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High Temperature Reactors

A review of Requirements and Concepts

ASME BPV Code, Section III, Division 5

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- Typical High Temperature reactors covered by Section III, Div. 5
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- Control of Materials
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- Quality Assurance for Components
  - NCA-4000 & HAA-4000

Disclaimer

The information provided in this seminar by the four presenters is the sole opinion and responsibility of each individual. It is not supported by the organizations employing them, by ASME or the committees of ASME or the participants of the ASME committees.

TING-LEUNG (SAM) SHAM BIOGRAPHICAL INFORMATION

Dr. T.-L. (Sam) Sham is the Technical Manager for Advanced Reactor Materials in the Nuclear Engineering Division at Argonne National Laboratory. His technical specialty is in deformation and failure of advanced materials and structural mechanics technologies for high temperature reactors. He is the Technology Area Lead of the advanced materials R&D program for the Office of Advanced Reactor Technologies (ART), Office of Nuclear Energy (NE), Department of Energy (DOE). The R&D portfolio cross-cuts the three reactor campaigns on Fast Reactors, Gas-cooled Reactors and Molten Salt Reactors in ART. In addition, Sham leads the DOE-NE international R&D efforts on advanced materials and code qualification for sodium-cooled fast reactor structural applications.

Dr. Sham is a member of the ASME Boiler and Pressure Vessel (BPV) Committee on Construction of Nuclear Facility Components (III). He chairs BPV III Subgroup on Elevated Temperature Design, which is responsible for the development and maintenance of design rules for nuclear components in elevated temperature service. He was elected ASME Fellow in 2000.

Before he joined Argonne in 2015, Dr. Sham was a Distinguished R&D Staff Member at Oak Ridge National Laboratory, held senior positions with AREVA NP Inc. and Knolls Atomic Power Laboratory, and was tenured faculty at Rensselaer Polytechnic Institute. He holds a B.Sc. degree, First Class Honour, in Mechanical Engineering from the University of Glasgow, Scotland, and M.S. and Ph.D. degrees (Mechanics of Solids and Structures) as well as an M.S. (Applied Mathematics) from Brown University in Providence, Rhode Island, USA.

ROBERT JETTER
BIOGRAPHICAL INFORMATION

Mr. Jetter has over 50 years' experience in the design and structural evaluation of nuclear components and systems for elevated temperature service. He was a contributor to the original ASME Code Cases eventually leading to Subsection NH and subsequent Section III, Division 5 for High Temperature Reactors. For over 25 years he chaired the Subgroup on Elevated Temperature Design (SG-ETD). He is currently a member of the Committee on Construction of Nuclear Facility Components (BPV-III), the Subcommittee on Design, Subgroup on High Temperature Reactors, Subgroup Elevated Temperature Design and several Working Groups developing the requirements for High Temperature Reactors.

Mr. Jetter was a member of a Department of Energy (DOE) steering committee responsible for elevated temperature design criteria, and was a consultant and reviewer on various DOE projects. In Rockwell /Atomics International, he participated in and directed design activities on the early sodium cooled reactors and space power plants through all the US LMFBR programs. He currently consults on the development and application of elevated temperature design criteria. He was an International Fellow for the Power Reactor and Nuclear Fuel Development Corporation at the Monju Fast Breeder Reactor site in Japan and co-authored the text "Design and Analysis of ASME Boiler and Pressure Vessel Components in the Creep Range". He is a Fellow of the ASME and received the ASME Dedicated Service Award in 2011.

TIM BURCHELL
BIOGRAPHICAL INFORMATION

Dr. Tim Burchell is Distinguished R&D staff member and Team Lead for Nuclear Graphite in the Nuclear Material Science and Technology Group within the Materials Science and Technology Division of the Oak Ridge National Laboratory (ORNL). He is engaged in the development and characterization of carbon and graphite materials for the U.S. Department of Energy. He was the Carbon Materials Technology (CMT) Group Leader and was manager of the Modular High Temperature Gas-Cooled Reactor Graphite Program responsible for the research project to acquire reactor graphite property design data. Currently, Dr. Burchell is the leader of the Next Generation Nuclear Plant graphite development tasks at ORNL. His current research interests include: fracture behavior and modeling of nuclear-grade graphite; the effects of neutron damage on the structure and properties of fission and fusion reactor relevant carbon materials, including isotropic and near isotropic graphite and carbon-carbon composites; radiation creep of graphites, the thermal physical properties of carbon materials. As a Research Officer at Berkeley Nuclear Laboratories in the U.K. he monitored the condition of graphite moderators in gas-cooled power reactors.

He is a Battelle Distinguished Inventor; received the Hsun Lee Lecture Award from the Chinese Academy of Science's Institute of Metals Research in 2006 and the ASTM D02 Committee Eagle Award in 2015. Dr. Burchell remains very active in both the ASTM and ASME. He is currently a member of the Committee on Construction of Nuclear Facility Components (BPV-III), member of the Subgroup on High Temperature Reactors, Chair of the Working Group on Graphite and Composite Materials, and a member of Subgroup on Materials, Fabrication and Examination and other related working groups and subgroups. Dr. Burchell is a Fellow of the American Carbon Society and a Fellow of ASME.

RICHARD W. BARNES BIOGRAPHICAL INFORMATION

Mr. Richard W. Barnes is the President and Principal Engineer of ANRIC Enterprises Inc. and has been actively involved for over 40 years in the development of the ASME and CSA Codes and Standards associated with Pressure Boundary for both nuclear and non-nuclear power plants. Mr. Barnes and ANRIC Enterprises Inc. offer technical assistance for companies registering Pressure Boundary products, solving technical issues associated with these products (both nuclear and non-nuclear). As a recognized Codes expert, he is consulted by organizations to assist in understanding and implementing Code requirements. Mr. Barnes also develops and delivers training on both the ASME and CSA Codes and Standards for delivery on-site at the ANRIC Learning Centre and off-site at the clients' premises.

Mr. Barnes sits on various committees responsible for the development of Codes and Standards. Mr. Barnes is past Chair (13 years) and member of the ASME Standards Committee on Construction of Nuclear Facility Components (BPV III); past Vice-Chair and member of the CSA Standard N285 Technical Committee on CANDU Nuclear Power Plant Systems and Components, Member of the CSA Standard B51Technical Committee, and Member of the CSA Standard N286 Technical Committee; and Contributing Member of the ASME B16 Standards Committee.

