US Nuclear Codes and **Swedish Guideline** on the structural design of concrete containments and other concrete structures at NPPs and other nuclear facilities

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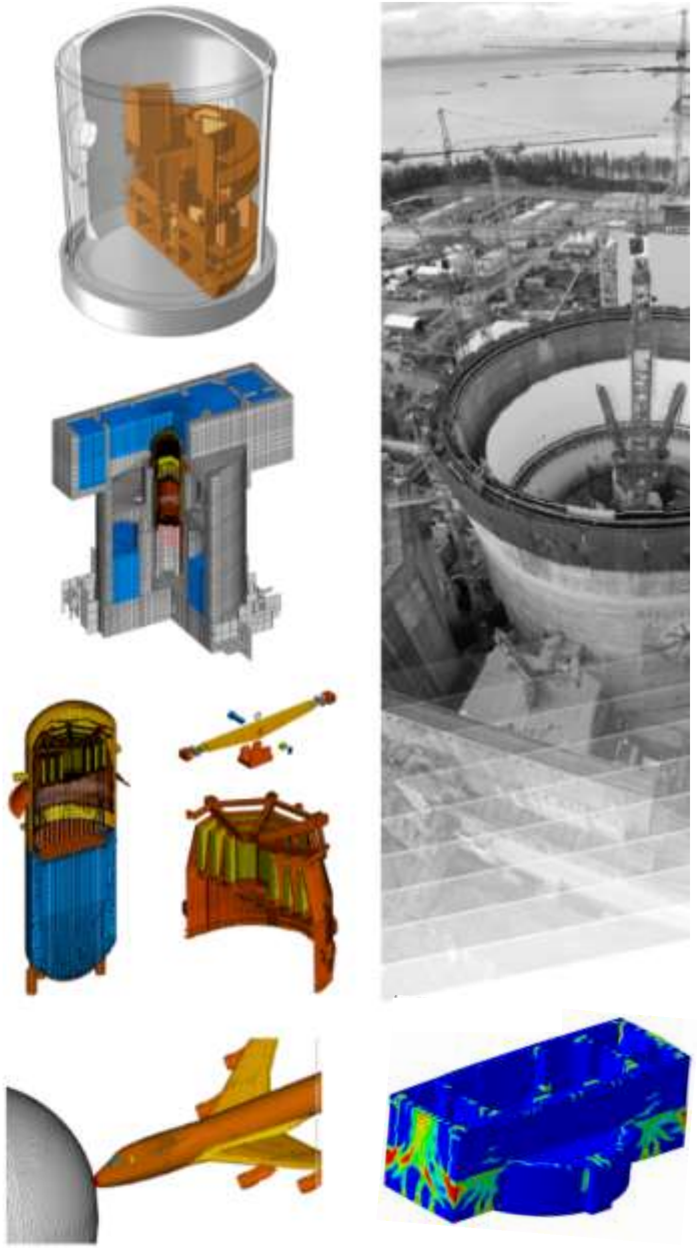
Seminar "Nuclear Construction Codes around the World", 7 September 2017, Cracow/Poland

SCANSCOT TECHNOLOGY

ENGINEERING SERVICES WITHIN THE NUCLEAR INDUSTRY
- Regulations, Codes & Standards and Requirements
- Advanced simulations of static/dynamic accidental events
- Structural design of concrete and steel structures
- Reference projects in Europe, North America and Asia

SOFTWARE PRODUCTS
- BRIGADE – Finite Element Analysis software for Bridge Design
- Reseller of ABAQUS (Finite Element Analysis software)

COOPERATION IN POLAND
- BUDSOFT – Realistic Simulation Solutions, Poznań, Poland



OLA JOVALL

US CODES

- Code Committee Voting Member: **ACI 349 – Other Safety-Related Nuclear Concrete Structures**
- Code Committee Voting Member: **ASME Sect III Div 2 – Code for Concrete Containments**
- Member of several Task Groups, Working Groups etc. regarding:
    - Structural design
    - Harmonization of ACI 349 and ASME Sect III Div 2
    - Intermediate and long-term development of ASME Sect III Div 2
    - Containment design for Design Extension Conditions & Design Extension External Events (DEC & DEEE)

SWEDISH DESIGN GUIDE DNB

- Editor and Main Author of the Swedish Radiation Safety Authority report 2017:07 - **Design Guide for Nuclear Civil Structures (DNB)**

CONTENT

SWEDISH DESIGN GUIDE DNB

- Background / Content / Status
- Connections with regulations
- Connections with Codes & Standards

US CODES

- Point out and discuss applicable documents
- Design Extension Conditions (DEC) and Design Extension External Events (DEEE)
- Code comparison examples

NUCLEAR POWER PLANTS IN SWEDEN

DESIGN AND CONSTRUCTION OF COMMERCIAL NUCLEAR POWER PLANTS

- Carried out during ~20 years
- Placing of first order 1965 (Oskarshamn 1)
- The latest plant connected to the grid 1985 (Oskarshamn Unit 3)

ALL-IN-ALL 12 COMMERCIAL UNITS WHERE CONSTRUCTED

- 9 BWRs (Asea-Atom, three different generations)
- 3 PWRs (Westinghouse)
- Situated at four different site

NUCLEAR POWER PLANTS IN SWEDEN

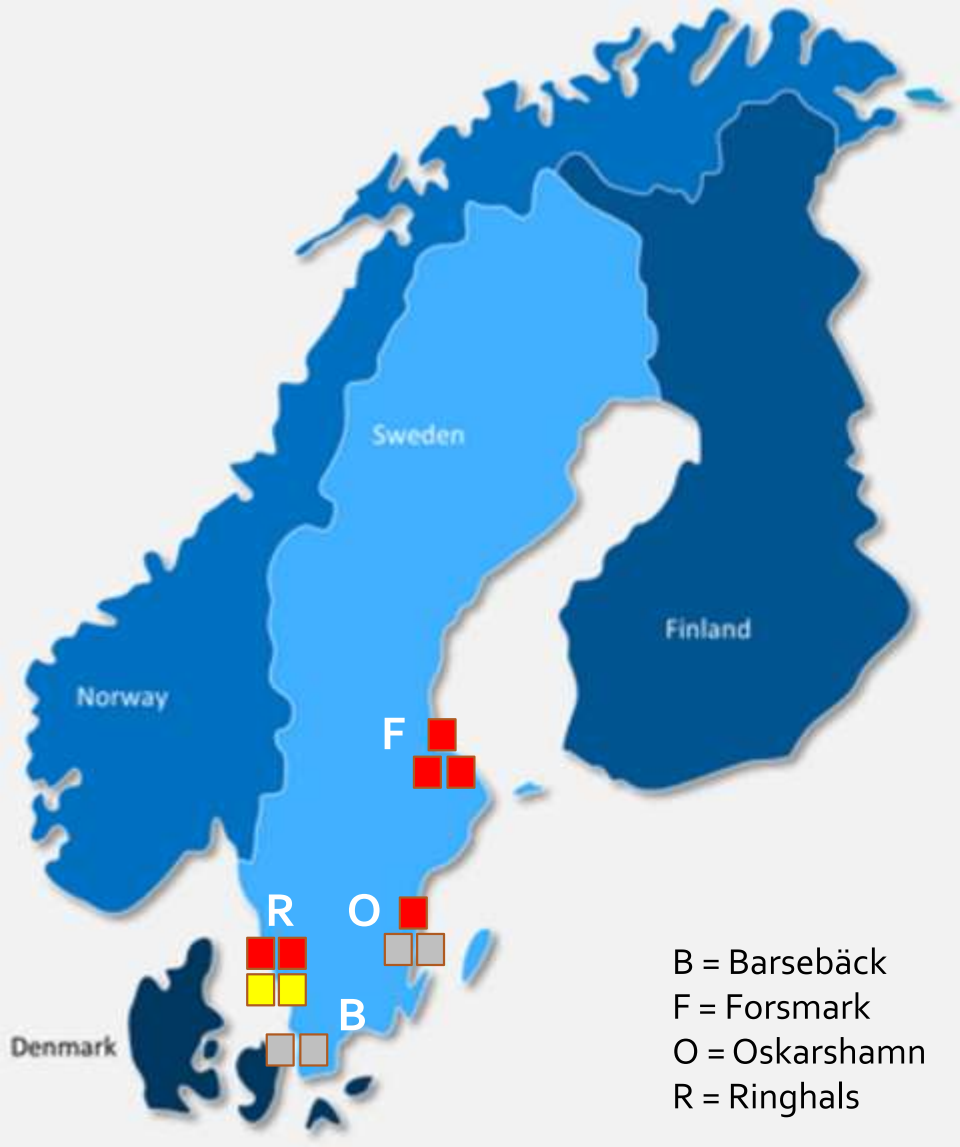
- Planned continued operation
- Decommission 2019 - 2020
- Decommissioned 1999, 2005, 2015, 2017
- New build

12 commercial NPP´s all-in-all

8 in operation

2 to be shut down in the near future

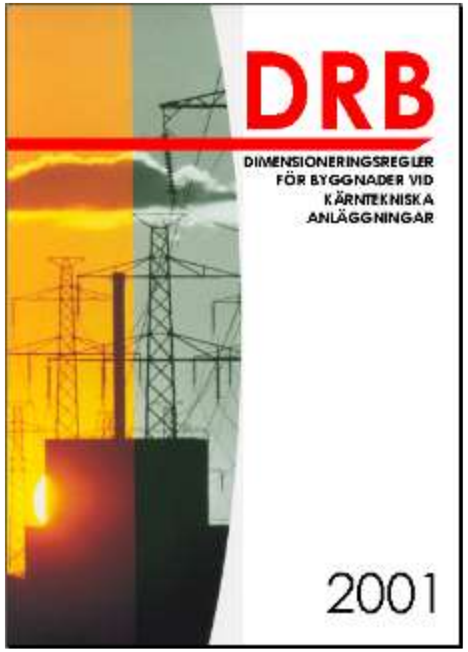
No new build projects



SWEDISH DESIGN GUIDE FOR NUCLEAR CIVIL STRUCTURES, DNB

BACKGROUND

- The original design of the Swedish units has been based on different set of design rules
- **The <u>previous Swedish design guide</u> ”Design Rules for Buildings at NPPs (DRB)”** where developed to have a common consistent set of design rules for future work
- Licensee initative
- Scanscot Technology assigned to write the report
- Issued 1998, updated 2001



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- Licensee initative
- Scanscot Technology assigned to write the report
- Issued 1998, updated 2001
- **Since based on the at that time Swedish Building Codes in force, when Eurocodes became mandatory it emerged the need for a new design guide complying with Eurocodes -> DNB**

ESTABLISHMENT OF THE DESIGN GUIDE (DNB)

