RAHP News Letter

No.12

HTGR Developments in the World

～Present Status and Future Plans～

March 2013

Research Association of
High Temperature Gas Cooled Reactor Plant
(RAHP), Tokyo, Japan

■ Introduction:

This News Letter is a brief summary of High Temperature Gas Cooled Reactor (HTGR) developments in the world, such as their backgrounds, targets, present status and future plans, and is the latest one, annually reviewed and issued by Research Association of HTGR Plant (RAHP), which is structured by Japanese industry (utility companies and nuclear plant vendors, etc.) and academia, as a part of promotion activities for industry, government, academia and the public of Japan and abroad to understand HTGR plants.

■ Backgrounds, targets and current trends of HTGR developments:

In the world, now, population is growing and people's level of life is increasing, and then,

- **Sustainability of energy (electric power, heat, transportation fuels), water and foods**
- **Protection of global environment**

are becoming the common subjects to solve.

As the countermeasures, "Unconventional fossil fuel", such as oil sand and shale gas, and "Low carbon and clean energy", such as nuclear energy and hydrogen, are under energetically development. Nuclear energy, in particular, is reviewed from viewpoints of its sustainability, cleanliness and variety, and even after "Fukushima nuclear accident" happened in March 2011, although some countries have targeted to "Away from nuclear", many countries are promoting nuclear energy development and/or its introduction, through enhancement of safety under Severe Accident conditions.

HTGRs are under development by advanced countries, and demand and resource countries as well, in light of inherent safety, high temperature energies (800-1,000 C; highly efficient electricity generation, hydrogen production, industrial process heat applications), nuclear non-proliferation, effective utilization of natural resources, industrial promotion, etc.

At present, "Test & Research Reactor" programs are in progress in Japan and China, "Prototype & Demonstration Reactor" programs", targeting operational start in about 2020, are in progress in China, USA and Kazakhstan, and many related developments such as new plant design proposal are under

way in many countries.

HTGRs in pursuit at present are all "Small Modular Reactor (SMR)s" of less than 600MWt/300MWe/Module, and target demands are, taking into account of marketability and technological maturity;

- **Near future in 2020's; lower than about 850 C: Steam cycle: "Power generation" & "Mid-Low temperature heat applications", such as hydrogen production, coal reforming, oil sand recovery & reforming, sea water desalination, etc.**
- **Future in 2030's; higher than about 900 C: Gas cycle: "Highly efficient power generation" & "High-Mid-Low temperature heat applications", such as highly efficient hydrogen production, fertilizer production, fuel cell vehicle (FCV), hydrogen reduction steel making, etc.**

World status of HTGR developments on country basis is summarized below. And development programs on stage basis are shown in Tables 1-3, and nuclear plants and process heat applications on example basis are shown in Figures 1-14.

■ Development Status on country basis:

(1) USA

Since 1993, USA (Department of Energy (DOE), General Atomics (GA) and Oakridge National Laboratory (ORNL), jointly with Russia (Minatom (presently Rosatom) and OKBM), has been developing Gas Turbine Modular Helium Reactor (GT-MHR) for nuclear non-proliferation (incineration of surplus plutonium from weapon dismantling) and power generation. The co-development is continuing with reduced scale.

DOE, since 2005, based on Energy Policy Act (EPA-2005), has been promoting "Next Generation Nuclear Plant (NGNP, actually HTGR plant) " program. On its way, taking into account of demand trend and technological maturity, its main purpose has been changed from "Hydrogen (& power generation)" to "Heat applications (& power generation)", and coolant outlet temperature from "higher than 950 C" to "750-800 C for the time being".

Works of "Phase 1 (2005-2010; plant conceptual design, technological selection)" had almost been finished, but it was decided not to proceed to

originally programed "Phase 2 (2011-2021; plant detailed design, construction and demonstration)", due to the reasons listed below, and presently R&D works are under way with reduced scale, such as manufacturing and irradiation characterization of coated particle fuels (CPFs) and high quality graphite materials.

- **Although potential demand is great, such as co-generation (heat & power), hydrogen production, recovery and reforming of oil sand(synthetic fuel production for transportation), further 3-4 M$ is needed to complete the total program.**
- **Enhanced cooperation between government & industry (participation by plant vendors, owners, operators and end-users) is needed.**
- **Review and selection of core design, plant site and its completion date are needed.**

During Phase 1, industries have participated and cooperated to the program. GA has proposed advanced versions of above mentioned GT-MHR, such as "Hydrogen production reactor (H2-MHR)", "Steam cycle reactor (SC-MHR)" and "Deep burn reactor (DB-MHR)", Westinghouse (WH) has proposed an advanced version of South African "PBMR", and Areva (-USA) has proposed an advanced version of ANTARES "SC-HTGR", respectively. Japanese Mitsubishi Heavy Industries (MHI), Toshiba and Fuji Electric have participated and cooperated to those proposals.

And "NGNP Industry Alliance" formed by nuclear plant vendors, utilities (Entergy, --), chemicals (Dow, --), etc. sorted customer's requirements, showed potential market survey results, such as about 800 modules in North America, and requested for the government on national strategic propulsion of the NGNP plant demonstration program. Independently of the government, it selected above-mentioned SC-HTGR as most desirable plant design, and is selecting construction site, targeting licensing application in 2015.

DOE is, on the other hand, since 2010, energetically promoting development of "Small Modular Reactors (SMRs)" including HTGRs, in light of enhancement of domestic manufacturing industries and employments.

(2) Canada

StarCore (USA and Canada) is deploying "StarCore Pebble Bed Reactor

(SPB)" program, based on potential demand of remote land (minings, small towns, strategic bases, etc.), and is under preparation of licensing application to Canadian Nuclear Safety Commission, targeting initial deployment in 2015.

(3) Russia

Russia is continuing development of an advanced version of GT-MHR of afore-mentioned USA-Russia joint program, such as power conversion system equipments and CPFs.

On the other hand, based on the above, it is deploying "MHR-T"program, targeting hydrogen production etc., and evaluating potential market of several hundred modules in Russian domain.

(4) Europe

Member countries of European Union (EU), such as France and Germany, are deploying nuclear energy joint development strategy, composed of 3 pillars of Next Generation LWRs, Fast Reactors and HTGRs (for hydrogen production, heat applications). So far, they have been promoting a series of HTGR programs, such as "European Sustainable Nuclear Energy Technology Platform (SNETP)", "Reactor for Process Heat, Hydrogen and Electricity Generation (RAPHAEL)", "End User Requirements for Industrial Process Heat Applications with Innovative Nuclear Reactors for Sustainable Energy Supply (EUROPAIRES)". And now, based on the above fruites, it is promoting "Nuclear Cogeneration Industrial Initiative (NC21)".