Mr. Barnes has received the ASME Dedicated Service Award, the Bernard F. Langer Nuclear Codes and Standards Award in recognition for his contributions to the nuclear industry. He is an ASME Fellow. Mr. Barnes has also received the CNA Outstanding Contribution Award and the CSA Award of Merit.

Background to the development of Section III, Division 5

INTRODUCTION

ASME Boiler and Pressure Vessel Code (BPV Code)

- The initial Code, Section I, was developed in 1911 to provide standardization of boilers designs whose failures/explosions were resulting in 50,000 deaths per year in the USA and Canada; at the end of the century 1800's, and early 1900's.
- The main focus of the BPV Code was prevention of the pressure boundary failure.
- The BPV Code today consists of 13 Sections and Section III is one of those Sections. There are five Divisions od Section III and the high temperature reactors requirements are covered by Division 5.
- The actual Sections of the BPV Code are listed in the next slides

The ASME Boiler and Pressure Vessel Code

I Power Boilers

II Material Specifications

Part A - Ferrous Material

Part B - Nonferrous materials

Part C - Welding Rods, Electrodes, and Filler Rods

Part D - Properties

The ASME Boiler and Pressure Vessel Code

III Subsection NCA - General Requirements for Div. 1 & Div. 2

III Division 1

Subsection NB	-	Class 1 Components
Subsection NC	-	Class 2 Components
Subsection ND	-	Class 3 Components
Subsection NE	-	Class MC Components
Subsection NF	-	Supports
Subsection NG	-	Core Support Structures
Subsection NH	-	Class 1 Components in Elevated Temperature Service

The ASME Boiler and Pressure Vessel Code

III Division 2	-	Code for Concrete Containments
III Division 3	-	Containment for Transportation and Storage of Spent Nuclear Fuel and High Level Radioactive Material and Waste (NUPACK)
III Division 4	-	Fusion Facilities
III Division 5	-	High Temperature Reactors
III Appendices		
III Code Cases		

The ASME Boiler and Pressure Vessel Code

- IV Heating Boilers
- V Nondestructive Examination
- VI Recommended Rules for Care and Operation of Heating Boilers
- VII Recommended Guidelines for the Care of Power Boilers

The ASME Boiler and Pressure Vessel Code

VIII Rules for the Construction of Pressure Vessels

- Division 1
- Division 2 - Alternative Rules
- Division 3 - Alternative Rules for the Construction of High Pressure Vessels

IX Welding and Brazing Qualifications

X Fiber-Reinforced Plastic Pressure Vessels

XI Rules for In-service Inspection of Nuclear Power Plant Components

XII Rules for Construction and Continued Service of Transport Tanks

XIII Pressure Relief Devices (in preparation)

US Government Initiative

- In 2000, the Generation IV International Forum (GIF) was formed to advance nuclear energy in order to fulfill future energy needs.

- There were four areas identified as requiring goals for future nuclear power:

  - **Sustainability:** the ability to meet the present energy needs and enhance the ability to meet the energy needs of the future indefinitely; focus on waste management and resource utilization and transportation, using nuclear process heat to manufacture hydrogen.

  - **Economic Competitiveness:** consider competitive costs and financial risks; reducing operating and capital costs; focus on efficiency, simplification, fabrication and construction techniques, standardization and modular design.

US Government Initiative

- **Safety and Reliability:** include safe and reliable operation, improved accident management and mitigation, investment protection, and reduced off-site response.
- **Proliferation Resistance and Physical Protection:** consider methods for controlling and securing nuclear material and nuclear facilities against unintentional and intentional actions.

ASME Initiative

- Around the year 2008 personnel from South Africa who were involved with the development of the Gas Cooled pebble bed reactor began working with ASME in the development of a Code under the auspices of ASME SEC III.
- This was further reinforced by the interest in the USA and Europe of the development of very high temperature reactor to support the development of the NGNP reactor for the production of hydrogen as an energy source.
- ASME responded to this interest in producing a road map with the interested parties leading to the development of a Code under Section III of the ASME Boiler and Pressure Vessel Code.

ASME Initiative

- The Code being developed not only covered the gas cooled reactors but also the Sodium liquid-metal fast breeder.
- It was considered that the fast breeder reactors could be used to reduce the actinide burden on the disposal requirements and had an potentially important part to play in the life-cycle of the nuclear reactor industry.
- The initial code was issued in November 2011 incorporating the Code Cases that Section III had developed for high temperature consideration.
- It has been developed to incorporate Subsection NH of Section III Division 1, which had been developed for the initial gas cooled designs.

Recent Developments

- The pebble bed reactor development was cancelled in South Africa.
- The drive towards a hydrogen economy in the European Union and the United States of America was cancelled. The need for the very high temperature gas reactor was no longer existed.
- The economic side of the reactor community decided that a smaller modular reactor had promise.
  - The capital required to build the SMR plants maybe significantly lower. Raising the investment capital to build a plant is a significant issue today unless a government underwrites the project.
- The environmentalists started to change their opinion about the benefits of nuclear power to the environment (in favour).
- Natural gas supplies now available at very cheap prices (“fracking”) further impacted the economics of nuclear power in North America and its potential as an energy source for the foreseeable future.

Recent Developments

- Opportunities for the smaller reactors started to present themselves. The concept that these smaller reactors could be transported to distant, relatively inaccessible places became a new dream.
  - The big benefit was that these reactors could be built in a shop with tight control on manufacture expenses and then transported to the site.
  - The potential for it to be significantly cheaper and politically acceptable.
  - At the end of life it could transported from the site; the disposition of the reactor would be significantly easier to handle.
  - The potential to control the reactor remotely and the ability to provide a more secure site (underground in some concepts) also has big appeal.
- This new potential together with the drive to produce a safer reactor design has led to the development of new concepts and high temperature reactors are part of this new dream.