STEERING COMMITTE

- The Swedish Radiation Safety Authority (SSM)
- The Swedish Licensee´s

PROJECT TEAM

- Scanscot Technology – Author of the report
- Prof. S. Thelandersson, Lund University, Sweden – Reviewer

EVALUATION OF THE REPORT

- Selected stakeholders – Review and comments
- Steering Committee – Review and comments;
  – Final acceptance of the report

Forsmark Kraftgrupp AB
Ringhals AB

Swedish Nuclear Fuel and Waste Management Co

CONTENT OF THE DESIGN GUIDE (DNB)

FIRST & SECOND EDITION (January 2014; June 2015)
- General requirements and design provisions
- Loads and load combinations
- Design of concrete containments and other structures
- Seismic design

THIRD EDITION (February 2017)
- Fire design
- Impactive & impulsive loading (explosions, missiles, APC)

FOURTH EDITION (February 2019), extend the sections on
- Design Extension Conditions/External Events (DEC/DEEE)
- Classification of buildings
- Materials

DESIGN GUIDE FOR NUCLEAR CIVIL STRUCTURES (DNB)

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PURPOSE OF THE DESIGN GUIDE (DNB)

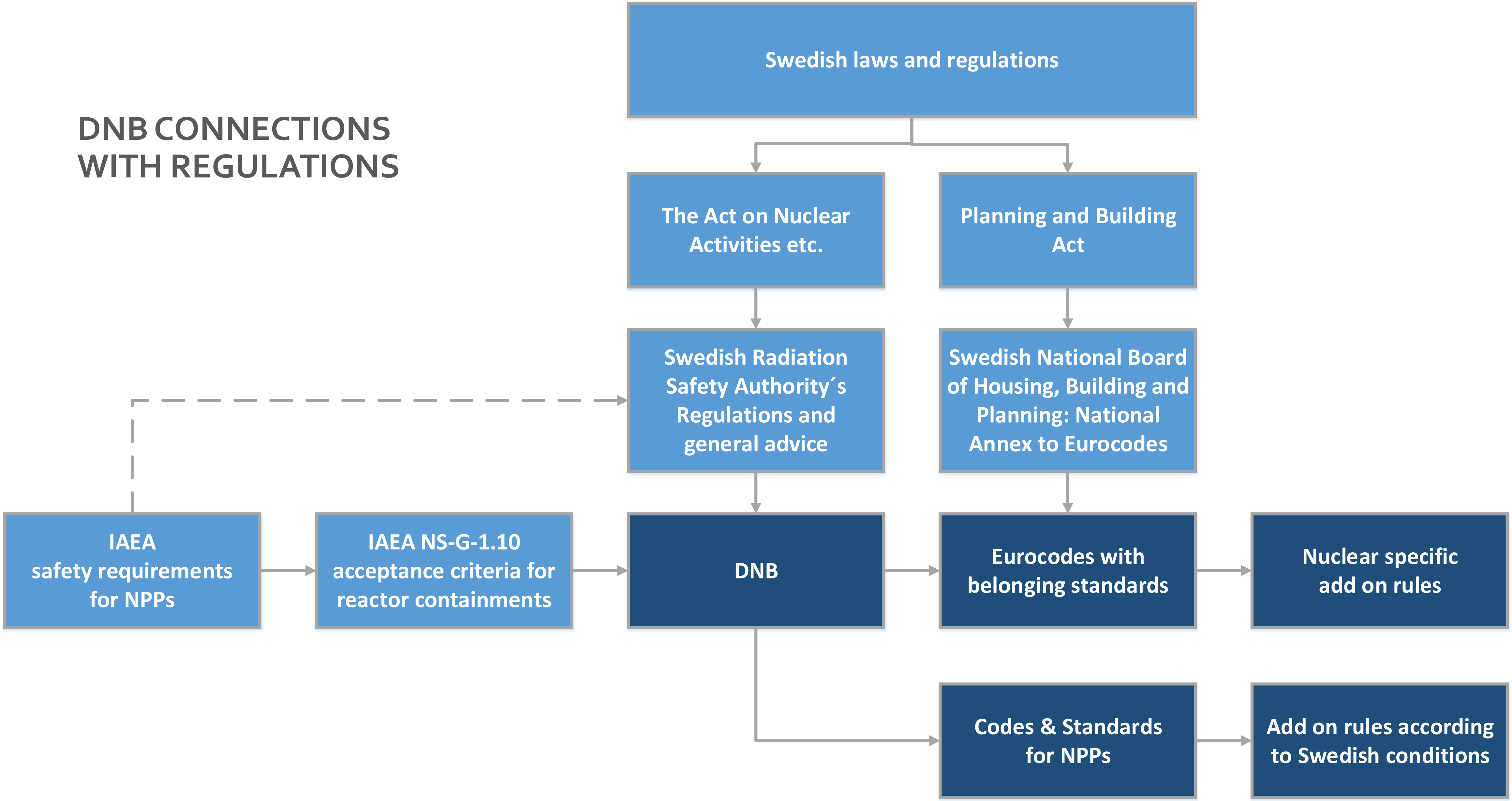
LICENSEE´S, SUPPLIERS etc.

- Non-mandatory guideline
- Consistent set of design rules
- Assist during verification of existing structures, and during the design of new structures

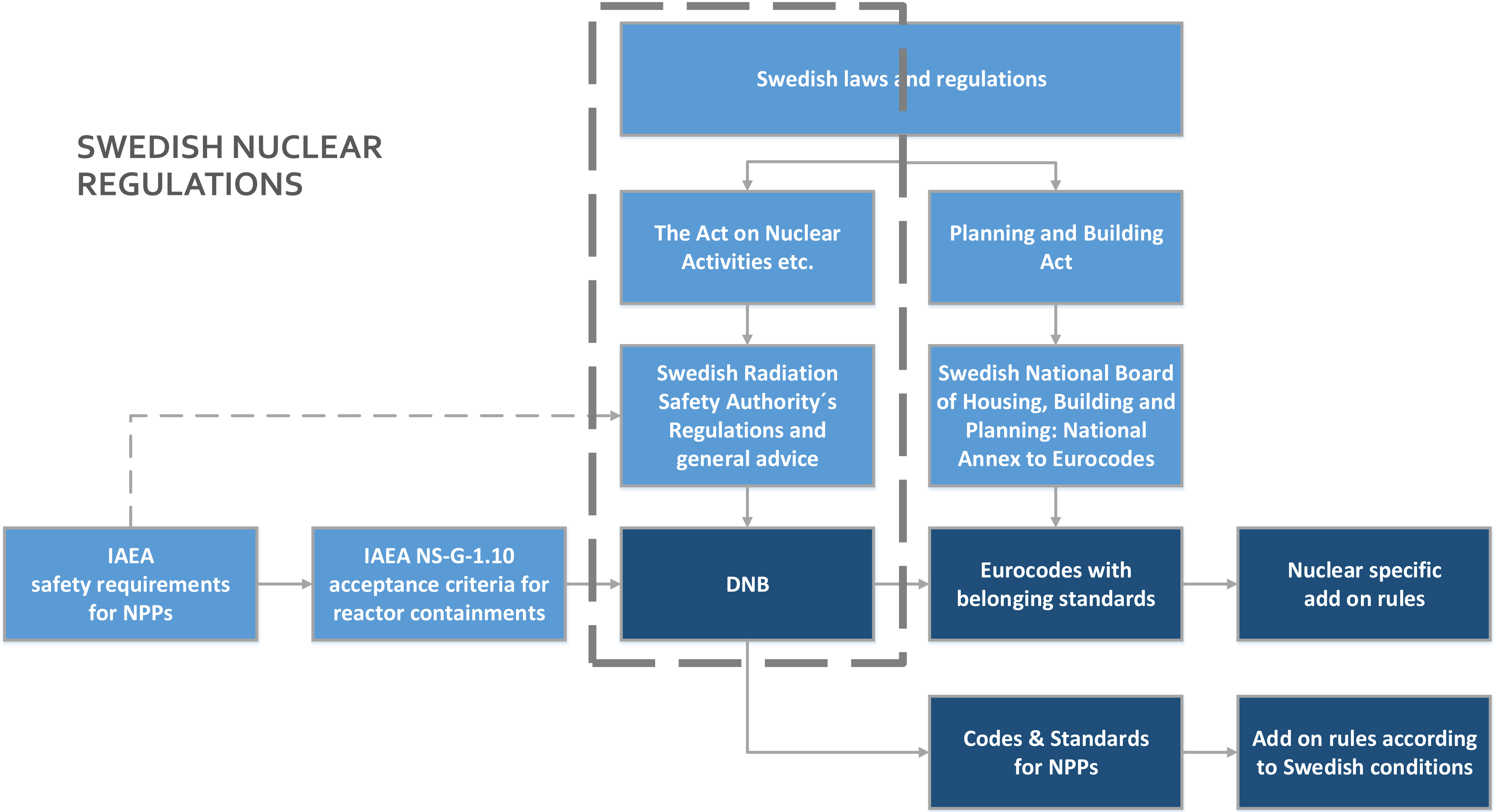
SWEDISH REGULATORY BODY (SSM)

- **"DNB to be used by SSM during safety assessments of structures"**
- "DNB could contribute to specify demands to be enforced for nuclear facilities"
- Ongoing development of New Regulations and corresponding General Advice Documents