In France, apart from such EU co-activities, Areva has been developing an advanced French version of GT-MHR "Areva's New Technology and Advanced Gas Cooled Reactor for Energy Supply (ANTARES)" and then, Areva-USA proposed the further advanced version "SC-HTGR" for US NGNP program. (Refer to (1) .)

(5) South Africa

Since 1993, national electricity supply company had been promoting "Pebble Bed Modular Reactor (PBMR)" program, based on German modular HTGR design (HTR-M) technology, and as a national energy strategy, and globally affecting to "Generation 4 Reactor" and/or "Small Modular Reactor (SMR)" programs. The program itself, however, had been terminated in 2010,

due to “Lehman Shock” related national bankruptcy.

But in 2011, one of the thorium companies STL started Thorium fueled HTGR “TH-100” program, designed plant concept, and presently is establishing a consortium for detailed design, construction and operation of the plant. Commercial production of thorium is to start in 2013.

(6) China

HTGR development is positioned as one of the important items in national energy strategy. As a part of it, “High Temperature Test Reactor (HTR-10)” program is in progress. “Phase 1 (Steam Turbine Cycle: -ST)” is continuing, and transitional works to “Phase 2 (Gas Turbine Cycle: -GT)” are under way, such as magnetic bearing development.

“High Temperature Reactor Pebble Bed Module (HTR-PM)” plant demonstration program had been delaying for several years due to troubles in manufacturing of reactor pressure vessel, execution of a series of sub-system demonstration of fuel manufacturing, fuel handling, steam generator system, etc. and safety review, executed after “Fukushima Accident”, March 2011. The construction has started in December 2012 in Shidaowan area, Shangdong Province, and its operational start is scheduled in late 2017.

As for commercial reactor program, total 18 reactor modules are planned to be installed at the same site above, and it is under study to uprate the module and to use thorium fuel which is quantitatively and domestically deposited.

(7) South Korea

As part of national strategy, “Water/Hydrogen/Electricity/ Nuclear Integrate (WHEN)” and “Nuclear Hydrogen Development & Demonstration (NuH2 & NHD&D)” programs are in progress. Utilities (KEPCO), heavy industries (Hyundai, --), steels (POSCO, --), etc. are participating. Plant demonstration is planned to be active in 2026.

(8) Kazakhstan

As part of national strategy of import and domestic fixation of foreign advanced technologies as prices of export of natural resources (such as uranium, iron ore, Rare Eearthes), “Kazakhstan HTR (KHTR)” experimental

and demonstration program is under way. Japan (Japan Atomic Energy Research and Development Agency (JAEA), Toshiba, Fuji Electric, Nuclear Fuel Industries (NFI), etc.) is fully supporting this program in terms of technology, plant design and education.

(9) Japan

Situation of nuclear energy development has drastically changed due to "Fukushima Accident" and the political power at that time (Democratic Party) declared of "Zero nuclear energy" policy. Although the power has changed to Liberal Democratic Party-New Komeito Coalition in late 2012, it is still not clear whether it will execute "Nuclear energy recession", "Re-start of reactor operation after safety review", "Export", "Development of new and safe reactors", or not.

Since 1970's HTGR has been under continuous development from view point of multi-purpose utilization of nuclear energy such as nuclear steel making etc. , including basic R&D, design, construction, operation and safety demonstration of High Temperature Engineering & Test Reactor (HTTR).

Japan is at the front end in key technologies, such as CPF production, high quality graphite structural material production, helium gas turbine design, hydrogen production (IS process), large size steel forging, etc..

Japan has no plan of its commercial deployment at present. But its participation, cooperation and international developmental leadership are required, under delaying condition of plant demonstration programs in China and USA. National positioning and practical propulsion of HTGR development are required to be in a hurry.

JAEA is executing a series of safety demonstration test using HTTR, and at present OECD/NEA Loss of Forced Cooling International Collaboration Test (HTTR-LOFC) is under way. Related equipments and hydrogen production technologies are also under development and/or demonstration.

JAEA, Mitsubishi Heavy Industries (MHI) and Toshiba, etc. are, independently or jointly, promoting conceptual design, market survey, series design of "Gas Turbine Reactor (GTHTR300: for power generation, hydrogen generation, co-generation, --)", "Small Steam Cycle Reactor (HTR50S, MHR-50/100is)", "Naturally Safe HTGR (NSHTR)", "Clean Burn HTGR (CBHTR)", etc. and/or development of oxidation resistant fuel and graphite, from view points of global heat & power demands, management of plutonium from

Light Water Reactor spent fuel, and searches for ultimately safe nuclear reactors which can endure even under severe accident conditions such as loss of coolant and ingress of air and/or water.

And Japan is fully cooperating to Kazakhstan HTGR program (refer to (8)), as part of measures of energy resource development & import and HTGR global deployment.

■ Information Sources:

(1) International conferences: HTR-2010 (Czech), ASME 2011 SMR (USA), ICONE20 (2012) (USA), HTR-2012 (Japan), --

(2) web: HTGR, HTR, Small & Modular Reactor (SMR), Generation 4 reactor, nuclear heat applications (hydrogen production, synfuel), --

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Table 1. "Test & Research Reactor Programs at a glance"
(as of Mar. 2013)(Test and research programs, using actual nuclear reactor)

Name, Organ, Country	Background, Purpose, Parameter	Present status, Future plan
HTTR : Temp. Eng'g Test Reactor ＜JAEA＞ ＜Japan＞ [Fig. 1]	◆ Nuc. ene. multi- purpose utilization (nuc. steel make, --) ◆ Test & res. of HTGR ◆ Oarai, Ibaragi Pref. ◆ 30MWt, 850C, (950C for short period)	◆ Under execution of OECD/NEA Loss of Forced Cooling Safety Demo. Test (HTTR-LOFC), equipment & H2 prod. dev't ◆ Under plan of H2 prod. demo, connecting to reactor (HTTR-IS)
HTR-10 : HTR Test Reactor ＜INET＞ ＜Chaina＞ [Fig. 2]	◆ Natural resources (coal, Th, etc.) ◆ Nuc. ene. multi- purpose utilization ◆ Test & res. of HTGR ◆ Outskirt of Beijing ◆ 10MWt/2.6MWe, -ST: 700C, -GT: 750-900C	◆ Ph.1 (Steam turbine: -ST) : continuing ◆ Ph.2 (Gas turbine: -GT): under prep. (dev't of mag. bearing, --) ◆ H2 production under development

Table 2. "Prototypical & Demonstration Reactor Programs at a glance" (as of Mar.2013)(Dev't programs, reactor site and funding are indicated) (Md: Module)