Application of Division 5

TYPICAL HIGH TEMPERATURE REACTORS

TYPE: Thorium-Uranium Salt Cooled Reactor

How the reactor works

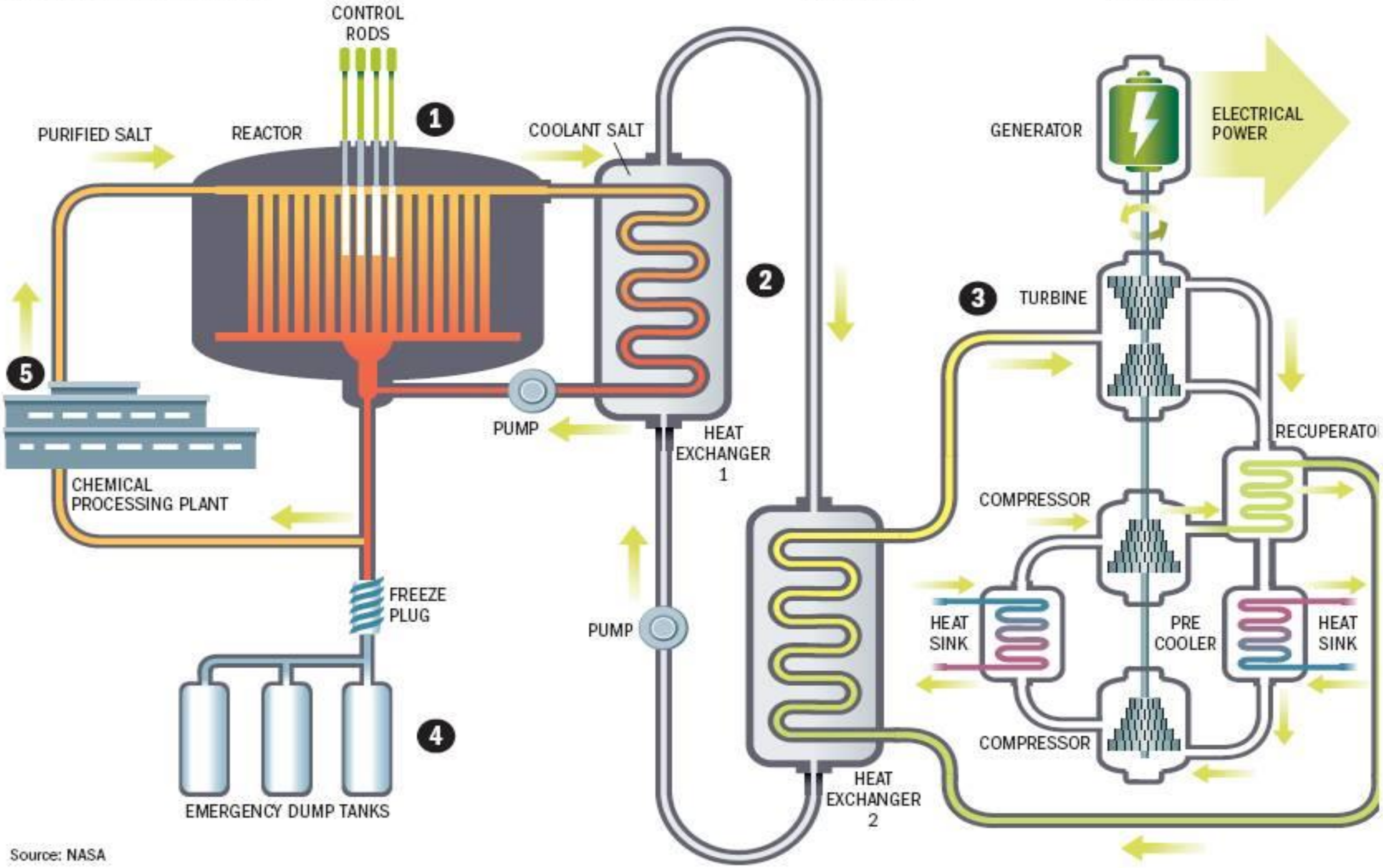
1. Thorium and uranium 233 are dissolved in molten lithium fluoride salt in the reactor. As fission occurs, heat is released and free neutrons start changing more thorium into uranium 233.

2. Heat from the reactor is transferred to another loop of molten salt that does not contain nuclear materials.

3. Heat is transferred to helium gas, which runs turbines that power a generator.

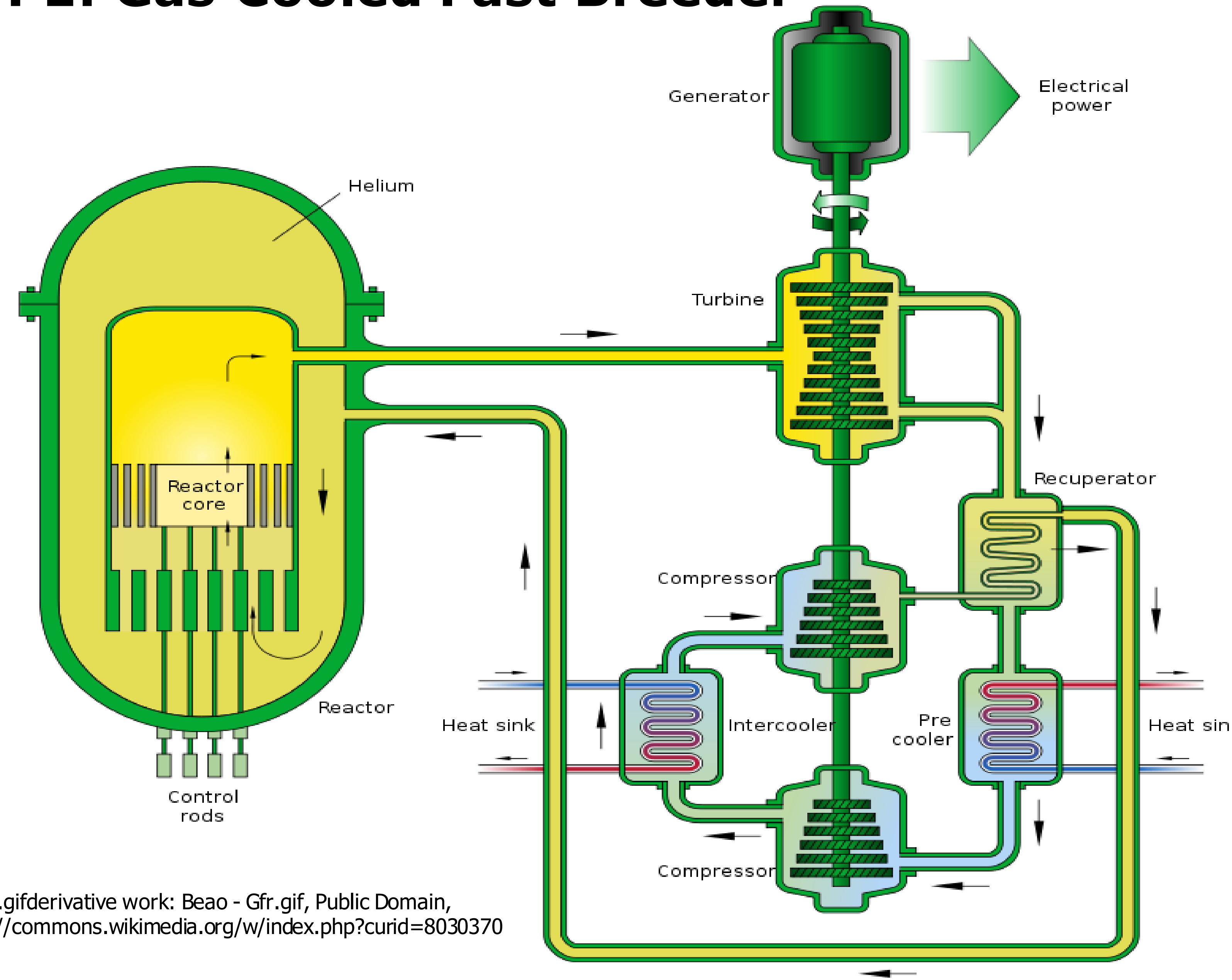
4. As an emergency measure, if the system gets too hot a plug designed to melt at a specific temperature releases the reactor's components into dump tanks.