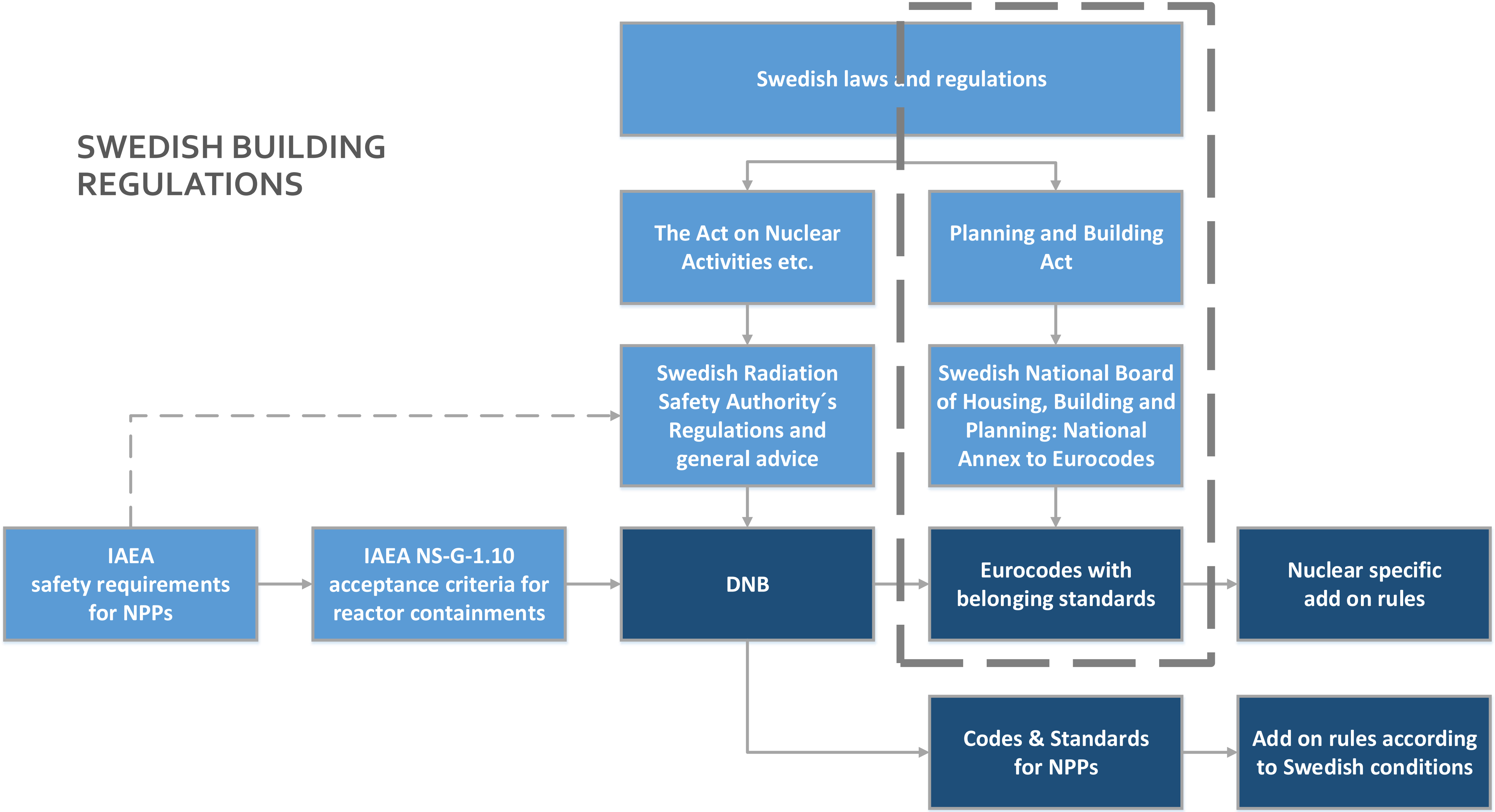
DNB CONNECTIONS WITH REGULATIONS



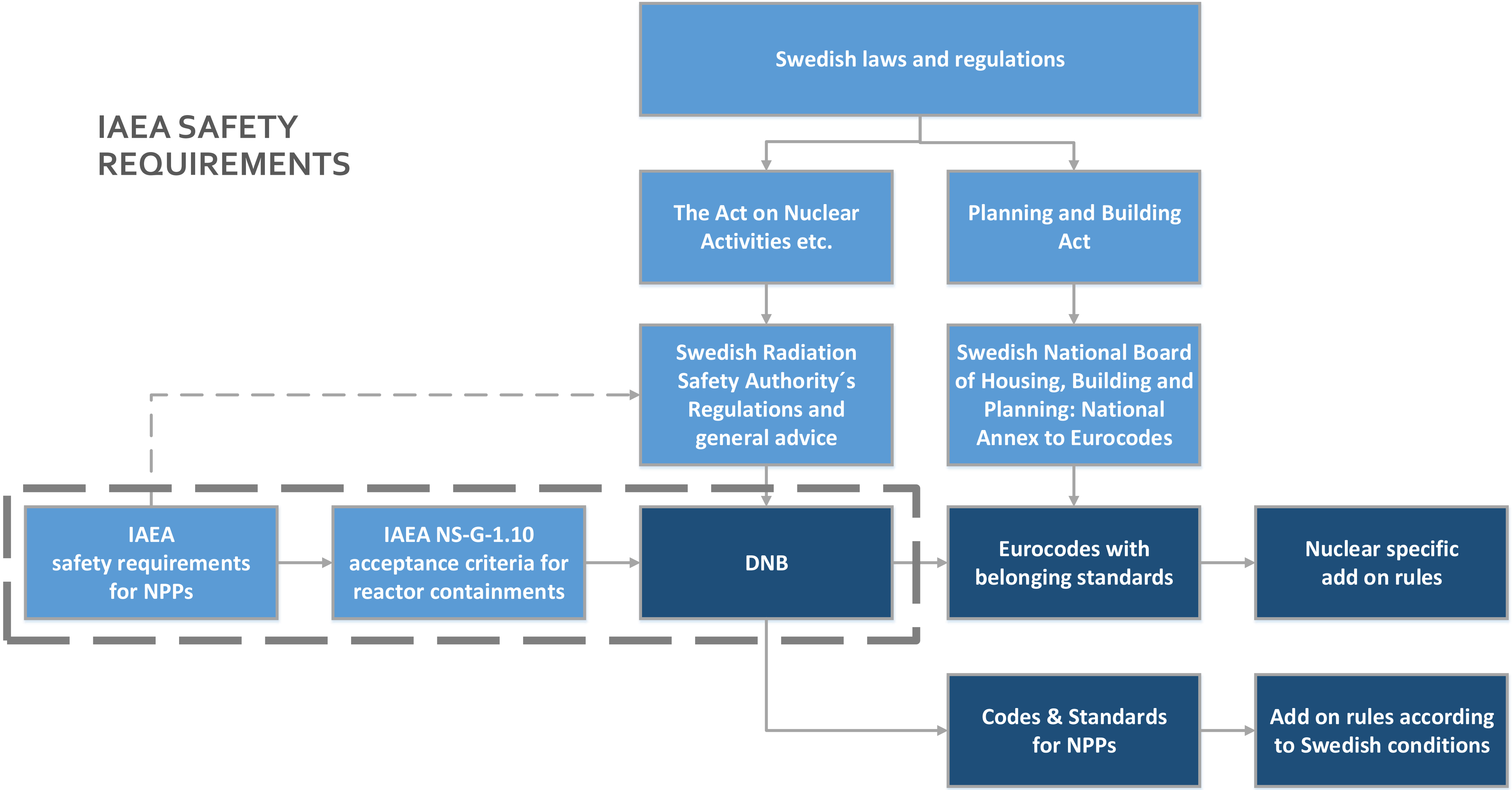
SWEDISH NUCLEAR REGULATIONS



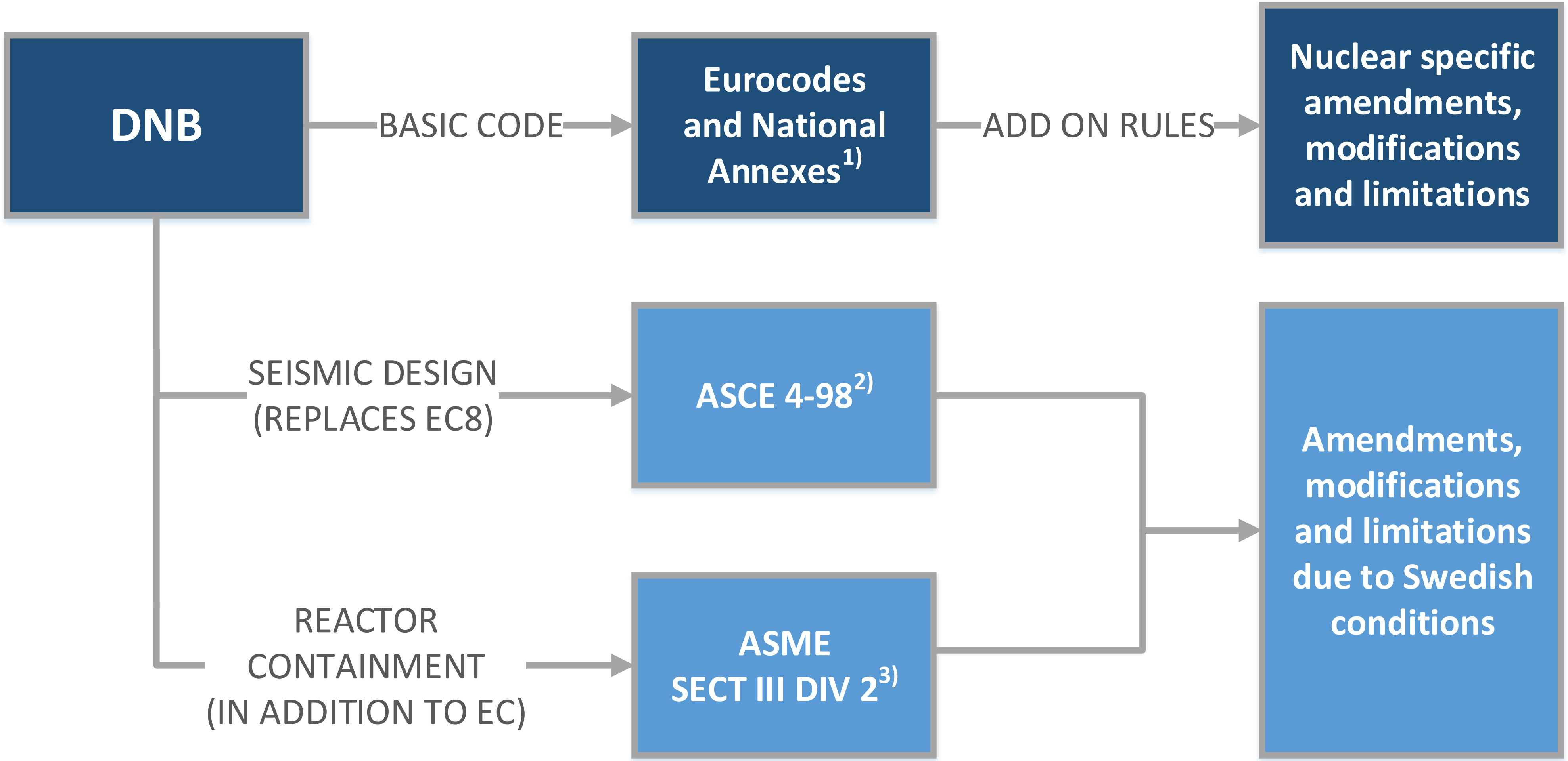
SWEDISH BUILDING REGULATIONS



IAEA SAFETY REQUIREMENTS



DNB CONNECTIONS TO DIFFERENT CODES & STANDARDS



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2) ASCE 4-98 Seismic Analysis of Safety-Related Nuclear Structures and Commentary
3) ASME Sect III Div 2 Code for Concrete Containments