Name, Organ, Country	Background, Purpose, Parameter	Present status, Future plan
NGNP : Next Generation NuclearPlant ＜DOE＞ ＜USA＞ [Figs. 3-5]	◆ Natural resources (coal, oil sand, oil shale,--) ◆ Ene. demand & CO2 release remarkable ◆ Ene. independence, clean ene. (H2, etc.), nuc. heat apps. (syn- fuels from coal, oil sand, --) ◆ Dev't of Gen.4 reactors, SMRs ◆ HTGR plant dev't & demo. ◆ Idaho (or the other) ◆ 600MWt? /? MWe/Md, 750-800C	◆ Ph.1 ('05-'10: plant concept design, tech. selection): mostly finished ◆ Various plant designs proposed by WH (PBMR-USA), GA and Areva-USA, with coop. by Japan (MHI, Toshiba, Fuji Electric) ◆ Alternate sites (Alabama, Alberta-Canada) under investigation ◆ Did not enter Ph.2 ('01-'21: detail design, construct., demo. ope.) due to lack of gov.-ind. alliance and funding. R&D works under way with reduced scale ◆ NGNP Industry Alliance (WH, Areva, Entergy, Dow, Toyo Tanso--) has selected Areva's design (SC-HTGR) as most desirable one for initial NGNP , and under site selection, targeting licensing in '15
HTR-PM : HTR Pebble Bed Module ＜INET/Huaneng/ CNEC＞ ＜Chaina＞ [Fig. 6]	◆ Nuc. ene. multi-purpose utilization ◆ HTGR plant demo. & commercialization ◆ Shidaowan, Sangdong Prov. ◆ 500MWt(=250MWt×2)/200MWe/Md, 750C	＜Demonstration plant＞ ◆ Under system demo. of fuel prod., fuel handling, steam generator, -- ◆ Safety reviewed after "Fukushima" ◆ Dec.'12: construction started ◆ End of '17, ope. start planned ＜Commercial plant＞ ◆ 18 Mds to be installed at same site with Demo. plant ◆ Md. uprating and Th fuel use are under study
KHTR : Kazakhstan HTGR ＜NNC＞ ＜Kazakhstan＞ [Fig. 7]	◆ Export of natural resources (iron ore, U, Th, --) and introduction & fixation of foreign advanced technologies ◆ HTGR dev't (power gen., regional warming, --) ◆ Kurchatov ◆ 50MWt/15MWe/Md, 900-950C	◆ Japan (JAEA, Toshiba, Fuji Elec., NFI--) is fully cooperating (tech., plant design, education,--) ◆ '13-: Feasibility study ◆ '20-: Ope. start planned

Table 3. "Other R&D Programs at a glance" (1/3)
(as of Mar.2013)(R&D programs other than "Test & Research Reactor" and "Prototype & Demo Reactor" programs)

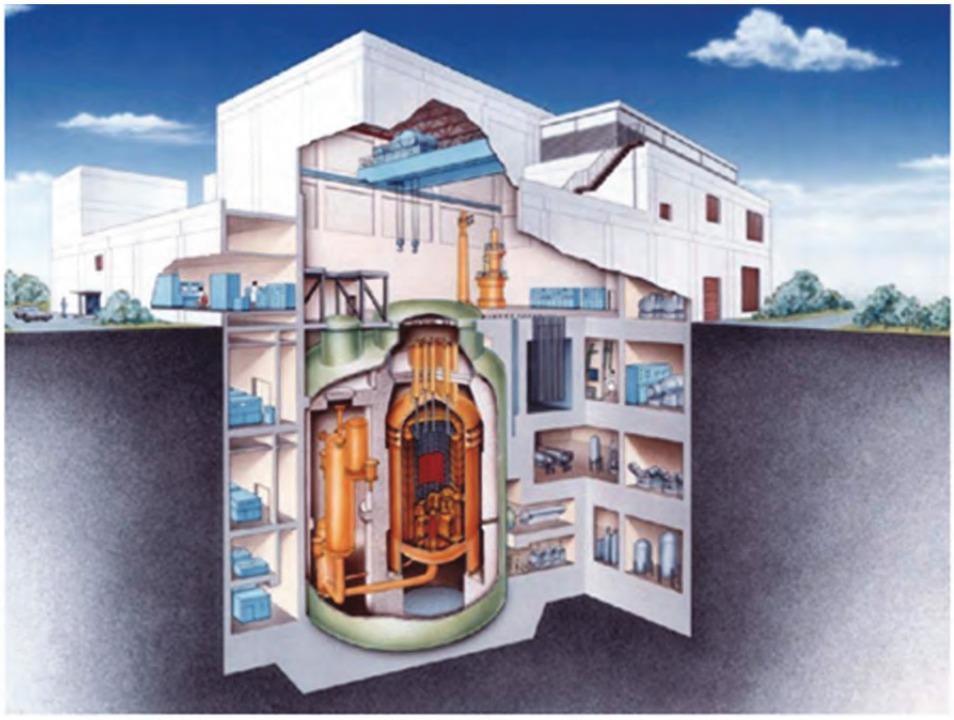
Name, Organ, Country	Background, Purpose, Parameter	Present status, Future plan
GT-MHR : Gas Turbine Md. Reactor ＜DOE/GA/ORNL/ Rosatom/OKBM＞ ＜USA/Russia＞	◆ Nuc. non-proliferation (incineration of dismantled & surplus Pu) and highly efficient gas turbine power gen. ◆ 600MWt/Md	◆ USA-Russia Joint Study continuing ◆ Deploying to H2-MHR, SC-MHR, DB-MHR -- in USA, and to MHR-T in Russia, respectively
H2-MHR : Md. Reactor for H2 prod. ＜GA＞ ＜USA＞	◆ US adv'd version of GT-MHR ◆ H2 production	◆ Design proposed for NGNP
SC-MHR : Md. Reactor for Steam Cycle ＜GA＞ ＜USA＞	◆ US adv'd version of GT-MHR ◆ Steam cycle (power gen., heat apps.)	◆ Design proposed for NGNP
DB-MHR : Deep Burn Md. Reactor ＜DOE/GA＞ ＜USA＞	◆ US adv'd version of GT-MHR ◆ Nuc. waste (Pu, TRUs) management, power gen., heat apps.	◆ Conceptual design finished ◆ (Based on this technology, Gas Cooled Fast Reactor (GFR, EM2) is under design)
SPB : StarCore Pebble Bed Reactor ＜StarCore＞ ＜Canada, USA＞	◆ Remote area demand (mining, small towns, strategic bases, --) ◆ Remote ope., using satellite ◆ 2 reactor Mds. Underground ◆ 10MWe/Md	◆ Licensing app. under prep. with Canadian Nuc. Safety Comm. ◆ '15: Initial deployment planned
GT-MHR : ＜Rosatom/ OKBM＞ ＜Russia＞	◆ Russian adv'd version of GT-MHR ◆ 600MWt/Md	◆ Plant under design ◆ Russian market under survey ◆ (Under plan to connect the technology to GFR development)
MHR-T : ＜Rosatom/ OKBM＞ ＜Russia＞	◆ Russian adv'd version of GT-MHR ◆ H2 prod. and gas turbine power gen. ◆ 600MWt/Md	