5. Because the salt in the reactor core is liquid, waste can be removed while the reactor is working. Solid-core reactors must be shut down to remove waste.



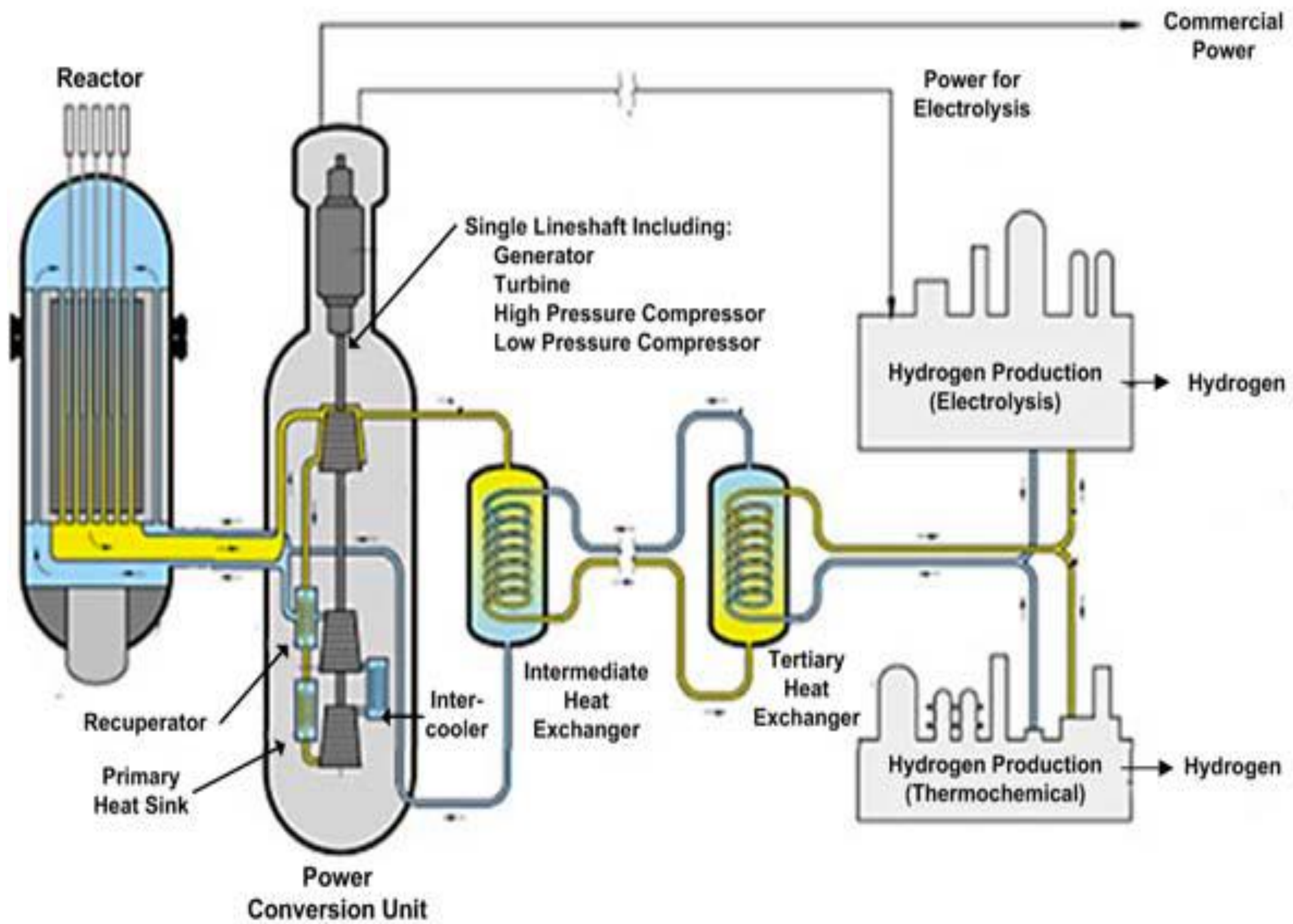
Source: NASA

TYPE: Gas Cooled Fast Breeder