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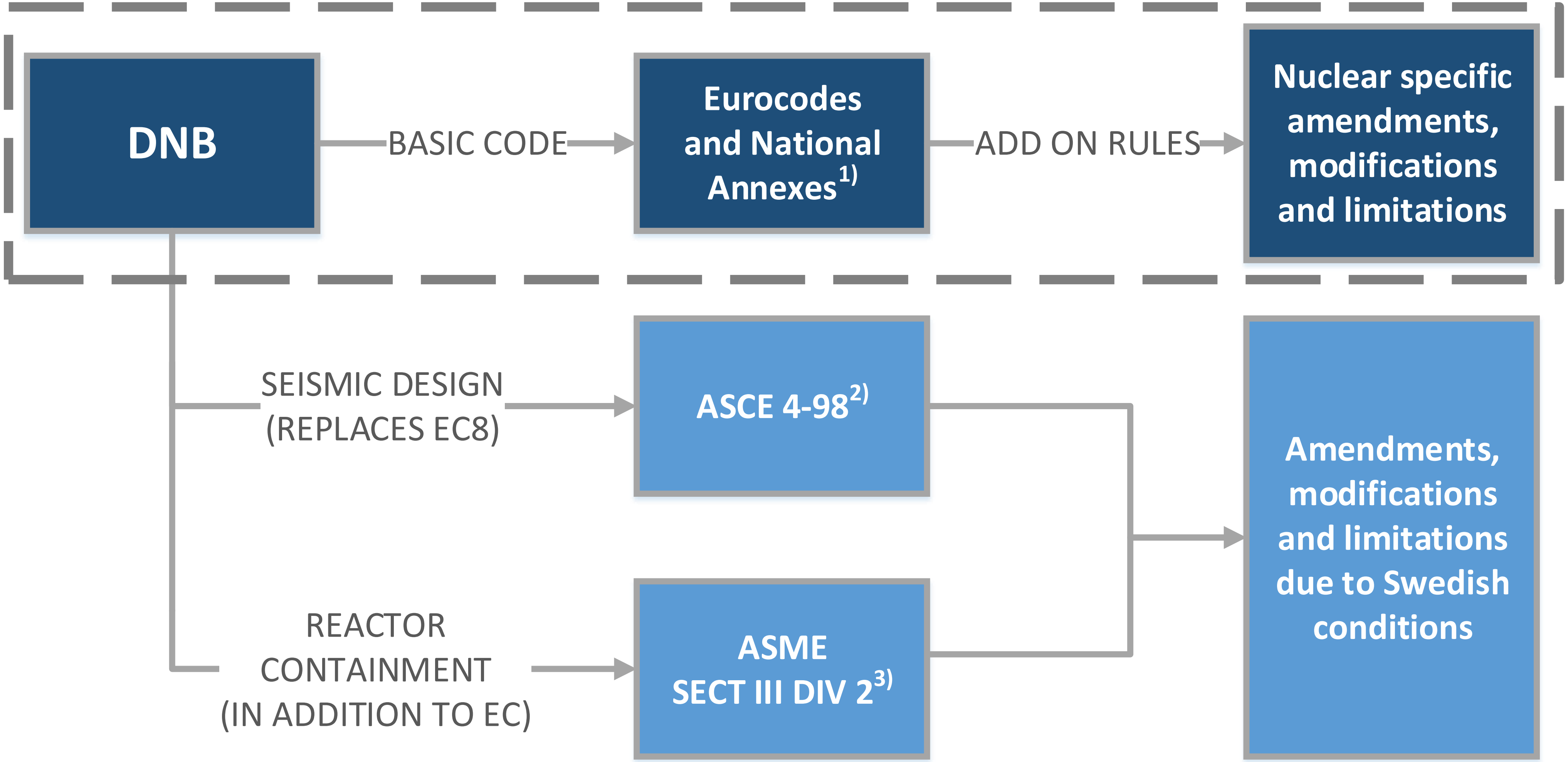

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SCANSCOT Technology

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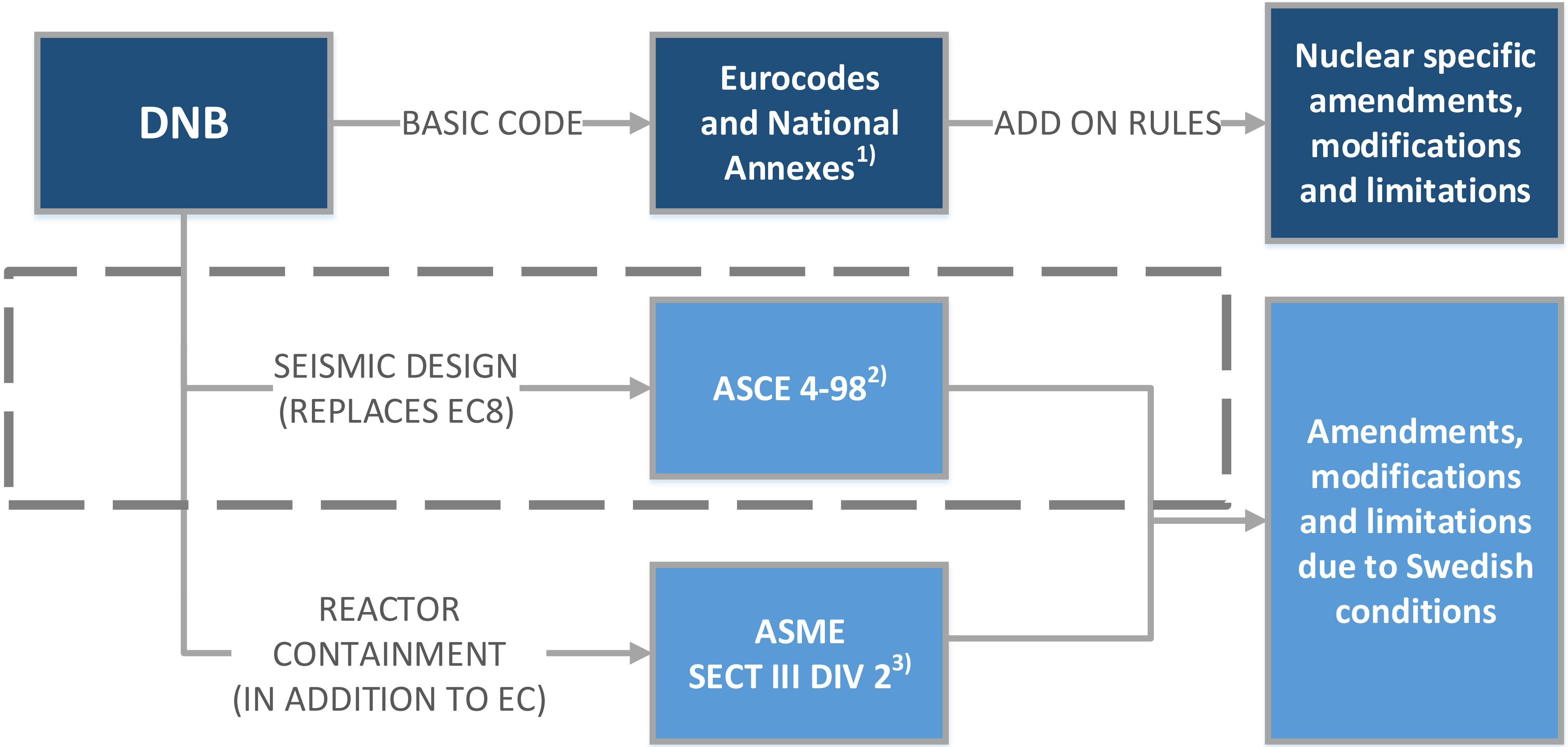

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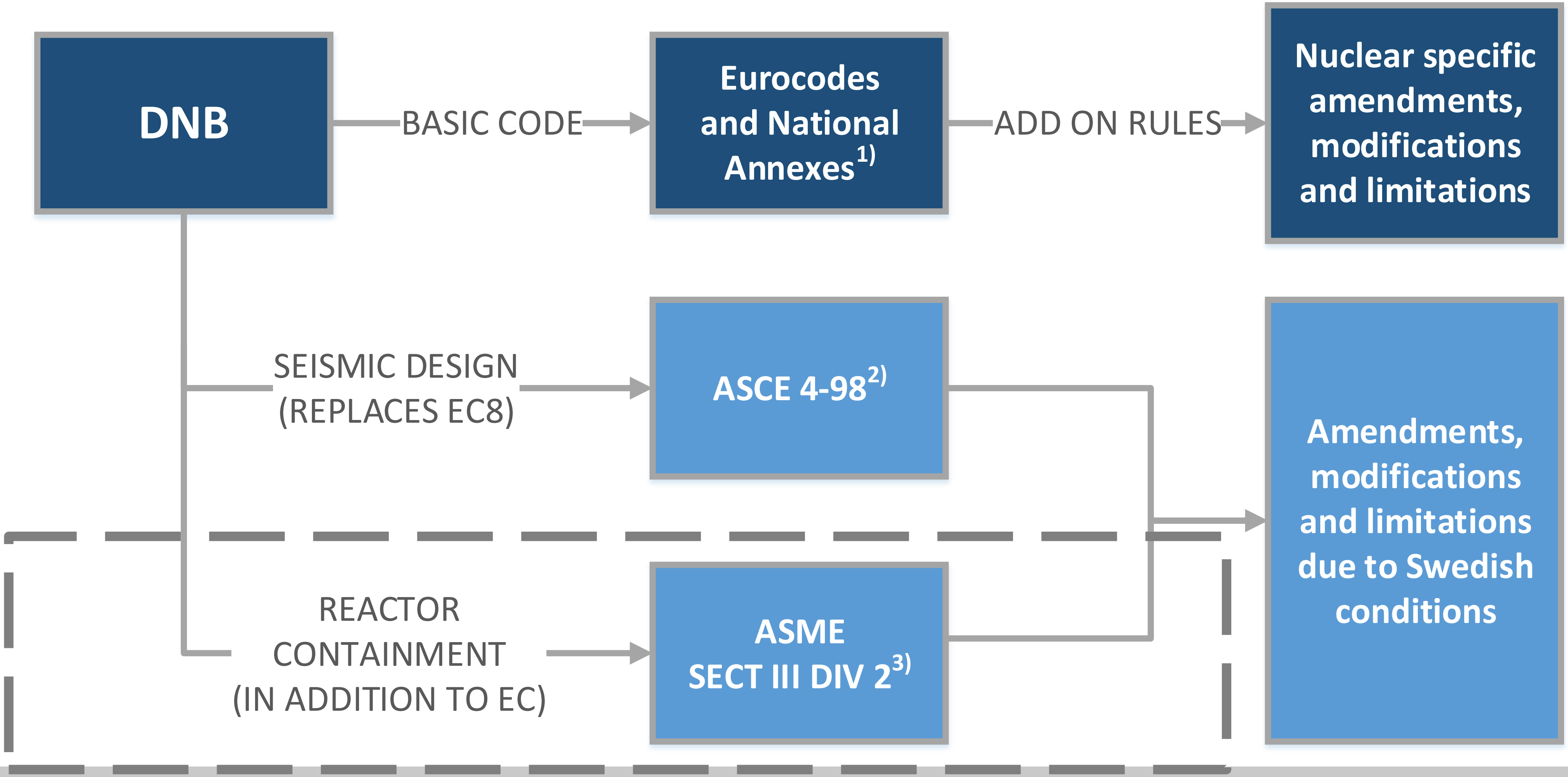