Table 3. "Other R&D Programs at a glance" (2/3)
(as of Mar.2013)(R&D programs other than "Test & Research Reactor" and "Prototype & Demo Reactor" programs)

Name, Organ, Country	Background, Purpose, Parameter	Present status, Future plan
SNE-TP : Sustainable Nuc. Ene. Tech. Platform ＜EC, EU＞	◆ EU co-strategic deployment, sorting & construction of HTGR dev't bases	◆ Under co-study on EU common nuc. ene. dev't target, strategy, requirements, schedule-- (reactor type, user's requirements, feasibility of int'l demonstrator--) ◆ Activities in process with relaying fruits of "Reactor for Process Heat, Hydrogen and Electricity production (RAPHAEL)", "End- user requirements for Process Heat Applications (EURO-PAIRES) "--
NC21 : Nuc. Co-gen. Ind. Initiative 21 ＜EC, EU＞ [Fig. 8]	◆ Activities on nuc. co-gen. demo plant within Europe	
ANTARES : Areva's New Tech. and Adv'd Gas Cooled Reactor for Ene. Supply ＜Areva＞ ＜France＞	◆ HTGR dev't (power gen., H2 gen., heat apps.)	◆ Adv'd version (SC-HTGR) proposed for NGNP (US) by Areva-USA, and selected by Ind. Alliance as most desirable plant design for initial NGNP (refer to NGNP)
TH-100 : Thorium fuel HTGR ＜STL＞ ＜S. Africa＞ [Fig. 9]	◆ Dev't experience on PBMR ◆ Effective use of Th (by-product of Rare Earthes mining) ◆ 100MWt/35MWe/Md, 750C	◆ '10: STL founded ◆ '11: Conceptual design finished ◆ '12～: Under settlement of consortium for plant detail design, construct. and operation ◆ '13～: Th commercial production
WHEN、NuH2&NHDD : Water/H2/Elec./Nuc. Integrate, Nuc. H2 Dev't & Demo. ＜KAERI＞ ＜S. Korea＞ [Fig. 10]	◆ H2 ene. dev't as part of nat'l strategy ◆ Dev't & Demo. of nuc. water, H2 & electricity	◆ KAIST and KIER are cooperating on H2 production development ◆ KEPCO (Utility), Hyundai-- (heavy industry), POSCO--(steel making) are participating

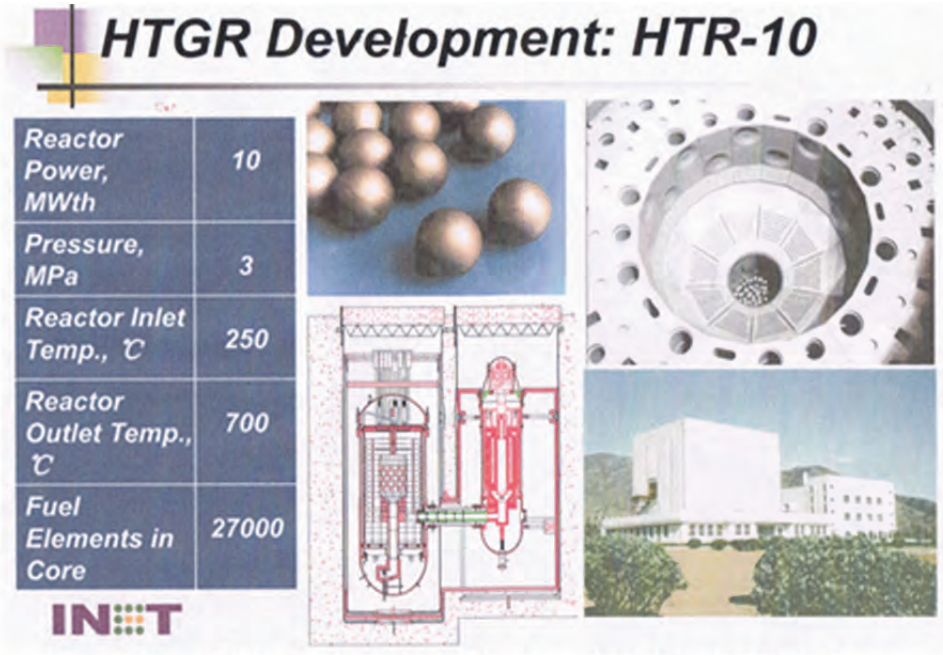
Table 3. "Other R&D Programs at a glance" (3/3)
(as of Mar.2013)(R&D programs other than "Test & Research Reactor" and "Prototype & Demo Reactor" programs)

Name, Organ, Country	Background, Purpose, Parameter	Present status, Future plan
GTHTR300 : Gas Turbine HTGR ＜JAEA＞ ＜Japan＞ [Fig. 11]	◆ Gas turbine cycle HTGR development ◆ <-X>: for power gen. ◆ <-C> : for co-gen. ◆ <-H> : for H2 gen. ◆ <-A> : for all dry plant ◆ 600MWt/Md, 850C	◆ Under execution of conceptual design, economic evaluation, -- ◆ Under safety demo test on Severe Accidents, using HTTR (refer to HTTR)
HTR50S : Steam Cycle Small HTGR ＜JAEA/ Toshiba/--＞ ＜Japan＞ [Fig. 12]	◆ Dev't of small HTGRs for developing countries (for power gen., steam supply) ◆ 50MWt/Md, 750C	◆ Conceptual design (basic parameters., systems) finished ◆ Under market survey
NSHTR : Naturally Safe HTGR ＜JAEA＞ ＜Japan＞ [Fig. 13]	◆ Dev't of HTGR capable to protect people and environment by natural & physical phenomenon only	◆ Under conceptual design, proposal and related tests
CBHTR : Clean Burn HTGR ＜JAEA＞ ＜Japan＞	◆ Incineration of Pu from LWR spent fuel	◆ Under conceptual design and proposal
MHR-50/100is : Mitsubishi HTGR ＜MHI, JAEA＞ ＜Japan＞	◆ Dev't of HTGR of small and improved safety for power gen. ◆ (FOAK) : 120MWt/50MWe/Md ◆ (NOAK) : 250MWt/100MWe/Md, 750C	◆ Conceptual design, market & economic survey finished ◆ Under study of business plan