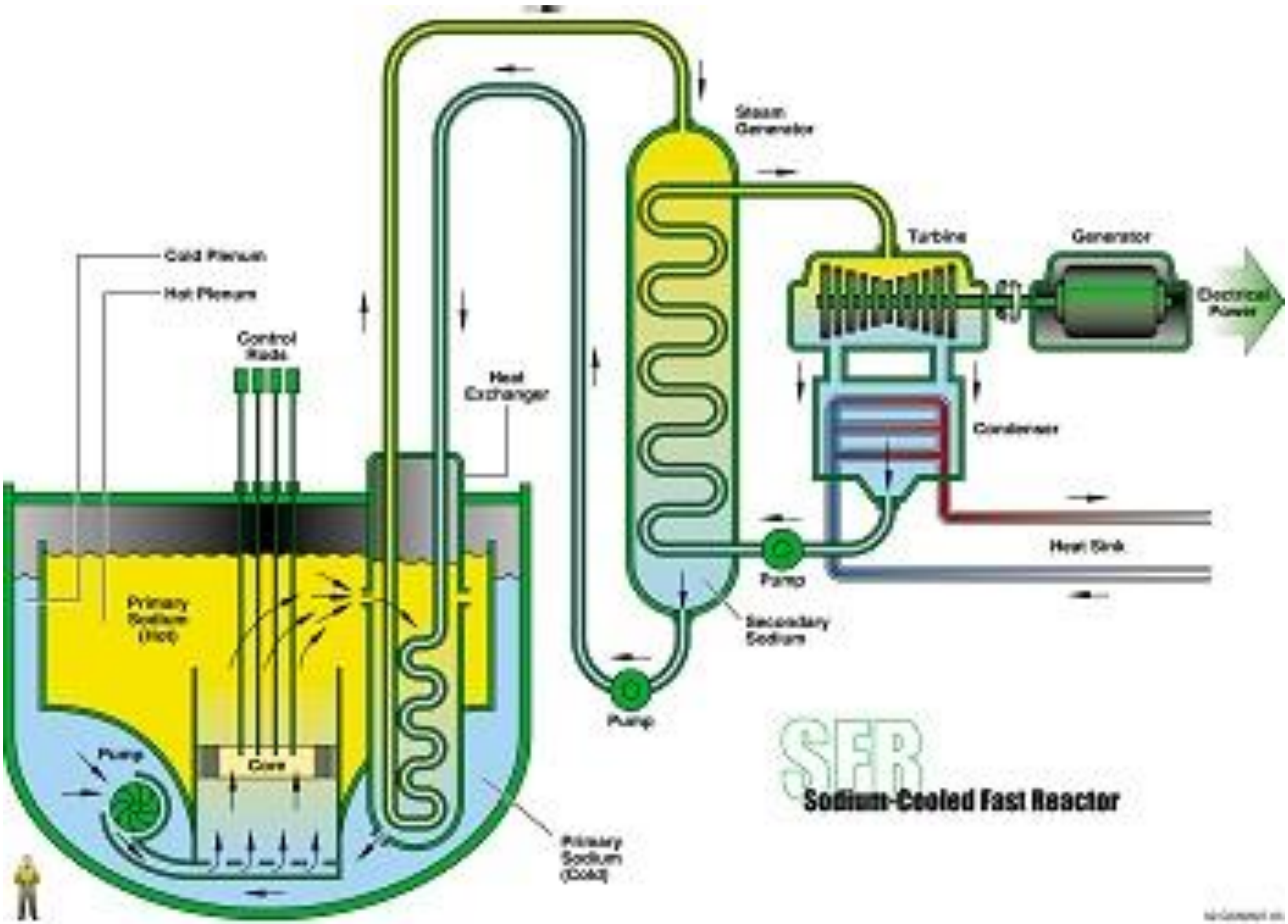
By Gfr.gifderivative work: Beao - Gfr.gif, Public Domain, https://commons.wikimedia.org/w/index.php?curid=8030370

TYPE: The NGNP Gas Cooled Reactor

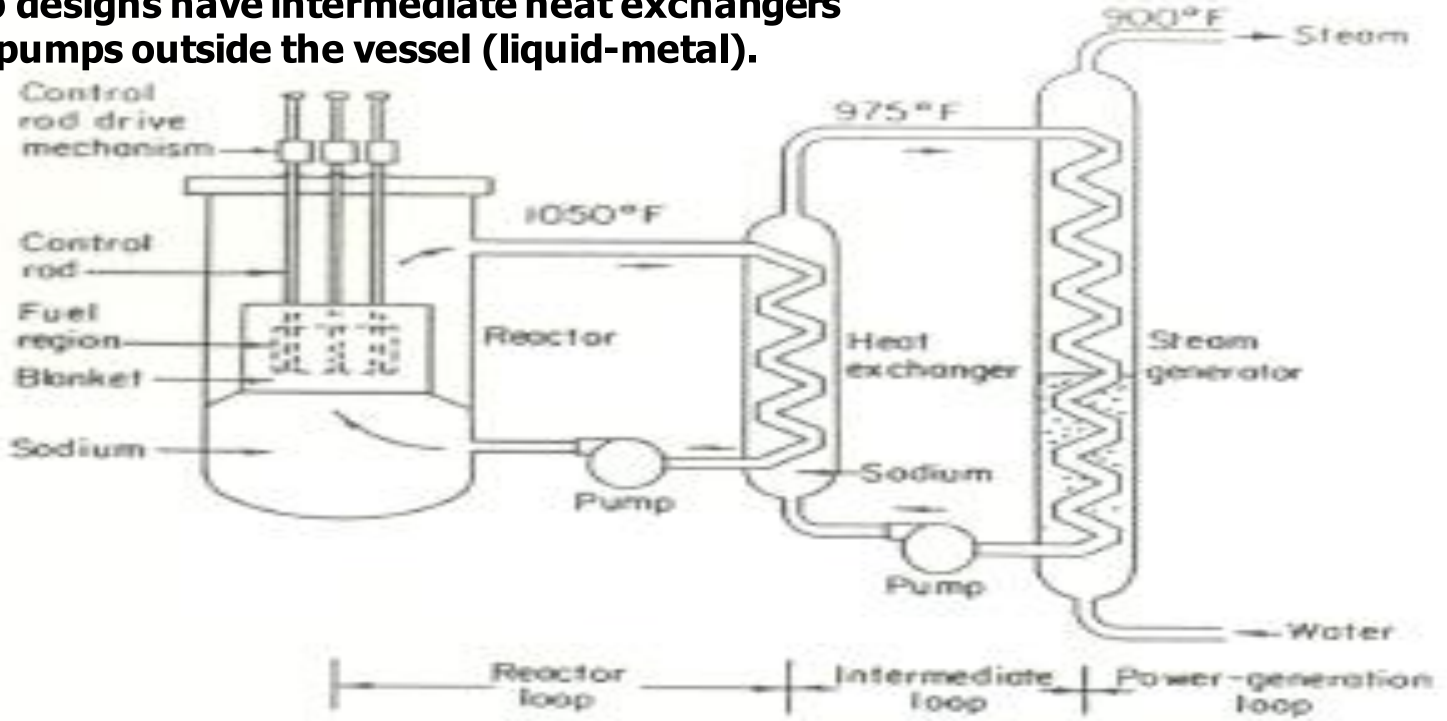


MPR Associates Inc.