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DNB CONNECTIONS TO DIFFERENT CODES & STANDARDS

EUROCODES

- The basic code adopted
- Applied together with the Swedish National Annexes

ASME SECT III DIV 2 CODE FOR CONCRETE CONTAINMENTS

- Adopted
- To comply with both Eurocodes and ASME Sect III Div 2

ACI 349 CODE REQUIREMENTS FOR NUCLEAR SAFETY-RELATED CONCRETE STRUCTURES

- Comparisons has been made between this code and DNB
- ACI 349 design approaches adopted if found appropriate
  (e.g. limitation of redistribution of section forces), but not included specific numerical values
- DNB design results compared with ACI 349 design results (as well as other codes)

DNB CONNECTIONS TO OTHER CODES & STANDARDS

ASCE 4-98 SEISMIC ANALYSIS OF SAFETY-RELATED NUCLEAR STRUCTURES

- Adopted
- Replaces Eurocode EN-1998

IAEA NS-G-1.10 GENERAL ACCEPTANCE CRITERIA FOR STRUCTURAL INTEGRITY AND LEAK-TIGHTNESS OF THE CONTAINMENT

- Next slides!

IAEA SAFETY REQUIREMENTS

GENERAL

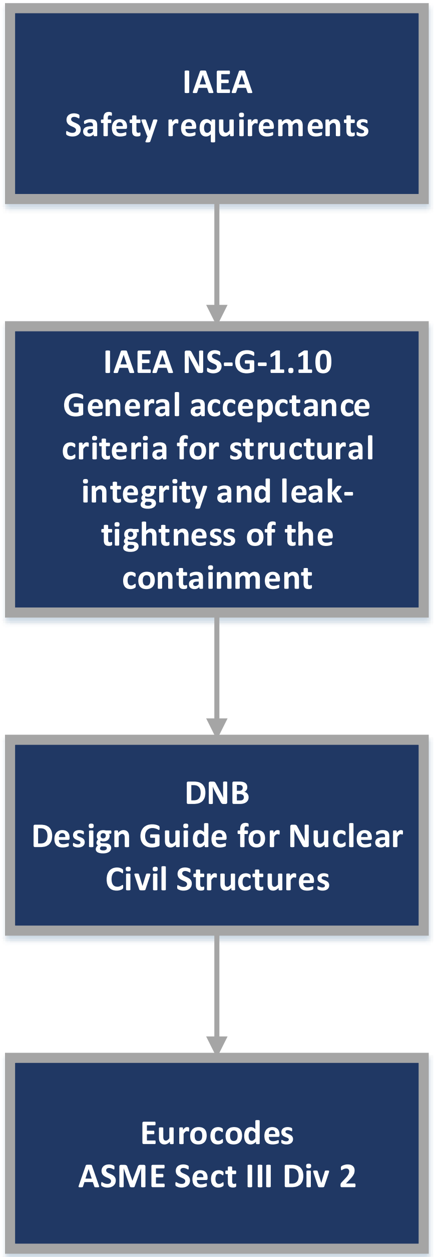
- IAEA specifies general safety requirements for Nuclear Power Plants.
- These requirements are normally adopted by National Safety Radiation Authorities.

IAEA NS-G-1.10 ON CONTAINMENTS

- IAEA specifies in NS-G-1.10 general acceptance criteria for the behavior of the reactor containment related to structural integrity and leak-tightness. These general acceptance criteria are in agreement with the overall safety requirements.

CONNECTION TO DNB

- DNB complies with the IAEA NS-G-1.10 general acceptance criteria for the reactor containment.



IAEA NS-G-1.10 GENERAL ACCEPTANCE CRITERIA FOR CONTAINMENTS

STRUCTURAL INTEGRITY

- Level I: Elastic range
- Level II: Small permanent deformations
- Level III: Large permanent deformations

LEAK-TIGHTNESS

- Level I: Leak-tight structure
- Level II: Limited increase of leak rate
- Level III: Large or very large increase of leak rate

ACCEPTANCE CRITERIA SPECIFIED FOR MAJOR LOAD COMBINATIONS

- Discrepancy: In Sweden we do not combine
  Design Basis Earthquake (DBE) with Design Basis Accident (DBA)

SSM / IAEA safety req.	EVENT CLASS		H1, H2	H3, H4	H5	
			Normal operation and anticipated events	Unanticipated events and improbable events	Highly improbable evenst	
					Design extension conditions (DEC)	Design extension external events (DEEE)
IAEA acceptance criteria	STRUCTURAL INTEGRITY		**Level I:** Elastic range	**Level II:** Small permanent deformations[1)]	**Level III:** Large permanent deformations[2)]	**DEEE that may lead to DEC** ⇐
	LEAK-TIGHTNESS		**Level I:** Leak-tight structure	**Level I:** Leak-tight structure	**Level II:** Limited increase of leak rate[2)]	
DNB Codes, structural analysis and accepted response	**Design of concrete structures**	Code	Eurocodes and ASME Sect III Div 2		Eurocodes	
		Structural analysis	Essentially elastic structural analysis		Plastic analysis	
		Response (cross section)	Elastic behavior	Partial yield	General yield	
	Design of steel liner	Code	ASME Sect III Div 2		Extrapolated demands based on ASME III 2	
		Liner	Limitation of allowable strain			
		Concrete	Limitation of allowable crack width			

1) Level II acceptable (instead of the more restrictive level I) due to a load factor of 1.5 for the LOCA overpressure.

2) Only for postulated events for which it has been decided that structural integrity and leak-tightness have be proven.

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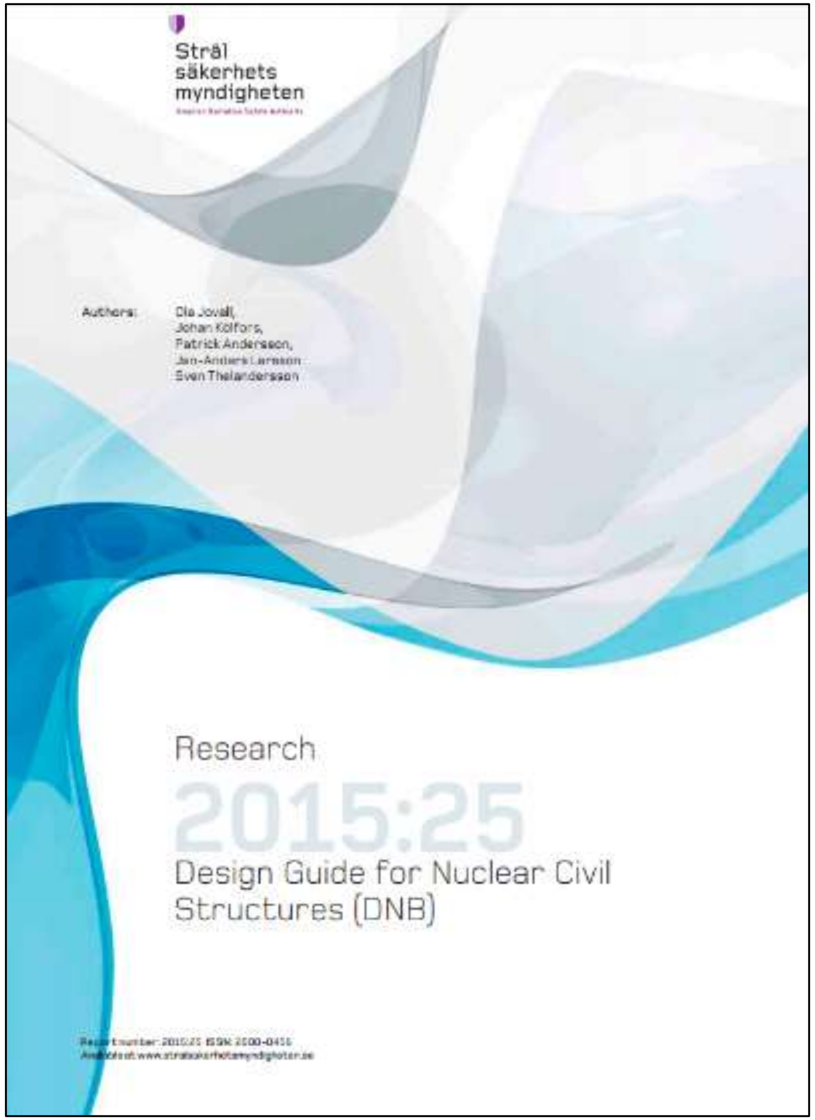
DESIGN GUIDE FOR NUCLEAR CIVIL STRUCTURES (DNB)

- Could be downloaded for free at the Swedish Radiation Safety Authority (SSM) webpage
- The latest edition SSM 2017:07 in Swedish only
- The previous edition SSM 2015:24 is available in an English translation SSM 2015:25

http://www.stralsakerhetsmyndigheten.se/Global/Publikationer/Rapport/Avfall-transport-fysiskt-skydd/2015/SSM_Rapport_2015_25_webb_1.pdf



US CODES - OVERVIEW

American Concrete Institute

ACI

www.concrete.org

American Society of Mechanical Engineers

ASME

www.asme.org

U.S. Nuclear Regulatory Commission

USNRC

www.nrc.gov

US CODES - OVERVIEW

ACI 318 Building Code Requirements for Structural Concrete and Commentary

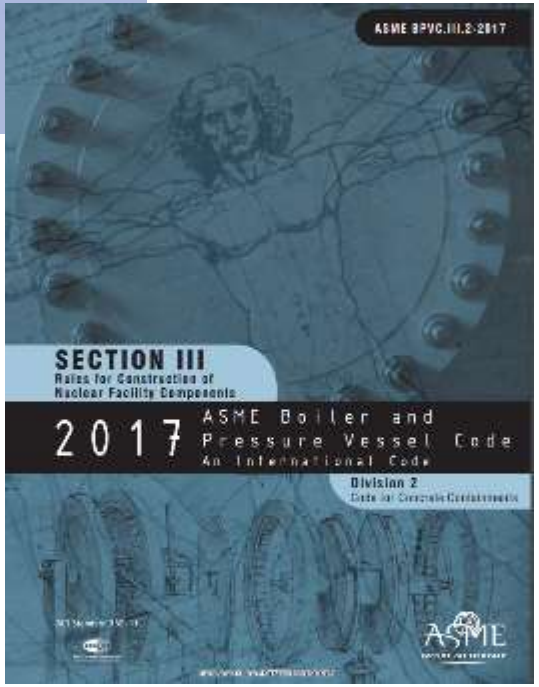
- The basic Code valid for conventional buildings

