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DOE Perspectives

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DOE Standards Support

Codes and Standards are valuable to industry and regulators alike because they provide criteria, requirements, and/or methods that represent industry best practices, and can be applied to satisfy regulatory requirements.

DOE supports the industry's development of these codes & standards primarily through:

- Focused research providing the technical bases for new or modified codes & standards
- Codes & standards committee participation by subject matter experts

Advanced Reactors

Advanced Non-LWRs include a range of High Temperature Reactor technologies:

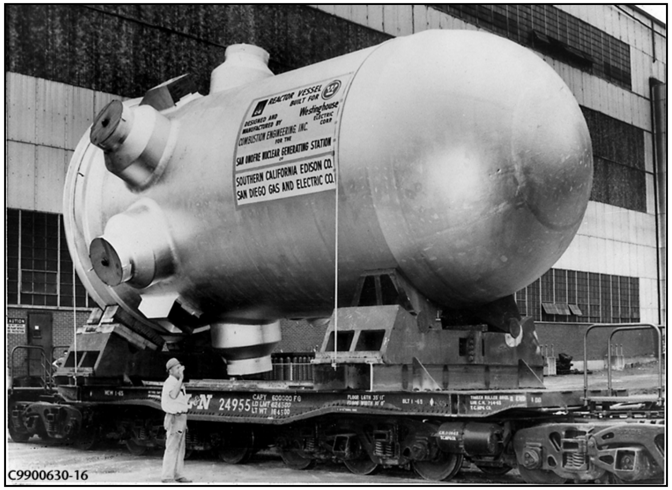
- Gas-cooled
- Liquid Metal
- Molten Salt

Perspectives in this presentation focus on the "downstream" processes related to industry and NRC endorsement of codes & standards

Other presenters will discuss the prioritization and development of codes & standards to support advanced non-LWR technologies

ASME Section III Treats Metallic Materials for Low & High Temperatures Differently

- **Allowable stresses for LWR & low-temperature advanced reactor components not time dependent**
  - **< 700°F (371°C) for ferritic steel and < 800°F (427°C) for austenitic matls**



PWR
RPV

Monju
SFR
IHX

- **At higher temps, materials behave in-elastically and allowable stresses are explicit functions of time & temp**
  - **Must consider time-dependent phenomena such as creep, creep-fatigue, relaxation, etc.**
  - **ASME Sec III Division 5 provides rules for construction of high temperature reactor components**

ASME Section III Division 5: High Temperature Reactors

Sec III Div. 5 contains construction and design rules for high-temperature reactors, including gas-cooled, liquid metal, & molten salt reactors

- **First Issued in Nov 2011, revised in 2013, 2015 & 2017**
- **Covers high-temperature metallic components explicitly**
- **Includes rules for graphite & ceramic composites for core supports & internals for first time in any international design code**
- **Covers low temperature metallic components, largely by reference to other portions of Sec III**

Construction Rules for Components of High Temperature Reactors Need to be Endorsed

- NRC has begun to assess ASME Section III Div. 5 for endorsement
  - Will enhance regulatory surety for HTR designers and license applicants
  - Very important since predecessor ASME rules have not typically been endorsed by NRC in advance of license applications

- ASME has formed task groups to support regulatory endorsement of Div 5

Chronology of Major Endorsement Efforts for ASME Section III Division 5

9/15 – Discussions at 1st DOE-NRC Workshop on Advanced Non-LWR Cooled Reactors on need for Div 5 endorsement

2/16 – Begin detailed discussions between NRO and DOE-NE on NRC plans for participation in relevant ASME Div 5 subgroups

3/16 – Endorsement by ASME BNCS of High Priority List for Div 5 Code Actions

6/16 – Presentation at 2nd DOE-NRC Workshop emphasizing need for and value of NRC endorsement of ASME Section III Division 5

2/17 – Two task Groups formed at ASME Code Week representing High Temperature Liquid- and Gas-Cooled Reactor working groups to define pathway and schedule for NRC endorsement of Div 5

- Metallic structures & components
- Non-metallic support structures

Industry's Further Optimization of Div. 5

- Opportunities to optimize certain technical aspects of Div. 5 have been identified
  - ASME has established task groups to pursue and address these aspects

- DOE's Advanced Reactor Technologies (ART) Office is conducting R&D supporting Div. 5 optimization topics including:
  - Resolution of numerous identified shortcomings in high temperature design methods (see review summaries)
  - Extension of materials allowables from 300,000 to 500,000 hrs to support 60-yr lifetimes of advanced reactors
  - Inclusion of graphite and & ceramic composites for core supports & internals for first time in any international design code

DOE-ART Materials Program Also Provides Technical Basis for ASME Division 5 Additions

- Additional Materials are being added to ASME Division 5
  - Alloy 617, high-temperature nickel-based alloy to allow higher temperature heat exchangers and steam generators
  - Alloy 709, super stainless steel, to significantly improve high temperature strength and expand design envelop, performance, safety, and economics for advanced reactors
  - Hastelloy N (proposed) high nickel alloy compatible with salt-cooled reactors
- Additional high temperature design methods are being added to Division 5
  - Improved design rules at very high temperatures based on idealized elastic perfectly plastic (E-PP) material behavior
  - Rules for use of compact heat exchangers for improved power conversion efficiencies
  - Rules for high-temperature weld overlay clad structures (proposed) for use of currently qualified ASME Div 5 materials and compatibility with molten salt reactors