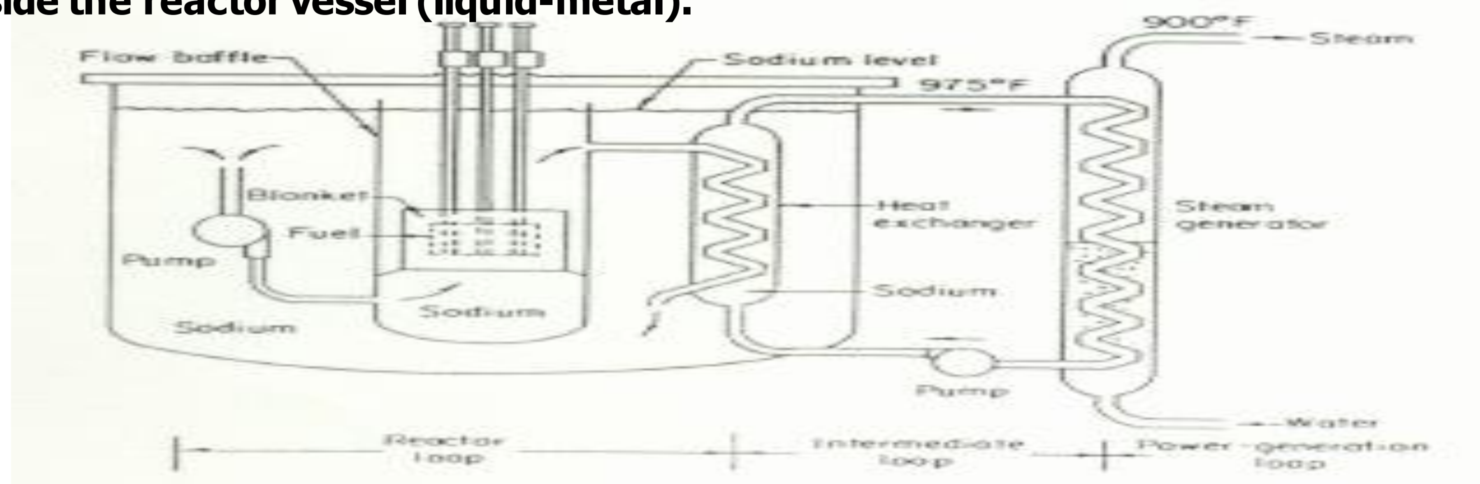
TYPE: Liquid-Metal Sodium Cooled Fast Reactor



Loop designs have intermediate heat exchangers and pumps outside the vessel (liquid-metal).



Pool designs have almost all equipment located inside the reactor vessel (liquid-metal).



Fast Reactors

Fast reactors can play a significant role in the management of actinides. The high energy neutrons are more effective at reducing the actinide burden.

The main benefits of the Fast Reactor are:

- Reduction of transuranic elements (requires a closed fuel cycle); reduces radiotoxicity and heat load of the resulting waste which facilitates waste disposal and geologic isolation.
- Effective utilisation of uranium resources through efficient management of fissile materials and multi-recycle.
- Higher levels of safety can be achieved through inherent and passive means - allows management of transients and bounding events with greater safety margins.

Molten Salt Reactors

Molten Salt Reactors (MSRs) use a fluid fuel in the form of very hot fluoride or chloride salt. The fuel salt is liquid and can be both the fuel and also the coolant.

There are many different types of MSRs. Probably the one receiving the most attention is the Liquid Fluoride Thorium Reactor (LFTR).

Thorium and Uranium are dissolved in a fluoride salt and can take advantage of the large amounts of Thorium minerals available; like the fast breeder can utilize the Uranium minerals.

There are also other fast breeder fluoride MSRs that do not use Thorium at all and there are chloride salt based fast reactors considered for their ability to utilize transuranics.

Molten Salt Reactors: Ref:Nick Touran, Ph.D.

MSR - Safety

- **Very low excess reactivity** — Continually refueled; extra fissile not required material to allow the reactor to operate for a long time.
- **Negative temperature coefficient of reactivity** — If the fuel heats up, it expands and becomes less reactive, keeping things stable. Not always true in graphite-moderated MSRs.
- **Low pressure** — The fuel and coolant are at atmospheric pressure. The salts have very high heat capacity so they can absorb a lot of heat. Their thermal conductivity much worse (x60) than liquid metal sodium.
- **No chemical reactivity with air or water** — The fuel salt generally is not violently reactive with the environment. MSR leaks are still serious because it is extremely radioactive fuel.
- **Drain tank failure mechanism** — If something goes wrong in a MSR, a freeze plug can melt, pouring the entire core into subcritical tanks.

Molten Salt Reactors: Ref:Nick Touran, Ph.D.