ACI 349 Code Requirements for Nuclear Safety-Related Concrete Structures & Commentary

- This Code is based on ACI 318

ASME Sect III Div 2 / ACI 359 Joint Code for Concrete Containments

- This Code is based on ACI 349



	ACI 349, other nuclear buildings	ASME Sect III Div 2 / ACI 359, containments
Type of Code	**Dependent code** (previously stand-alone) “Same as ACI 318” Only stating topics when deviating	**Stand-alone code** All paragraphs included

	ACI 349, other nuclear buildings	ASME Sect III Div 2 / ACI 359, containments
Type of Code	**Dependent code** (previously stand-alone) "Same as ACI 318" Only stating topics when deviating	**Stand-alone code** All paragraphs included
Connection to other code	**ACI 318** By reference Normally lag one edition	**ACI 349** By incorporating similar design paragraphs Update to follow ACI 349 updates "ad-hoc" Sometimes rather large differences

	ACI 349, other nuclear buildings	ASME Sect III Div 2 / ACI 359, containments
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Connection to other code	**ACI 318** By reference Normally lag one edition	**ACI 349** By incorporating similar design paragraphs Update to follow ACI 349 updates "ad-hoc" Sometimes rather large differences
Design philosophie	**Load and resistance factor design (LRFD) code** Load factors - reflect the probability Flexure and tension – stress/strain allowable Shear – strength equation	**Combination of ACI LRFD and ASME allowable stress design (ASD)** Load factors - reflect the severity, matching the safety factor principle of an ASD code Flexure and tension – stress/strain allowable Shear – strength equation

	ACI 349, other nuclear buildings	**ASME Sect III Div 2 / ACI 359, containments**
Content (design)	General requirements Materials Loads and load combinations Structural analysis procedures Structural design resistance / allowables Serviceability requirements Durability requirements Detailing	

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Content (design)	General requirements Materials Loads and load combinations Structural analysis procedures Structural design resistance / allowables Serviceability requirements Durability requirements Detailing	
Specific topics (compared with the connected code)	Earthquake resistant design Impactive & impulsive loading Anchoring-to-concrete Thermal considerations	Leak-tightness: Steel liner design Cylindrical shell design

STANDARDS AT DIFFERENT LEVELS

Level	Description	
1	**Level 1 comprises Standards for structural safety and actions on structures; in particular, basic reliability and durability requirements are established.**	Design
2	**Level 2 consists of Standards for the design and detailing of structures.**	Design
3	Level 3 gives information on structural materials, products and the execution of structures.	Materials
4	Level 4 consists of Standards for the testing of materials and products.	Testing
5	Level 5 comprises Standards for protection and repair of existing structures	Repair

EUROCODES AS DESIGN CODE AND OTHER CEN STANDARDS

Level	Description	Conventional buildings
1	**Level 1 comprises Standards for structural safety and actions on structures; in particular, basic reliability and durability requirements are established.**	CEN Standards (i.e. Eurocodes)
2	**Level 2 consists of Standards for the design and detailing of structures.**	CEN Standards (i.e. Eurocodes)
3	Level 3 gives information on structural materials, products and the execution of structures.	CEN Standards
4	Level 4 consists of Standards for the testing of materials and products.	CEN Standars
5	Level 5 comprises Standards for protection and repair of existing structures	CEN Standards

APPLYING US DESIGN CODES

Level	Description
1	**Level 1 comprises Standards for structural safety and actions on structures; in particular, basic reliability and durability requirements are established.**
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4	Level 4 consists of Standards for the testing of materials and products.
5	Level 5 comprises Standards for protection and repair of existing structures

Nuclear power plants

Design: ASME and ACI Codes

Design: ASME and ACI Codes

Materials: ??? CEN Standards ???

Testing: ??? CEN Standards ???

US CODES – WHICH EDITION TO APPLY?

THE LATEST EDITION

- This ensure that the latest knowledge and findings has been incorporated

THE EDITION ADOPTED OR ENDORSED BY USNRC

- This is not the latest edition, USNRC lag behind
- However, the benefit is that the edition is checked and accepted by a major Regulatory Body, and that
- the Code could be used together with USNRC documents regulating the design of nuclear structures.

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HERE WE CHOSE TO GO WITH USNRC

- This since the USNRC documents and the US Codes combo constitute a complete, consistent and comprehensive package

USNRC – DOCUMENT STRUCTURE

REGULATORY REQUIREMENTS

- Code of federal regulations (CFR)

REGULATORY GUIDANCE DOCUMENTS

- Regulatory guides
- Interim staff guidance
- Standard review plans
- Office instructions
- Review standards

USNRC – DOCUMENT STRUCTURE

REGULATORY REQUIREMENTS

- Code of federal regulations (CFR)

REGULATORY GUIDANCE DOCUMENTS

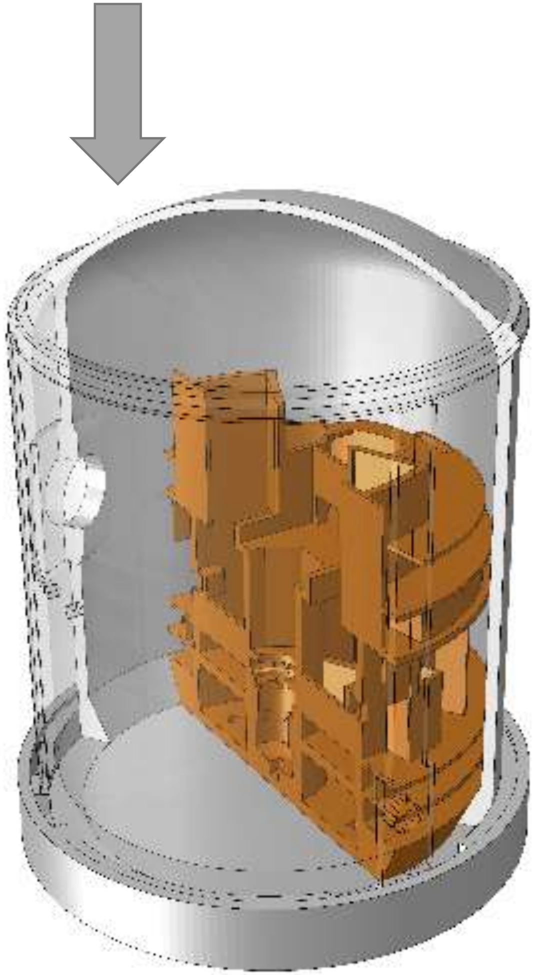
- Regulatory guides (RG)
- Interim staff guidance
- Standard review plans (SRP)
- Office instructions
- Review standards

COLLECTION OF US CODES AND USNRC GUIDANCE DOCUMENTS

CONCRETE CONTAINMENTS – ASME + USNRC

- ASME Section III, Division 2, Subsection CC
  Code for Concrete Reactor Vessels and Containments
- ASME Section XI, Subsection IWL
  Requirements for Class CC Concrete Components of Light-Water Cooled Plants
- ASME Section XI, Subsection IWE
  Requirements for Class MC and Metallic Liners of Class CC Concrete Components of Light-Water Cooled Power Plants

- Standard Review Plan (SRP) 3.8.1
  Concrete Containments
- Regulatory Guide (RG) 1.136
  Design Limits, Loading Combinations, Materials, Construction, and Testing of Concrete Containments



CONCRETE CONTAINMENTS

- RG 1.18
  Structural Acceptance Test for Concrete Primary Reactor Containment
- RG 1.35
  Inservice Inspection of Ungrouted Tendons in Prestressed Concrete Containment Structures
- RG 1.35.1
  Determining Prestressing Forces for Inspection of Prestressed Concrete Containments
- RG 1.90,
  Inservice Inspection of Prestressed Concrete Containment Structures with Grouted Tendons.
- RG 1.107
  Qualifications for Cement Grouting for Prestressing Tendons in Containment Structures

CONCRETE CONTAINMENT CODE

ASME CODE CASES

If urgent need

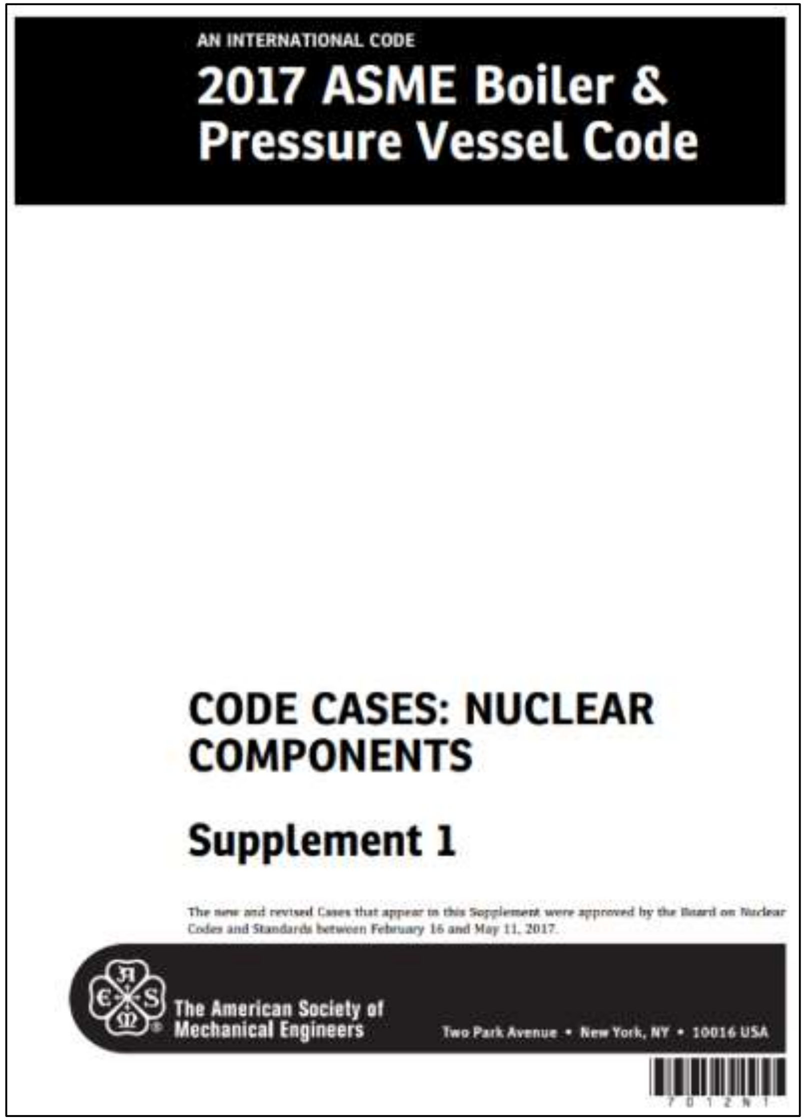
- for alternative rules concerning issues not covered by existing Code, or
- for an early implementation of an approved Code revision