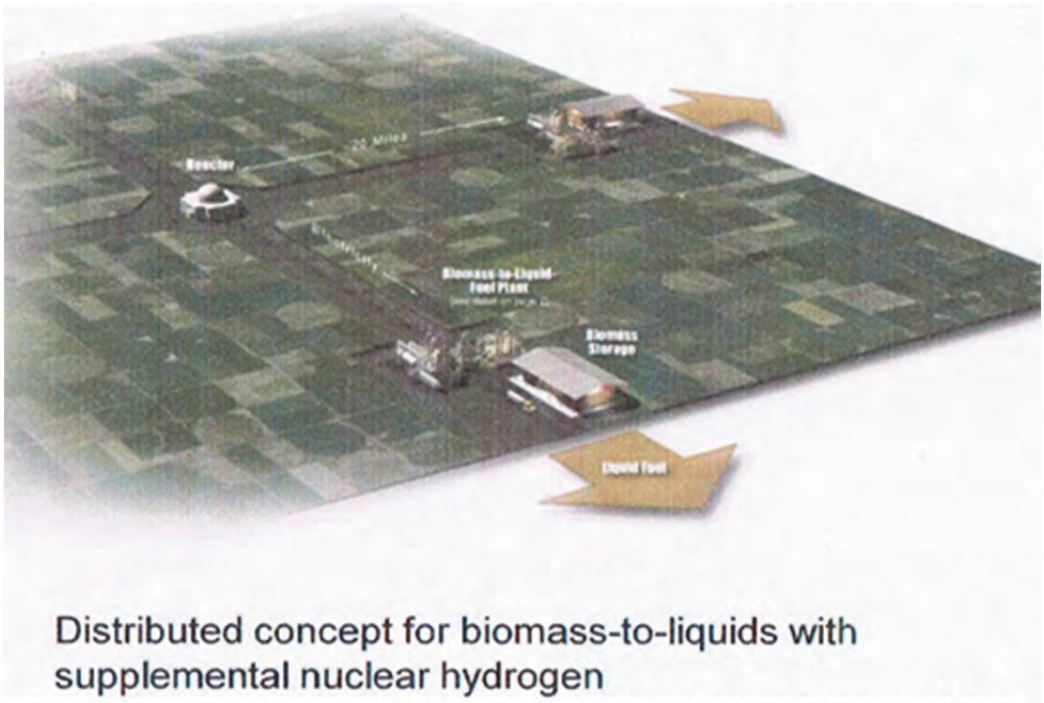
（JAEA HP）

Fig.1　(Japan) HTTR Cross Section



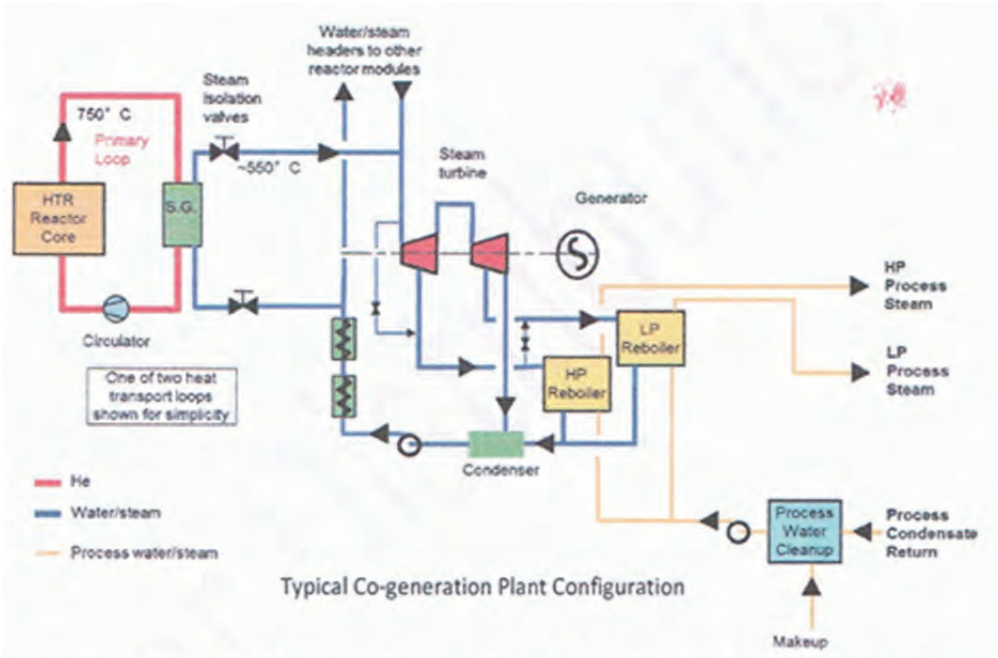
（Sun Yuliang (INET), "Potential Contributions of Modular HTGRs to Energy Supplies in China", IAEA Technical Meeting on Options to enhance Energy Supply Security with NPPs based on SMRs, Oct.3-6, 2011, IAEA, Vienna）

Fig.2　(China) HTR-10 Main Parameters and Cross section



(J.O'Brien, INL; VHTR R&D FY12 Tech. Review Mtg, 2012.5.22-24, Salt Lake City)

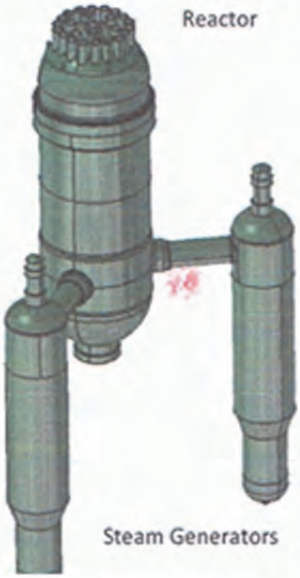
Fig.3 (USA) Distributed Concept for Biomass-to-Liquids with Supplemental Nuclear Hydrogen



(Summary Decision Paper – Reference Modular HTGR Reactor Design Concept and Plant Configuration for Initial Applications, NGNP Industrial Alliance, 2012.2.7)

Fig.4 (USA) NGNP Reference Design Concept and Plant Configuration for Initial Applications (1)