MSR - Economics

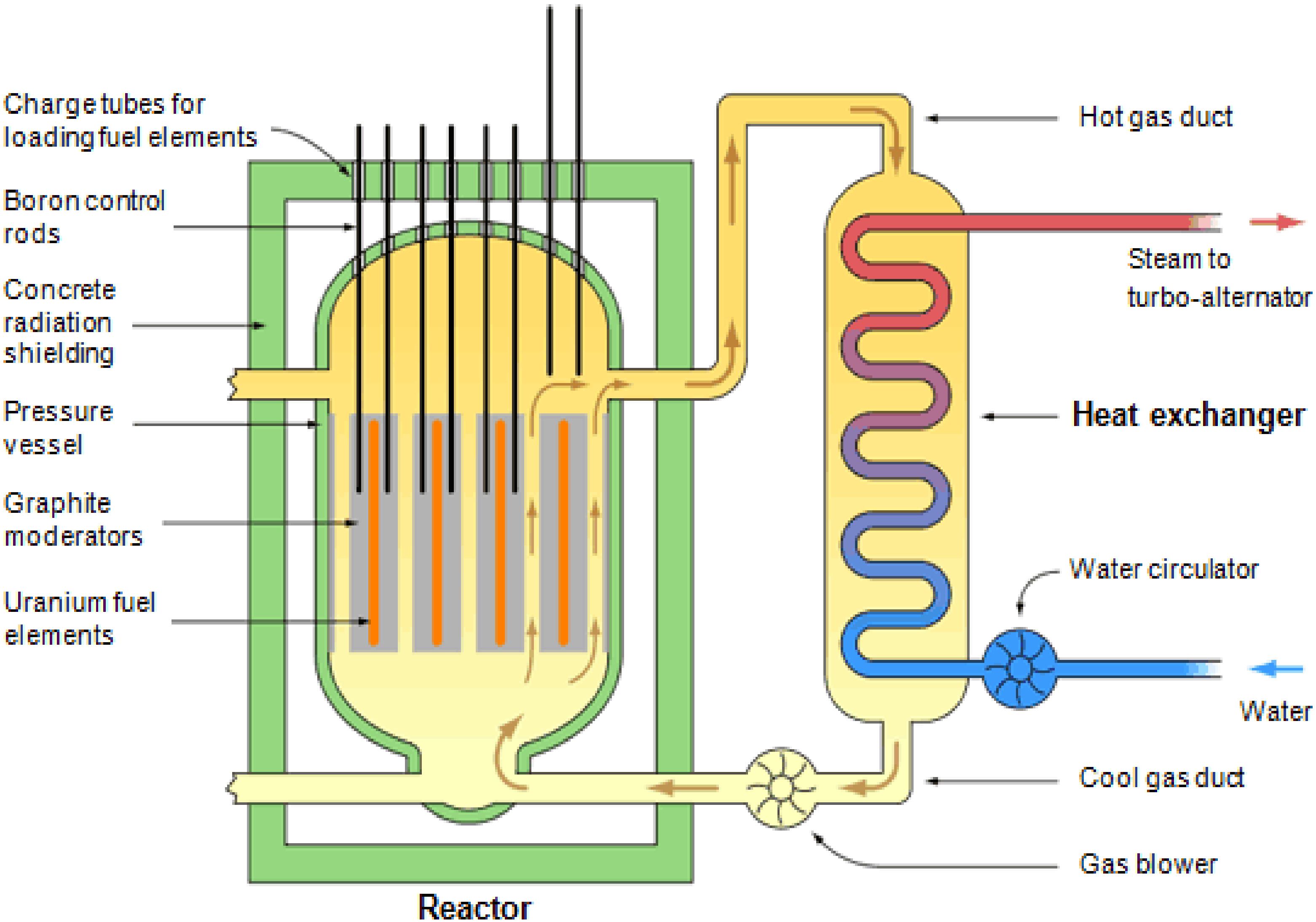
- **Online refueling** —MSRs can refuel while at full power (no downtime for refuelling). This allows high capacity factors, improving economics. The reactors will still have to shut down to do maintenance.
- **No fuel fabrication** — No need to build fuel assemblies, fuel pellets, cladding tubes, core support structures, flow orifices, etc. MSRs are basically just vats of fuel.
- **High temperatures possible** — Molten salts can operate at very high temperatures; power cycles convert heat to electricity with much less loss; industrial processes often require high-grade heat; high temperatures without a pressurized coolant.
- **Smaller containment** — System pressure is low and the heat capacity is high, the containments can be smaller and thinner.

Molten Salt Reactors: Ref:Nick Touran, Ph.D.

MSRs – Some Issues

- Proliferation -The main political barrier to MSRs is their perceived bomb-factory capabilities.
  - The fuel is already completely cut open and melted.
  - Protactinium-233 decays to pure, weapons-grade U-233. Many Thorium-cycle MSRs have to capture Pa as it is produced, remove it while it decays to U-233 and then reinsert it into the reactor. Pa-233 absorbs too many neutrons to maintain a breeding cycle. The problem here is that that ex-core U-233 is basically pure weapons-grade U-233.
  - Inventory tracking is difficult. Materials plate out in the reactor and in the chemical plant. It is difficult to keep track of all of the actinides. The IAEA safeguards track the actinides. It will be difficult for the IAEA to distinguish plate-out losses from actual proliferative losses.
- Other Issues: Material Degradation, Tritium production, Remote maintenance, Complex chemical plant

TYPE: Gas Cooled Reactor



TYPE: Water Cooled Reactor

B&W mPower small modular reactor. Source: Babcock & Wilcox.

Section IIII, Division 5

IMPORTANT CONCEPTS

Important Concepts

- Section III is a component with requirements for the construction of components by organizations taking the responsibility for meeting the full requirements of the Code.

- Section III, Division 5 (Div. 5), as part of Section III, is also Component Code but does not stand alone from Division 1 because the reactors have some components operating at high temperatures and some at low temperatures.

- It provides requirements to ensure structural integrity for components and structures
  - Operating at high temperatures and that maybe
  - Operating either at either low pressures or at High Pressures (depending on the reactor concept).

- Section III, Div. 5 provides generic requirements that can be applied to any concept operating at high temperatures and either low or high pressures.

Important Concepts

- It recognizes that high temperature reactors concepts are diverse and addresses the main variations under consideration at this time.
- The high temperature reactors concepts under consideration at this time are either based on the fast neutron regime (breeders) or the thermal regime (gas cooled and salt cooled).
- The significant impact on the code for reactors in the thermal regime is the need for a moderator.
- At this time the moderator being used/considered is graphite. It is an integral part of the core design and fits under the umbrella of core support which is located inside a vessel.
- Its properties and resulting design must be addressed due to its impact on the pressure boundary components.

Important Concepts

- In the pressure retention regime, the code requires a minimum thickness be met. This concept is to prevent plastic collapse (gross failure) and allows the focus to be placed on the mechanisms that cause failure through degradation as a result of operation.
- For the high temperature application, the quantification of minimum thickness has to take into account the loads at temperature and time at temperature. This will be developed further in our presentation.
- For graphite structures the functional requirement to limit deformation from loading to allow the control rods to function correctly, (more than), maintain adequate margin against failure.