ASME may issue a Code Case:

- Code Cases: Nuclear Components (Sect III Div 2: 19)

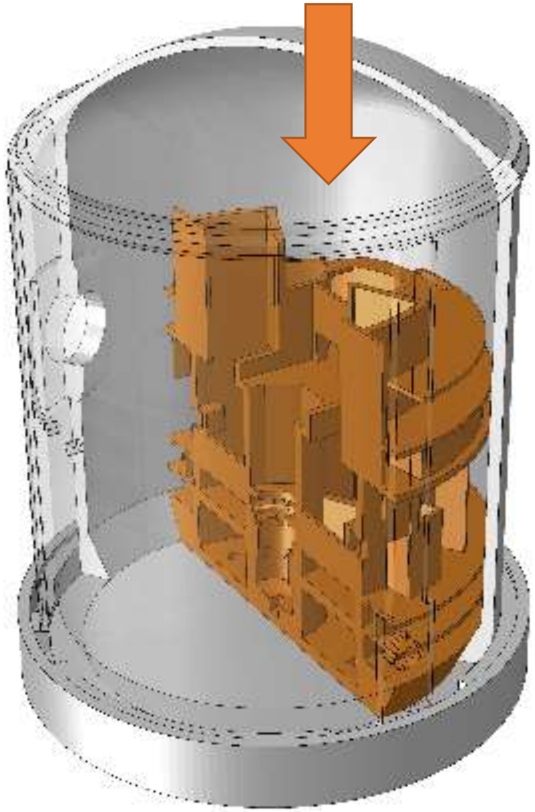
USNRC APPROVAL

- RG 1.84
  Design, Fabrication, and Materials Code Case Acceptability, ASME Section III
- RG 1.193
  ASME Code Cases Not Approved for Use



CONCRETE INTERNAL STRUCTURES OF CONTAINMENTS – ACI + ASME + USNRC

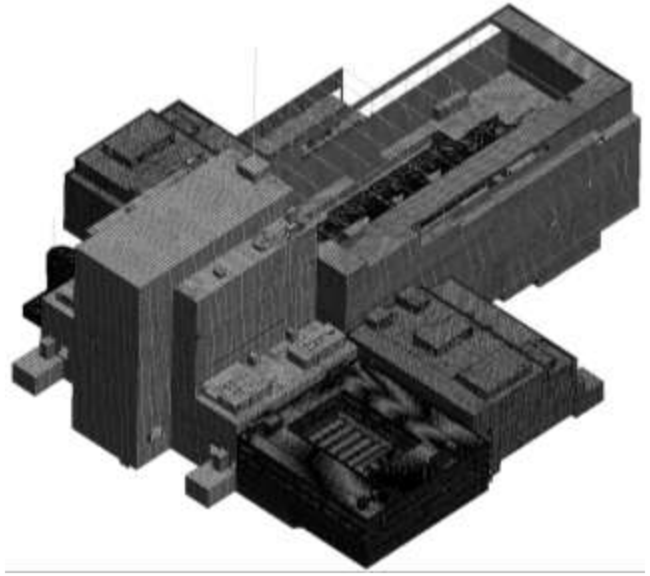
- ACI 349
  Code Requirements for Nuclear Safety-Related Concrete Structures
- ASME Section III, Division 2, Subsection CC,
  Code for Concrete Reactor Vessels and Containments
  (if important pressure boundaries between compartments)
- SRP 3.8.3
  Concrete and Steel Internal Structures of Steel or
  Concrete Containments
- RG 1.142
  Safety-Related Concrete Structures for Nuclear Power
  Plants (Other Than Reactor Vessels and Containments)
- RG 1.199
  Anchoring Components and Structural Supports in Concrete

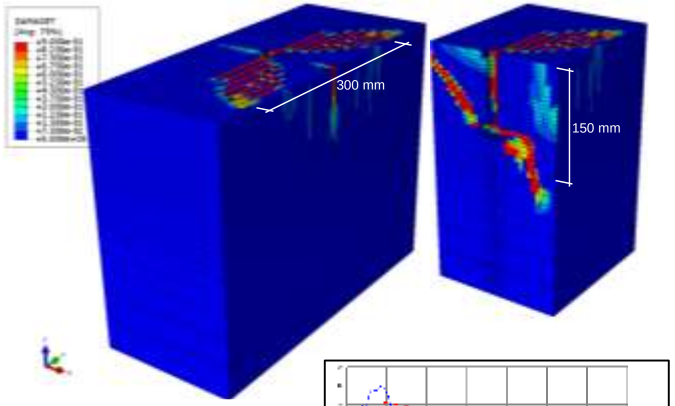


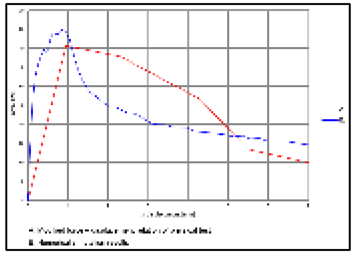
OTHER SEISMIC CATEGORY I STRUCTURES - ACI + USNRC

- ACI 349
  Code Requirements for Nuclear Safety-Related Concrete Structures

- SRP 3.8.4
  Other Seismic Category I Structures
- RG 1.142
  Safety-Related Concrete Structures for Nuclear Power Plants (Other Than Reactor Vessels and Containments)
- RG 1.199
  Anchoring Components and Structural Supports in Concrete







FOUNDATIONS – ACI + USNRC

- ACI 349
  Code Requirements for Nuclear Safety-Related Concrete Structures

- SRP 3.8.5
  Foundations
- RG 1.142
  Safety-Related Concrete Structures for Nuclear Power Plants
  (Other Than Reactor Vessels and Containments)
- RG 1.199
  Anchoring Components and Structural Supports in Concrete

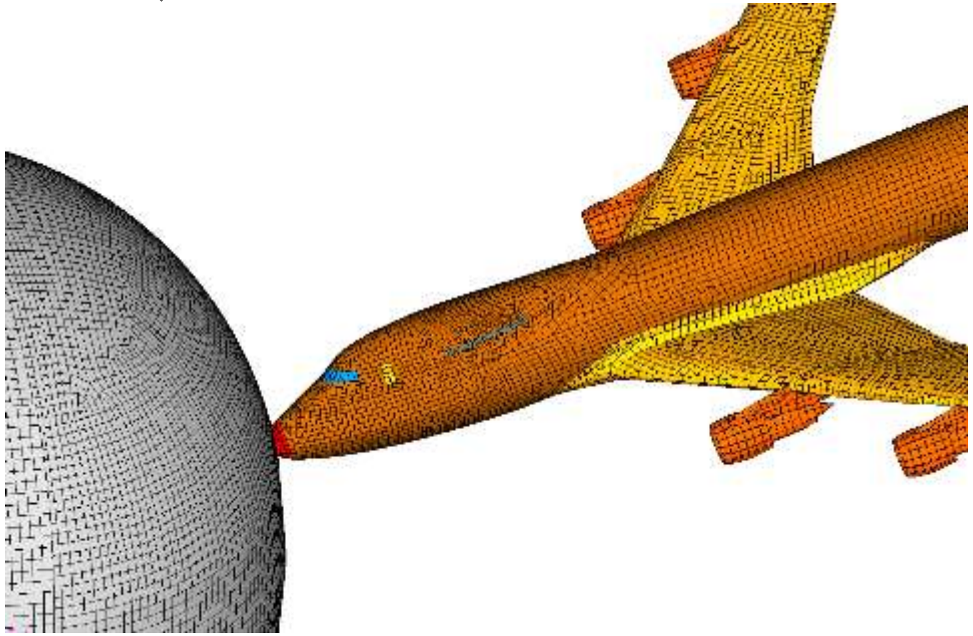
DESIGN EXTENSION CONDITIONS AND DESIGN EXTENSION EXTERNAL EVENTS

NEW NUCLEAR POWER PLANTS

- DEC and DEEE could governing the dimensioning of the concrete structures
- DEC
  - Severe accidents (large pressure levels inside the containment)
- DEEE
  - Severe earthquake
  - Airplane crash (large commercial airliner)

US CODES AND REGULATORY GUIDANCE

- The terms DEC and DEEE not introduced
- Beyond design basis accidents BDBA are discussed



DESIGN EXTENSION CONDITIONS AND DESIGN EXTENSION EXTERNAL EVENTS

BDBA IN ASME SECT III DIV 2 - CONTAINMENTS

- Nothing
- A Design Code, hence excluding beyond design accidents

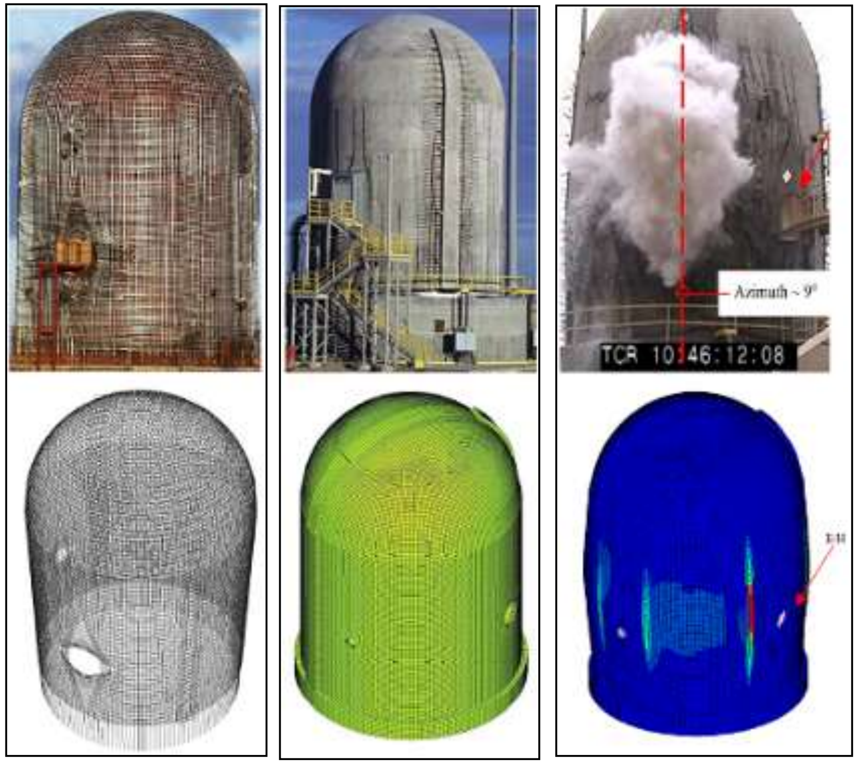
BDBA IN ACI 349 – OTHER NUCLEAR STRUCTURES

