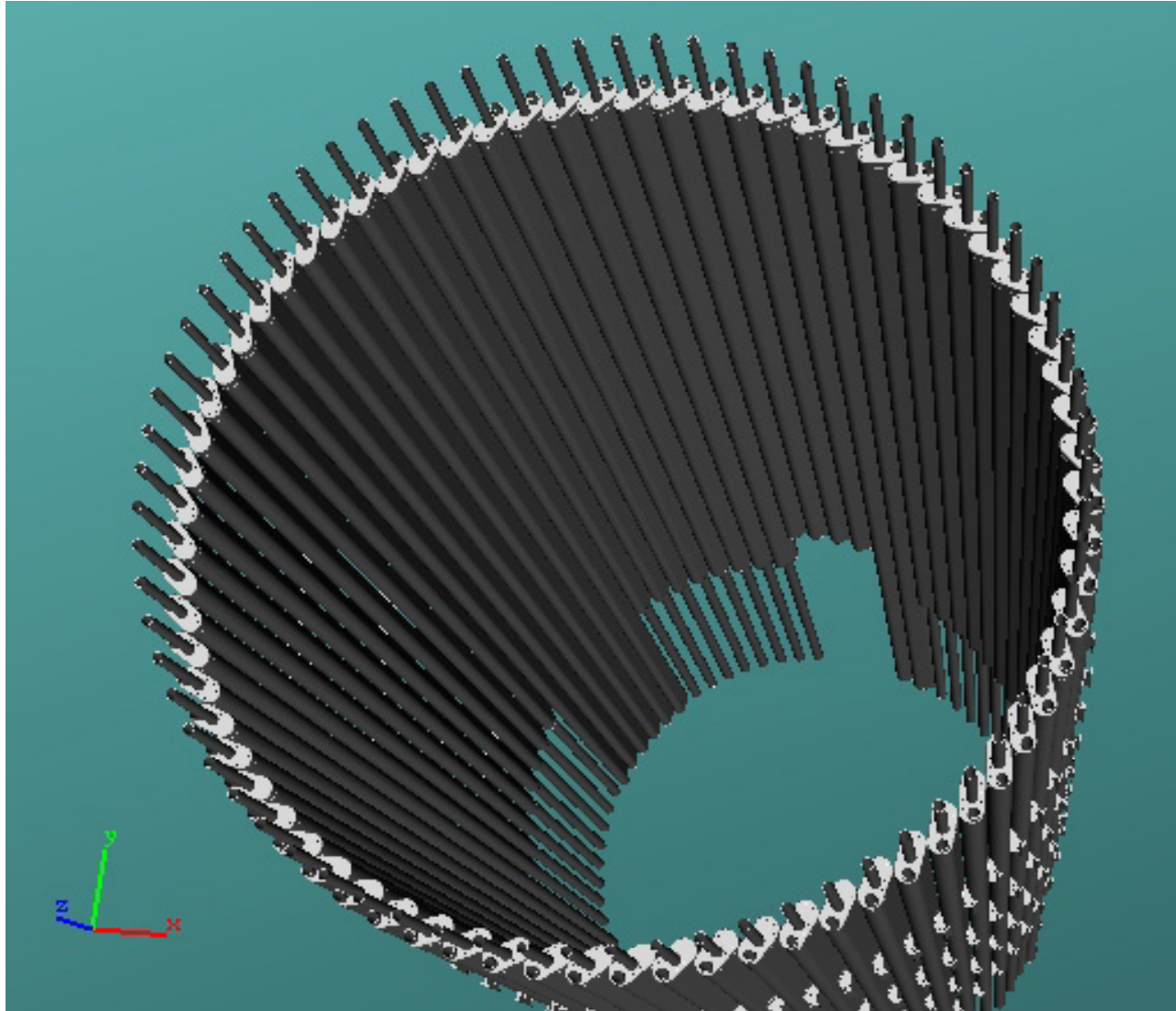


PBMR-DPP RCCS Concept

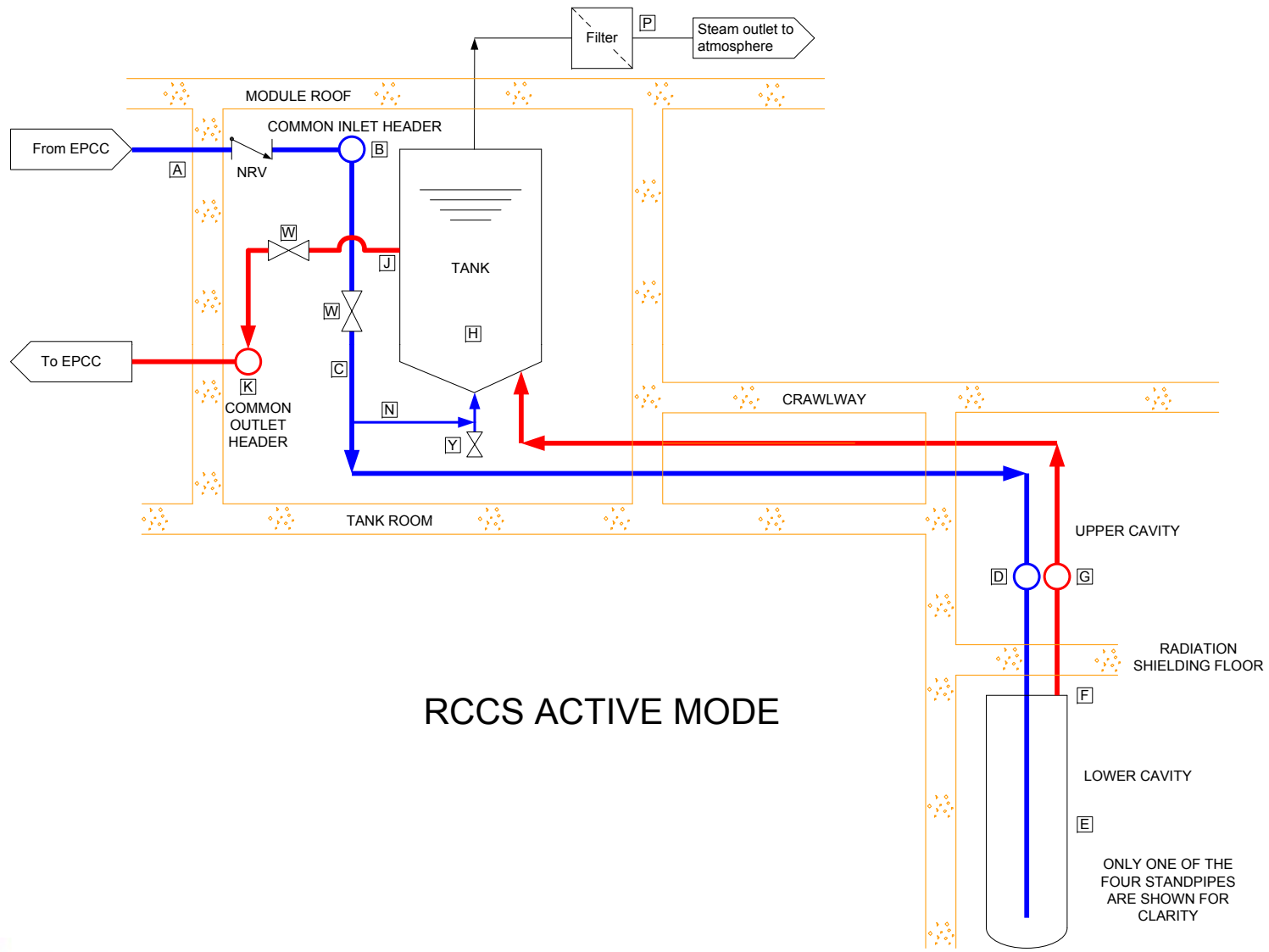
- **Water-cooled**
- **Standpipes surround vessel**
- **18 independent circuits**
 - 1 tank
 - 4 standpipes
- **Active and passive modes**