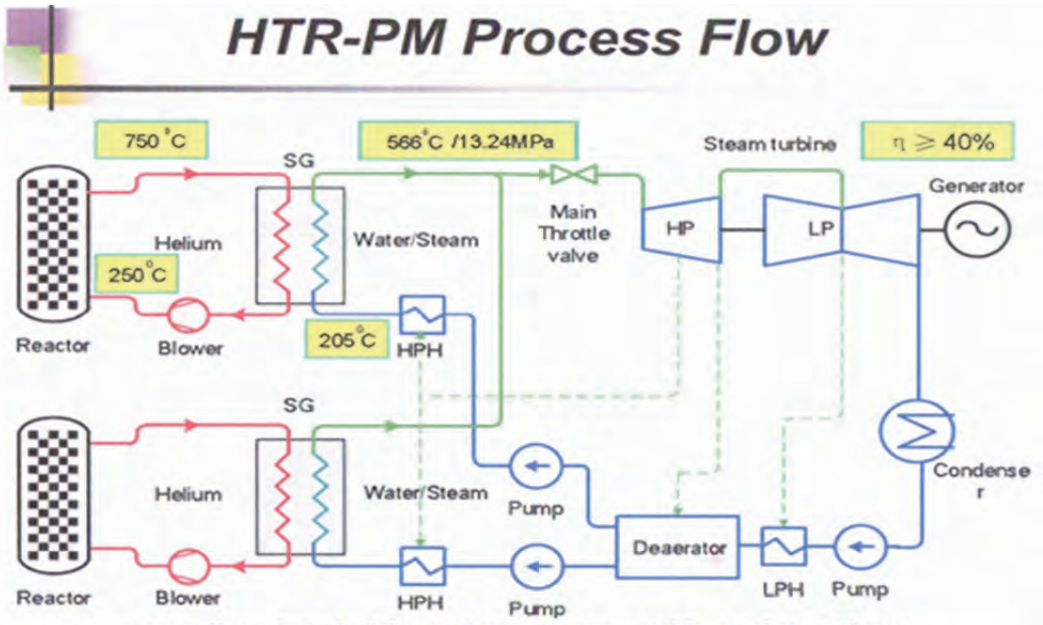
AREVA Design - Nominal Parameters	
Fuel type	TRISO particle
Core geometry	102 column annular 10 block high
Reactor power	625 MWt
Reactor outlet temperature	750°C
Reactor inlet temperature	325°C
Primary coolant pressure	6 MPa
Vessel material	SA 508/533
Number of loops	2
Steam generator power	315 MWt (each)
Main circulator power	4 MWe (each)
Main steam temperature	566°C
Main steam pressure	16.7 Mpa



Nuclear Process Steam Supply System

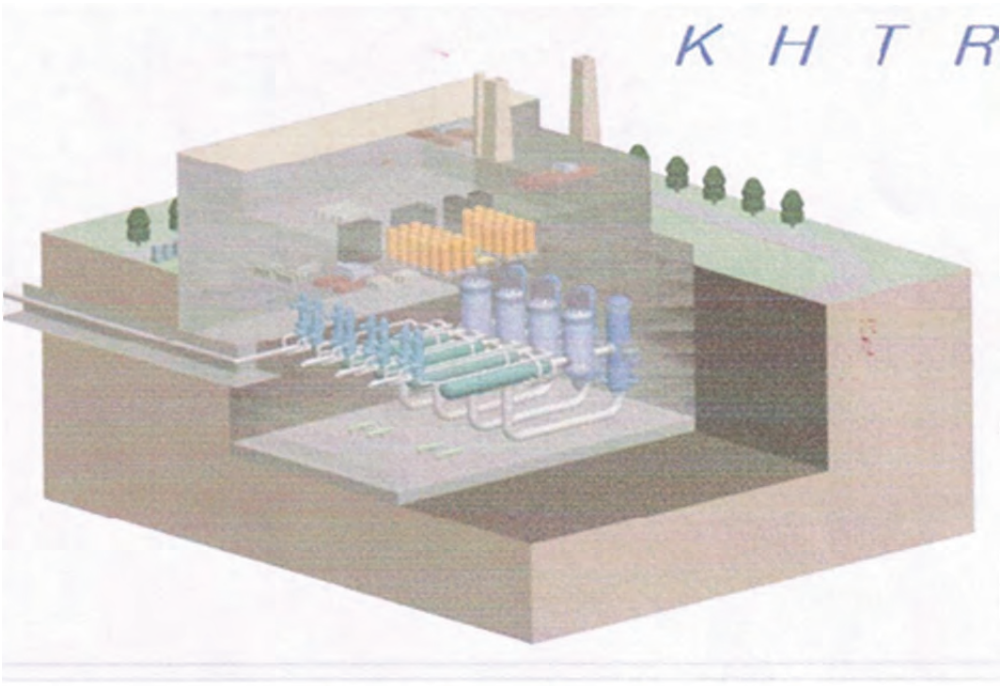
(Summary Decision Paper – Reference Modular HTGR Reactor Design Concept and Plant Configuration for Initial Applications, NGNP Industrial Alliance, 2012.2.7)

Fig.5 (USA) NGNP Reference Design Concept and Plant Configuration for Initial Applications (2)



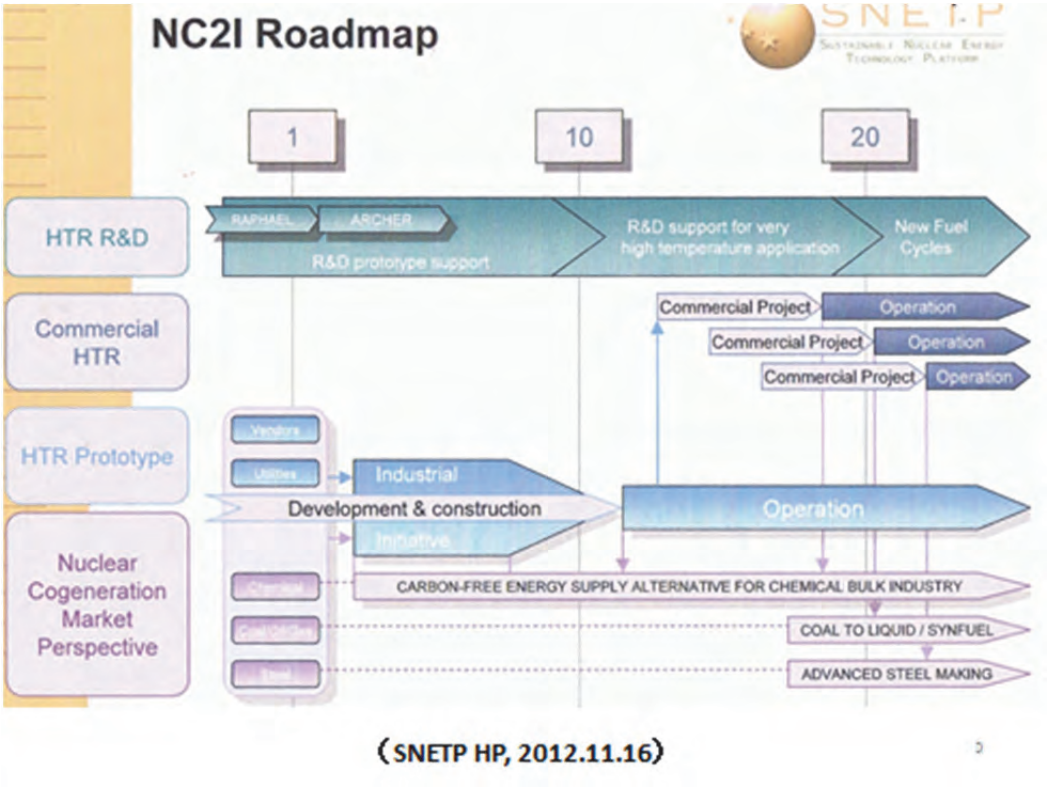
Sun Yuliang (INET), "The HTR-PM Reactor and its Fuel Cycle from Non-Proliferation Perspective", IAEA TM, Aug.15-18, 2011