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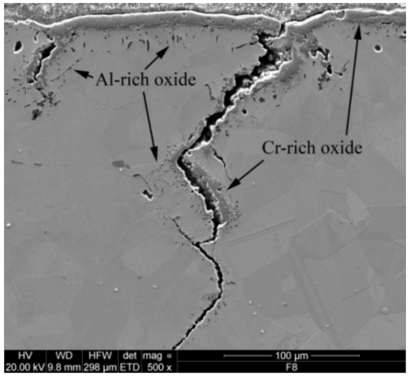
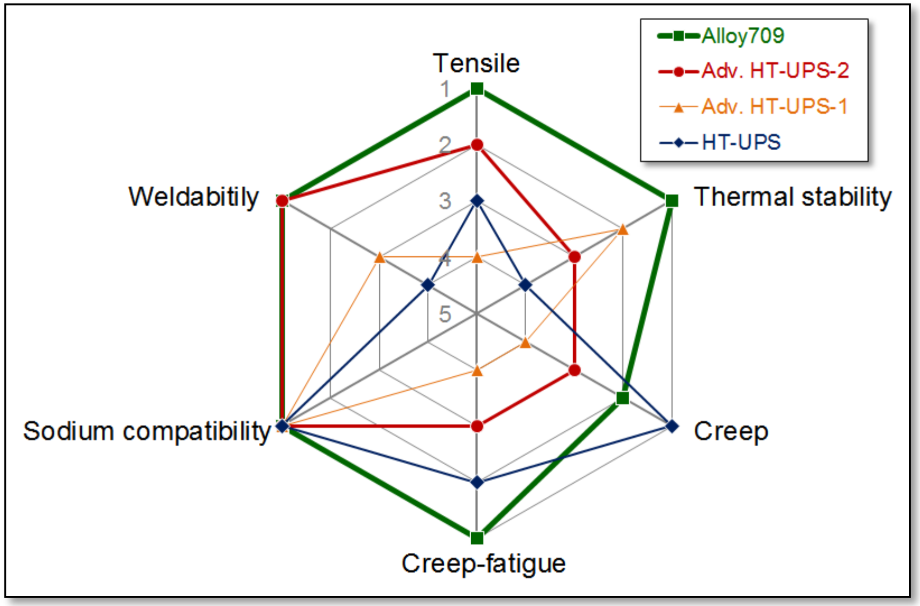
Additional High-Temperature Alloys, Now Being Qualified, Will Provide Additional Options for Nuclear Construction

- **Alloy 617 Code Case being approved**
  - Advanced gas reactor heat exchangers & steam generators up to 950°C and 100,000 hrs
  - Low-temperature Code Case (T < 427°C) approved and high-temperature CC approval in progress
  - Anticipate inclusion in 2019 edition of Sec III Div 5



Creep-fatigue crack 617

- **Alloy 709 selected for Code qualification**
  - Will provide improved performance, design envelop, and cost reduction for LMRs
  - Roughly double existing creep strength of existing stainless steels in Sec III Div 5
  - Qualification testing begun



DOE-ART Materials Program Provides Technical Basis for Establishing New Regulatory Requirements

- **Corrosion studies of materials for usage with high temperature reactor coolants**
  - **Evaluation of alloys, graphite, and composites in HTGR helium chemistries and air/steam ingress**
  - **Evaluation of current Code-qualified and proposed new alloys for compatibility with sodium for fast reactor applications**
  - **Evaluation of current Code-qualified and advanced materials for compatibility with salt-cooled reactors**
- **Development and validation of irradiation-effects models**
  - **Qualification of irradiation and irradiation-creep effects for graphite behavior for ASME Section III Division 5**
  - **Development of validated models for predicting very high dose neutron exposures for fast reactor applications using ion irradiations**

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Ongoing High Priority ASME Code Committee Actions Endorsed by BNCS and Supported by DOE R&D Activities

Topics	2019 Edition	Beyond 2019
New simplified analysis methods (EPP) that replace current methods based on linear analysis (and can be used at higher temperatures) for all Class A materials	X	
Adequacy of the definition of S values used for the design of Class B components, which is based on extrapolated properties at 100,000 hours, in light of application to 500,000 hours design	X	
Construction rules for "compact" heat exchanges		X
Incorporation of new materials such as Alloy 617 and Alloy 709 (austenitic stainless)	A617	A709
Pursuit of "all temperature code"		X
Complete the extension of Class A materials for 500,000 hr-design	304H, 316H	Grade 91, 2¼Cr-1Mo, Alloy 800H
Develop design by analysis rules for Class B components (including compact HX)		X
Add non-irradiated and irradiated graphite material properties		X
Develop rules for cladded components for molten salt reactor applications		X

ASME Section III Division 5 Needs to Be Updated and Endorsed

- **There is a recognized need to expand use of consensus-based codes and standards in the advanced reactor regulatory framework to minimize time to completion, provide flexibility in implementation, and enhance regulatory surety**
- **Discussions between NRC's Office of New Reactors, DOE-NE's Office of Advanced Reactor Technologies, and ASME's Sub-Group on High Temperature Reactors have initiated the process for NRC to evaluate and eventually endorse Division 5**
- **A lack of NRC endorsement of ASME construction rules for advanced non-LWRs represents a significant regulatory risk that delays development & deployment and discourages commercial interest**

Path Forward

- DOE will continue to interact with industry as stakeholders identify which codes and standards are of highest priority
- These priorities are a key input to the establishment and ongoing implementation of DOE's research and technical support activities