PBMR-DPP RCCS Water Curtain Arrangement

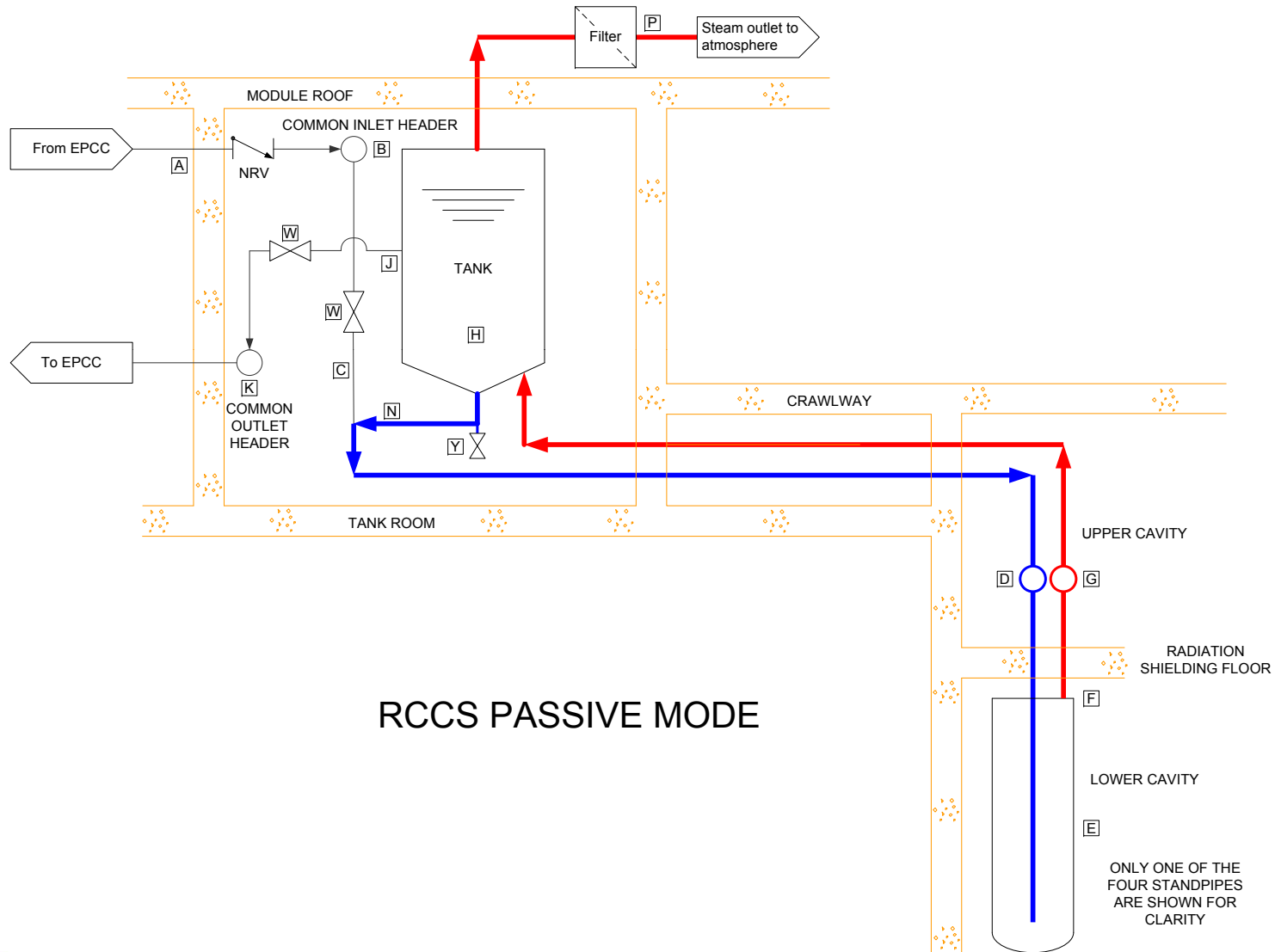


PBMR-DPP RCCS Active Mode



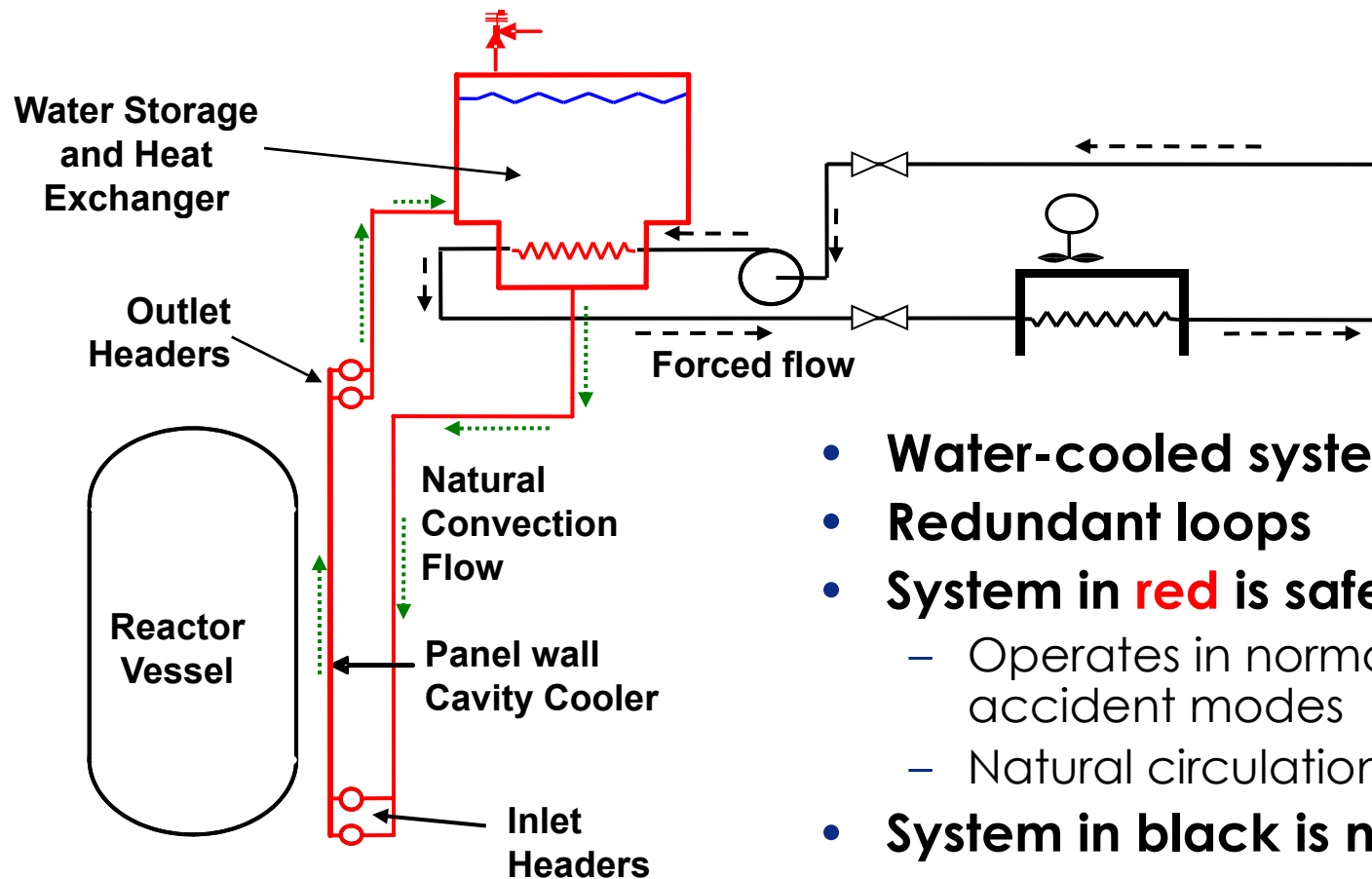
RCCS ACTIVE MODE

PBMR-DPP RCCS Passive Mode



RCCS PASSIVE MODE

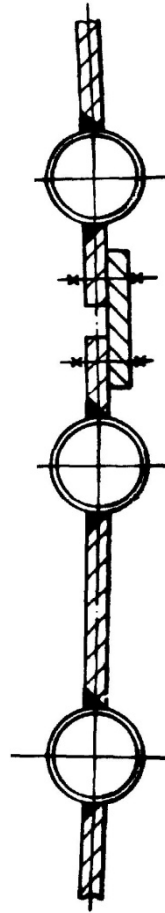
AREVA RCCS Concept



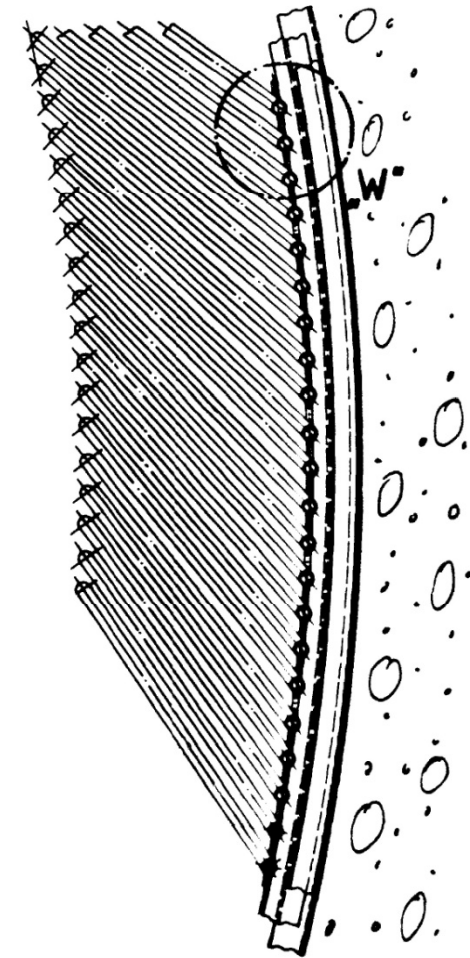
- **Water-cooled system**
- **Redundant loops**
- **System in red is safety-related**
 - Operates in normal and accident modes
 - Natural circulation driven
- **System in black is non-safety**
 - Operates during normal operation
 - Forced circulation

AREVA RCCS Panel Wall Concept

- Cavity lined with panels of welded “finned” tubes
- Comparable to panels for HTR-Modul and NP-MHTGR



Panel tube cross section



Wall panel section

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Overall RCCS Performance Factors