Fig.6 (China) HTR-PM Plant Process Flow



（jaea.go.jp/04/o-arai/nhc/jp/intro/international/）

Fig.7　(Kazakhstan) KHTR Plant Concept



（SNETP HP, 2012.11.16）

Fig.8　(EU) Nuclear Co-generation Industry Initiative (NC21) Roadmap

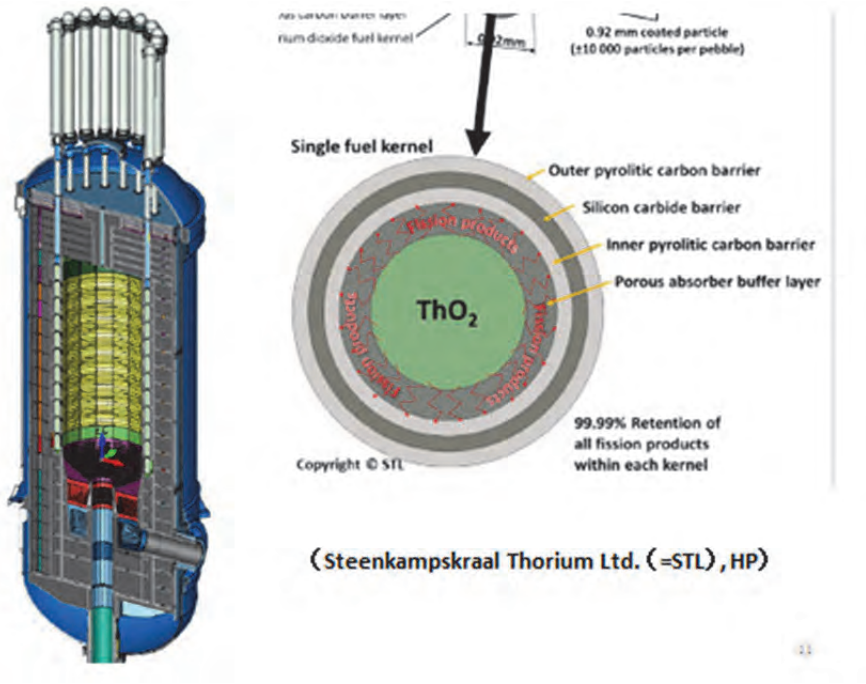


Fig.9 (S. Africa) Thorium Fuel HTGR (TH-100)

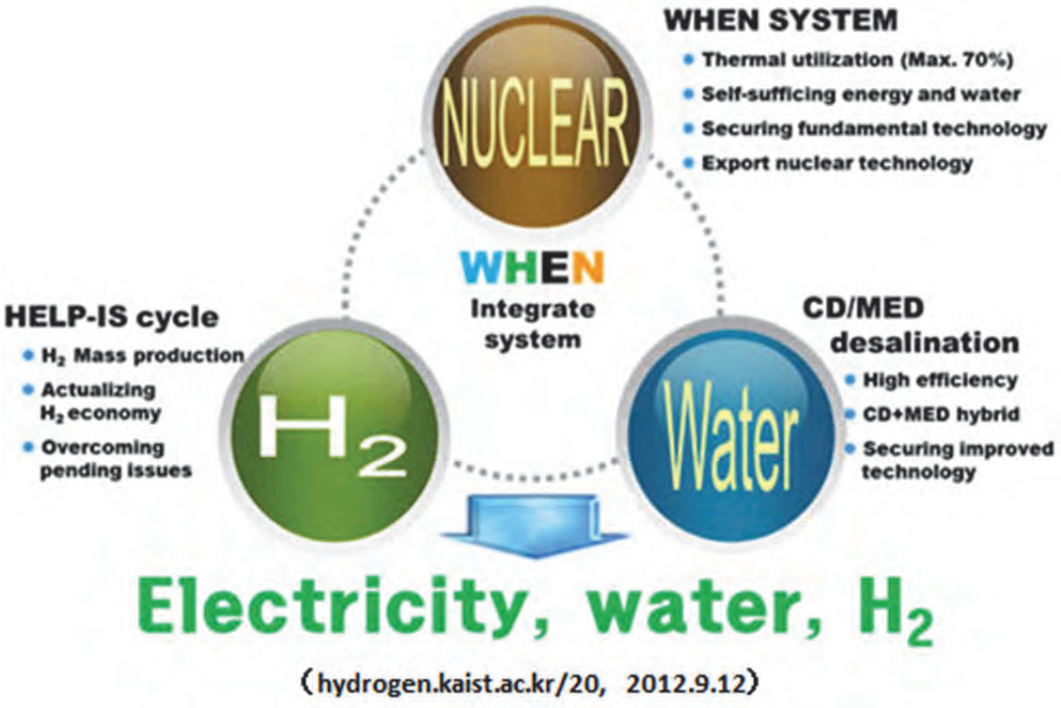
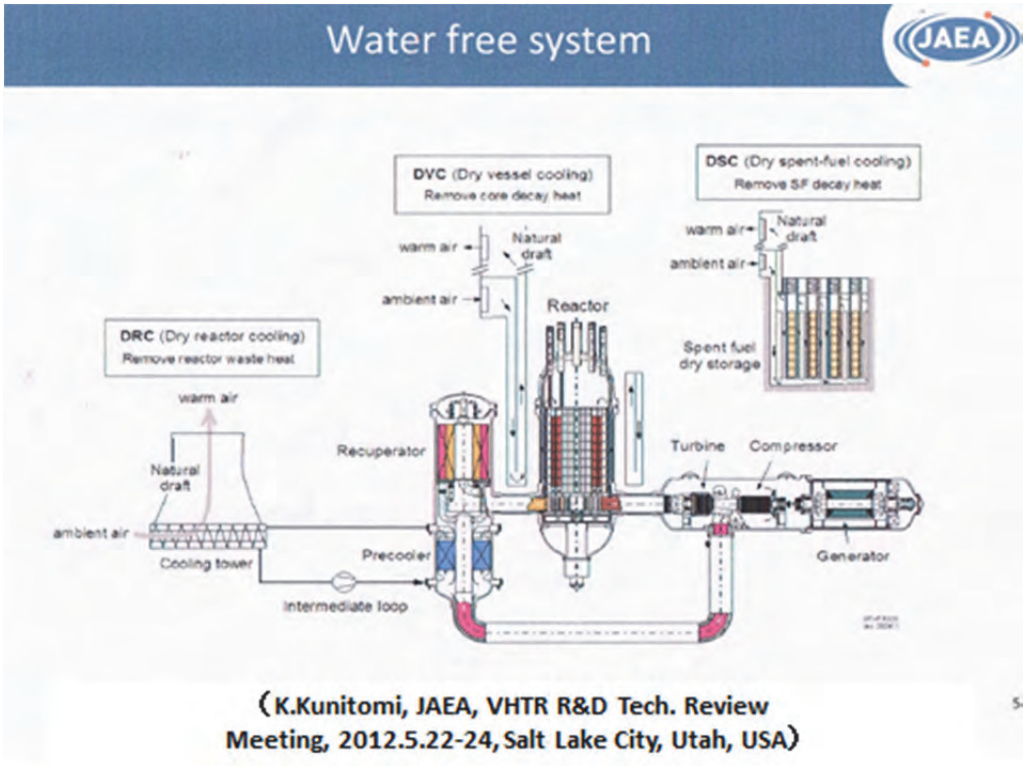
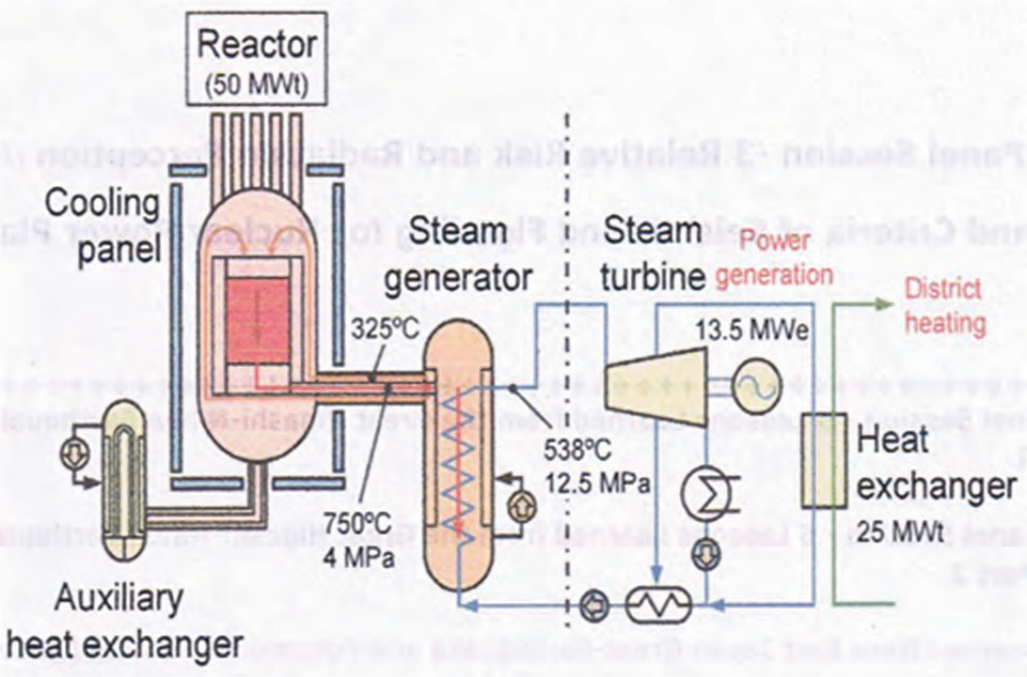