- Not in the main body of the code
- However, the Commentary discuss a BDBA earthquake
- An essentially elastic design for the Design Basis Earthquake (DBE) together with a ductile detailing ensure enough margins for BDBA
- Limitation of concrete compression strains for DBE ensure enough margins for BDBA

DESIGN EXTENSION CONDITIONS AND DESIGN EXTENSION EXTERNAL EVENTS

USNRC GUIDANCE ON BDBA

- RG 1.216
  Containment Structural Integrity Evaluation for Internal Pressure Loadings Above Design-Basis Pressure
- RG 1.217
  Guidance for the Assessment of Beyond-Design-Basis Aircraft Impacts



COMPARISONS OF CODES & STANDARDS, EXAMPLE NO.1

Comparison between DNB, Eurocodes and ASME Sect III Div 2/ACI 349

- Reactor containment and reactor building
- Typical structural elements compared (i.e. cylindrical wall; slab; beam)
- Capacities compared are the load levels the structure can resist for different failure modes (tension; bending; shear)
- The capacities are normalized to the DNB capacity (i.e. the DNB capacity is always 1)
- Yellow color -> most conservative code

Capacities compared are the load levels the structure can resist for different failure modes

The capacities are normalized to the DNB capacity (i.e. the DNB capacity is always 1)

Yellow color -> most conservative code

Reactor containment cylindrical wall	DNB	Eurocodes	ASME III 2
Prestressed			
Maximum membrane capacity	1	1.06	0.94
Bending moment – ULS	1	1.07	0.93
Shear - ULS	1	1.40	1.00
Not prestressed			
Maximum membrane capacity	1	1.11	0.84
Bending moment – ULS	1	1.16	0.84
Shear - ULS	1	1.08	1.00

Capacities compared are the load levels the structure can resist for different failure modes

The capacities are normalized to the DNB capacity (i.e. the DNB capacity is always 1)

Yellow color -> most conservative code

Reactor building	**DNB**	**Eurocodes**	**ACI 349**
Slab			
Bending – ULS	1	1	1.10
Bending – ALS	1	1	1.12
Shear - ULS	1	1	1.22
Shear - ALS	1	1	1.39
Beam			
Bending – ULS	1	1	1.20
Bending – ALS	1	1	1.36
Shear - ULS	1	1	0.75
Shear - ALS	1	1	0.84

COMPARISONS OF CODES & STANDARDS, EXAMPLE NO. 2

Comparison between Eurocodes and ASME Sect III Div 2

- Reactor containment cylindrical wall
- Load combinations on the vertical axis
- Different situations on the horizontal axis
- Red color = Eurocodes governs (lowest capacity)
- Green color = ASME governs (lowest capacity)
- Faded colors = Close cut

Load comb.	Case	1-1	2-1	3-1	4-1	1-2	2-2	3-2	4-2
	Reinforcement	No	No	No	No	Yes	Yes	Yes	Yes
	Shear force kN	N/A	N/A	N/A	N/A	4000	4000	4000	4000
	Bend. moment kNm	0	0	4150	4150	0	0	4150	4150
	Compr. Stress MPa	0.5	5	0.5	5	0.5	5	0.5	5
Category	Table	3.10	3.12	3.14	3.16	3.11	3.13	3.15	3.17
Test	Service ULS	EC	~ (EC)	EC	~ (ASME)	EC	EC	EC	EC
	Factored ULS	~ (EC)	EC	EC	~ (EC)	EC	EC	EC	EC
Normal Constr.	Serv. 50% ULS	EC	EC	EC	ASME	ASME	EC	ASME	~ (EC)
	Serv. 67% ULS	EC	EC	EC	EC	EC	EC	EC	EC
	Serv. 75% ULS	EC	EC	EC	~ (ASME)	EC	EC	EC	EC
S.E.	Fact. 1.5 ULS	EC	EC	EC	EC	EC	EC	EC	EC
	Fact. 1.3 ULS	EC	EC	EC	EC	EC	EC	EC	EC
	Fact. 1.0 ULS	ASME	ASME	ASME	ASME	EC	EC	EC	EC
Others	Fact. 1.5 ULS, acc	ASME	ASME	~ (ASME)	ASME	ASME	~ (EC)	ASME	ASME
	Fact. 1.25 ULS, acc	~ (EC)	~ (EC)	EC	ASME	ASME	EC	ASME	EC
	Fact. 1.0 ULS, acc	EC	~ (EC)	EC	~ (ASME)	EC	EC	EC	EC

Radial shear (88 comparisons)

- Load combinations on the vertical axis
- Different situations on the horizontal axis
- **Red color = Eurocodes governs**
- **Green color = ASME III 2 governs**
- Faded colors = Close cut

Load comb.	Case	1	2	3	All
	Comp. stress hoop	0	0	5	All
	Comp. stress mer.	0	5	5	All
	Shear reinf.	No	No	No	Yes
	Category Table	3.36	3.37	3.38	3.39
Test	Service ULS	EC	ASME	EC	EC
	Factored ULS	EC	ASME	EC	EC
Normal Constr.	Serv. 50% ULS	EC	ASME	~ (EC)	ASME
	Serv. 67% ULS	EC	ASME	EC	EC
	Serv. 75% ULS	EC	ASME	EC	EC
S.E.	Fact. 1.5 ULS	EC	ASME	EC	EC
	Fact. 1.3 ULS	EC	EC	EC	EC
	Fact. 1.0 ULS	EC	ASME	ASME	EC
Others	Fact. 1.5 ULS, acc	EC	ASME	ASME	ASME
	Fact. 1.25 ULS, acc	EC	ASME	EC	ASME
	Fact. 1.0 ULS, acc	EC	ASME	EC	ASME

Tangential shear (44 comparisons)

- Load combinations on the vertical axis
- Different situations on the horizontal axis
- **Red color = Eurocodes governs**
- **Green color = ASME III 2 governs**
- Faded colors = Close cut

Load comb.	Steel part		Reinforcement	Tendons
	Category	Table	3.43	3.44
Test	Service ULS		EC	EC
	Factored ULS		EC	ASME
Normal Constr.	Serv. 50% ULS		ASME	EC
	Serv. 67% ULS		EC	
	Serv. 75% ULS		EC	
S.E.	Fact. 1.5 ULS		EC	~(ASME)
	Fact. 1.3 ULS		EC	EC
	Fact. 1.0 ULS		EC	EC
Others	Fact. 1.5 ULS, acc		ASME	ASME
	Fact. 1.25 ULS, acc		ASME	ASME
	Fact. 1.0 ULS, acc		ASME	ASME

Bending moment and tension capacity (22 comparisons)

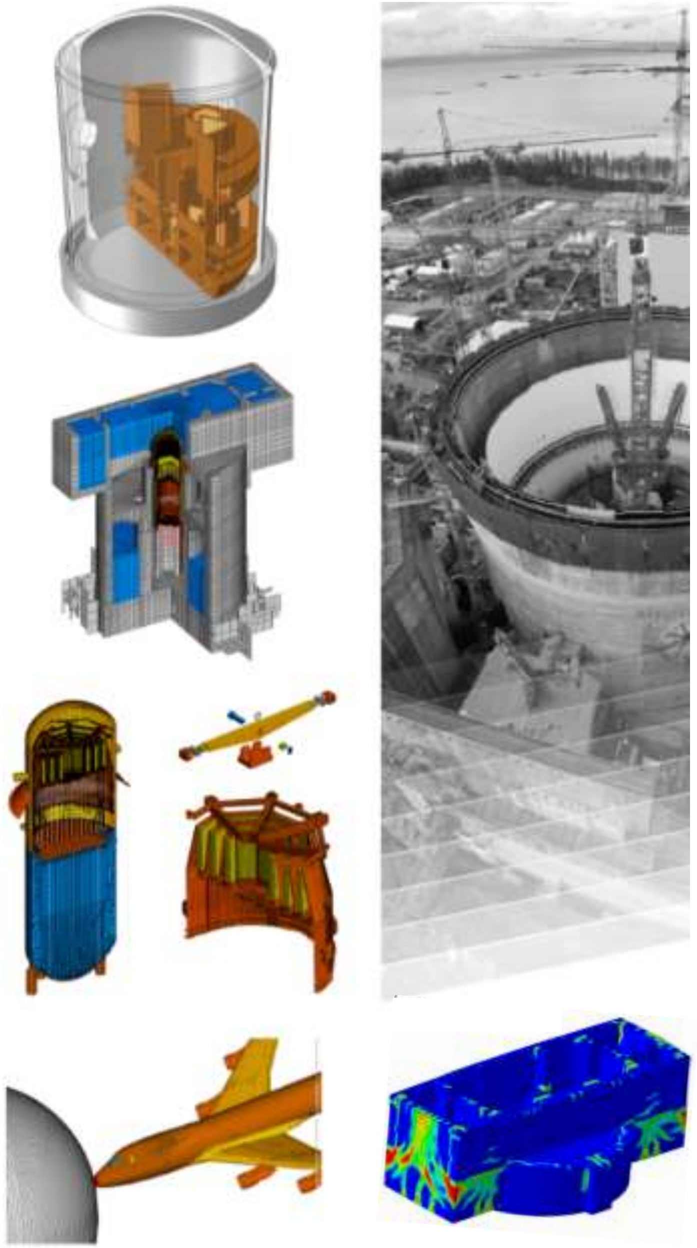
- Load combinations on the vertical axis
- Different situations on the horizontal axis
- **Red color = Eurocodes governs**
- **Green color = ASME III 2 governs**
- Faded colors = Close cut

COMPARISONS OF CODES & STANDARDS

Conclusion

- Unfortunately, it is hard to say that one of the codes envelope another!
- Hence, the decision in DNB to demand compliance with both Eurocodes and ASME Sect III Div 2

THANK YOU FOR YOUR ATTENTION!



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