- **Performance for each function**
 - Vessel heat removal
 - Cavity “cooling”
 - Concrete surface protection
- **Heat removal mechanisms**
 - Thermal radiation (~80%)
 - Convection (~20%)
- **Overall reactor heat removal**
 - Depends on reactor size and operating temperature
 - Typically 1-2 MWt during normal operation
 - Typically 1-3 MWt at accident peak
- **Local effects**
 - Local reactor effects
 - RCCS discontinuities

RCCS Operating Modes

- **Normal operation**
- **Accident conditions**
- **Single loop operation**
- **Active cooling**
- **Passive cooling**
- **Dryout (and refill)**
 - Typically BDBE
- **Failed RCCS**
 - Typically BDBE

Performance Sensitivity

- **RCCS heat removal rate is similar during normal operation and accidents**
 - On-line monitoring of RCCS performance confirms system status
- **Accident fuel temperatures are insensitive to RCCS performance**
- **Vessel temperatures are more sensitive to RCCS performance but still not a strong function**
- **Reactor cavity concrete temperatures are a strong function of RCCS performance**

Other Considerations

- **Failure modes**
 - Leaks
 - Blockage
 - Dryout
- **Environmental effects**
 - Emissivity
 - Cavity atmosphere
- **Performance monitoring**
 - Overall heat removal
 - Local temperatures

Summary

- **RCCS maintains cavity wall and reactor vessel temperatures**
- **RCCS is a simple system**
- **A wide variety of potential RCCS configurations is possible**
- **Fuel temperatures are insensitive to RCCS performance**
- **Concrete temperatures are a strong function of RCCS performance**
- **Normal operation provides confirmation of system status**