Fig.10 (S. Korea) Water/Hydrogen/Electricity/Nuclear (WHEN) Integrate System Concept



(K.Kunitomi, JAEA, VHTR R&D Tech. Review Meeting, 2012.5.22-24, Salt Lake City, Utah, USA)

Fig.11 (Japan) GTHTR300-A (Water free Plant) Concept



HTR-50S

(Y.Inaba, et al (JAEA), JAEA-Technology 2012-019)

Fig.12 (Japan) HTR-50S Flow Diagram for Co-generation

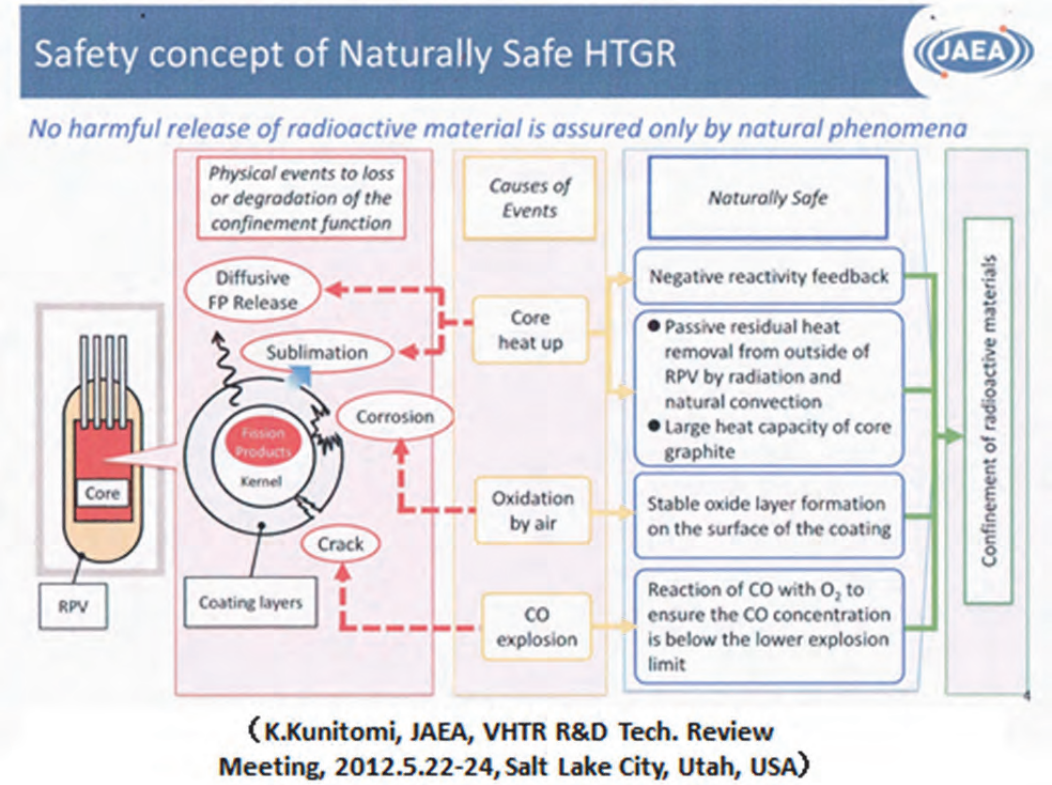


Fig.13 (Japan) Naturally Safe HTGR (NSHTR) Concept