Division 5 – Contents
High Temperature Reactors

- SUBSECTION HA GENERAL REQUIREMENTS
  - Subpart A Metallic Material
  - Subpart B Graphite Materials
  - Subpart C Composite Materials
- SUBSECTION HB CLASS A - METALLIC PRESSURE BOUNDARY
  - Subpart HA Low Temperature Service
  - Subpart HB Elevated Temperature Service
- SUBSECTION HC CLASS B - METALLIC PRESSURE BOUNDARY
  - Subpart A Low Temperature Service
  - Subpart B Elevated Temperature Service

Division 5 – Contents
High Temperature Reactors

- SUBSECTION HF CLASS A AND CLASS B METALLIC SUPPORTS
  - Subpart A Low Temperature Service
- SUBSECTION HG CLASS A – METALLIC SUPPORT STRUCTURES
  - Subpart A Low Temperature Service
  - Subpart B Elevated Temperature Service
- SUBSECTION HH CLASS A – NON-METALLIC SUPPORT STRUCTURES
  - Subpart A Graphite Materials
  - Subpart B Composite Materials

High Temperature Reactors

CLASSIFICATION

What is Classification?

- Classification is a system concept
  - The process/safety system is given a classification based on stated criteria (often referred to as "system safety criteria").
- System Safety Criteria may be found in engineering standards or in regulatory and enforcement documents applicable to the nuclear power plant site.
- SEC III is a component construction code.
- The components usually inherit the classification of the system in which they are located.

Selection of Code Class

- **Section III does not provide guidance** in the **selection of a specific classification** to fit a component in a given system.
- Guidance is **derived from systems safety criteria** for the specific types of nuclear power systems, such as PWR, BWR or HTGR.
- **The Owner** of a nuclear power plant **shall be responsible** for applying the system safety criteria to classify the equipment.
- **Classification shall be included in the Design Specification.**
- In Canada CSA N285.0 contains the guidance for our existing reactor concepts.

Classification in SEC III

- SEC III provides rules for construction of items designated as Code Classes A and B.
- These rules are intended to be applied to the items in high temperature reactor systems and their supporting systems.
- Code Class recognizes the levels of importance associated with the function of each item as related to the safe operation of the nuclear power plant.
- The Code Class provides a choice of rules that provide assurance of structural integrity and quality commensurate with the relative importance assigned to the individual items of the nuclear power plant.

Subsection HA, Subpart A

- The rules of Subsection HA, Subpart A provide the general requirements for the metallic components used in the high temperature reactor systems and their supporting systems.
  - (a) The rules of Subsection HA, Subpart A are contained in Divisions 1 and 2, Subsection NCA, except for those paragraphs or subparagraphs replaced by the corresponding numbered HAA paragraphs.
  - (b) Division 1 rules may use different terminology than Division 5 (e.g., Class 1 and Class 2 versus Class A and Class B, etc.) but the application and use of these rules is identical for Division 5 construction.

Subsection HA, Subpart A

- (c) Division 1, Class 1 requirements are applicable but shall be referred to as Division 5, Class A.
- (d) Division 1, Class CS requirements are applicable but shall be referred to as Division 5, Class A.
- (e) Division 1, Class 2 requirements are applicable but shall be referred to as Division 5, Class B.
- **(f) Division 1, Class 3 and Class MC requirements are not applicable to Division 5 construction.**

Section III, Division 5 Organization & Classification (current)

Class	Subsection	Subpart	Subsection ID	Title	Scope
General Requirements					
Class A, B	HA	A	HAA	Metallic Materials	Metallic
Class A		B	HAB	Graphite and Composite Materials	Nonmetallic
Class A Metallic Pressure Boundary Components					
Class A	HB	A	HBA	Low Temperature Service	Metallic
Class A		B	HBB	Elevated Temperature Service	Metallic
Class B Metallic Pressure Boundary Components					
Class B	HC	A	HCA	Low Temperature Service	Metallic
Class B		B	HCB	Elevated Temperature Service	Metallic
Class A and Class B Metallic Supports					
Class A & B	HF	A	HFA	Low Temperature Service	Metallic
Class A Metallic Core Support Structures					
Class A	HG	A	HGA	Low Temperature Service	Metallic
Class A		B	HGB	Elevated Temperature Service	Metallic
Class A Nonmetallic Core Components					
Class A	HH	A	HHA	Graphite Materials	Graphite
Class A		B	HHB	Composite Materials	Composite

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Section III, Division 5
Organization & Classification (proposed)

Class	Subsection	Subpart	Subsection ID	Title	Scope
General Requirements *					
Class A, B, & SM	HA	A	HAA	Metallic Materials	Metallic
Class SN		B	HAB	Graphite and Composite Materials	Nonmetallic
Class A Metallic Pressure Boundary Components					
Class A	HB	A	HBA	Low Temperature Service	Metallic
Class A		B	HBB	Elevated Temperature Service	Metallic
Class B Metallic Pressure Boundary Components					
Class B	HC	A	HCA	Low Temperature Service	Metallic
Class B		B	HCB	Elevated Temperature Service	Metallic
Class A and Class B Metallic Supports					
Class A & B	HF	A	HFA	Low Temperature Service	Metallic
Class SM Metallic Core Support Structures *					
Class SM	HG	A	HGA	Low Temperature Service	Metallic
Class SM		B	HGB	Elevated Temperature Service	Metallic
Class SN Nonmetallic Core Components *					
Class SN	HH	A	HHA	Graphite Materials	Graphite
Class SN		B	HHB	Composite Materials	Composite

* Class designation being balloted

Limits of Division 5 Rules

Excluding Subsections HA, HF and HH, the Subsections of Division 5 consist of two subparts.

Subpart A addresses the rules for low temperature service and Subpart B addresses the rules for elevated temperature service.

Table HAA-1130-1 establishes the maximum temperature limits for the material under consideration at which the low temperature service rules shall be used.

Elevated temperature service rules shall be used for temperatures above those listed in Table HAA-1130-1 (but limited to temperatures established in the applicable rules) for the material under consideration.

Table HAA-1130-1

Values of T_{max}
Various Classes of Permitted Materials

Materials	T_{max} ^{0}F (^{0}C)
Carbon Steel	700 (370)
Low Alloy Steel	700 (370)
Martensitic Stainless Steel	700 (370)
Austenitic Stainless Steel	800 (425)
Nickel-Chromium-Iron	800 (425)
Nickel-Copper	800 (425)