



A Comparison of the ASME and European Standards to achieve safe boiler operation

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ASME Governor**



Abstract

Boiler plant designed and manufactured to the ASME and EN Standards have equivalent levels of safety but have a different approach in terms of the role of the Inspecting Body and the technical requirements.

ASME tends to focus on the critical safety requirements which is supported by the technical specifications of the Manufacturer whereas the EN Standard is more prescriptive.

An overview comparison of the two Codes will be presented together with an outline of the proposals for incorporation of a new Part in the ASME Code which will be applicable to ultra- supercritical boiler plant.



Why Me? – My Code Background

ASME

Member of :

Council on Standards and Certification

Board on Strategic Initiatives for Standards and Certification (Vice Chair)

Section I Committee – Power boilers

Section I Sub-Group – Fabrication & Examination

Section II Sub-Group – International Material Specifications

Committee on B&PV Conformity Assessment

BSI

Chairman of : **Pressure Equipment Standards Policy Committee**

Past Chairman of: **BS1113 Committee and UK representative on European Boiler Committee**

ISO

Member of ISO TC11 – International Standards for Boilers and Pressure vessels

Chairman of TC11 WG11 – Conformity Assessment Procedure

Leader of international group of experts to assist ISO secretariat



Why is there not an ISO Standard ?

In an ideal world there would be a single, comprehensive ISO Standard but this is not the case

Most countries have their own Health & Safety Legislation

Main Standards used worldwide tend to be developed by USA (ASME) and Europe (CEN)

Other national standards tend to be a derivative of these

CEN completed the development of new EN Standards to comply with the Pressure Equipment Directive which took over 10 years.

To create an ISO Standard would be a lengthy process mainly due to the difficulties of achieving the necessary level of compromise among the member countries

The main reasons for this are the differing approaches historically taken by regulatory authorities, and differences in the underlying design and construction philosophies in the various national and regional product standards.



Boiler Standards

For boiler plant we currently have two main Standards

ASME Section I

a well established Standard that has been developed over many years

EN12952

a relatively new European Standard which in the main is an integration of the best parts of British and German Standards

How do they compare?

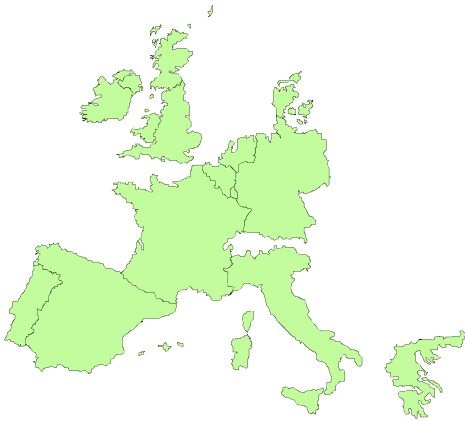




CE marking has been a feature of EC legislation since 1987.

It indicates a declaration by the Manufacturer that the product or system complies with the essential requirements of the Directive(s) relevant to that product or system.

Member States are required to presume compliance and therefore the product or system can be placed on the market without initial challenge by the national administrations.

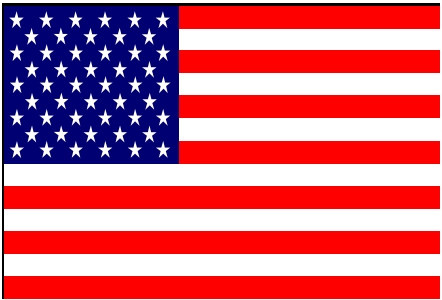




'S' marking has been a feature of **US** legislation since 1915.

It indicates a declaration by the Manufacturer that the product or system complies with the essential requirements of the ASME I relevant to that product or system.

Regulators are required to presume compliance and therefore the product or system can be **'erected'** on the market without initial challenge by the national administrations.



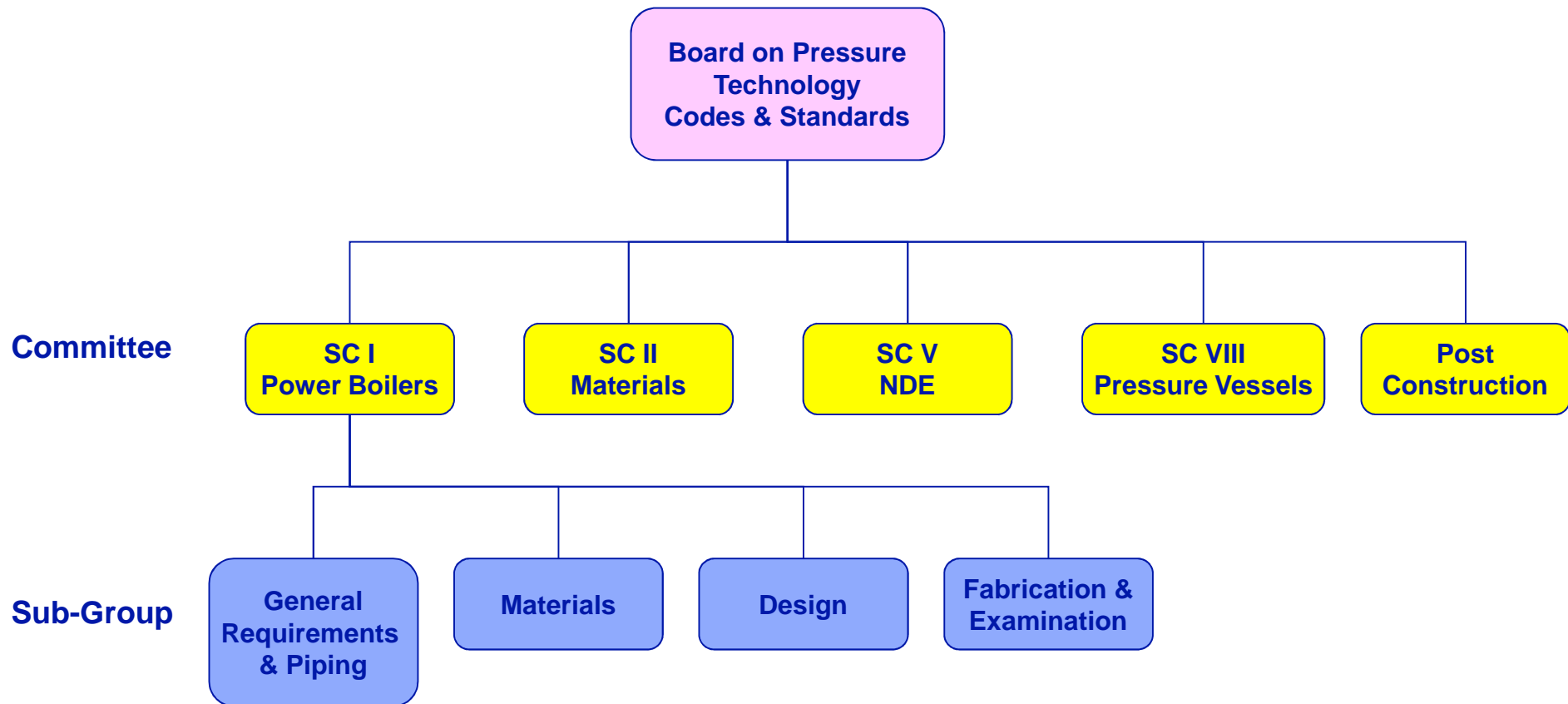


ASME Boiler Committee 1911

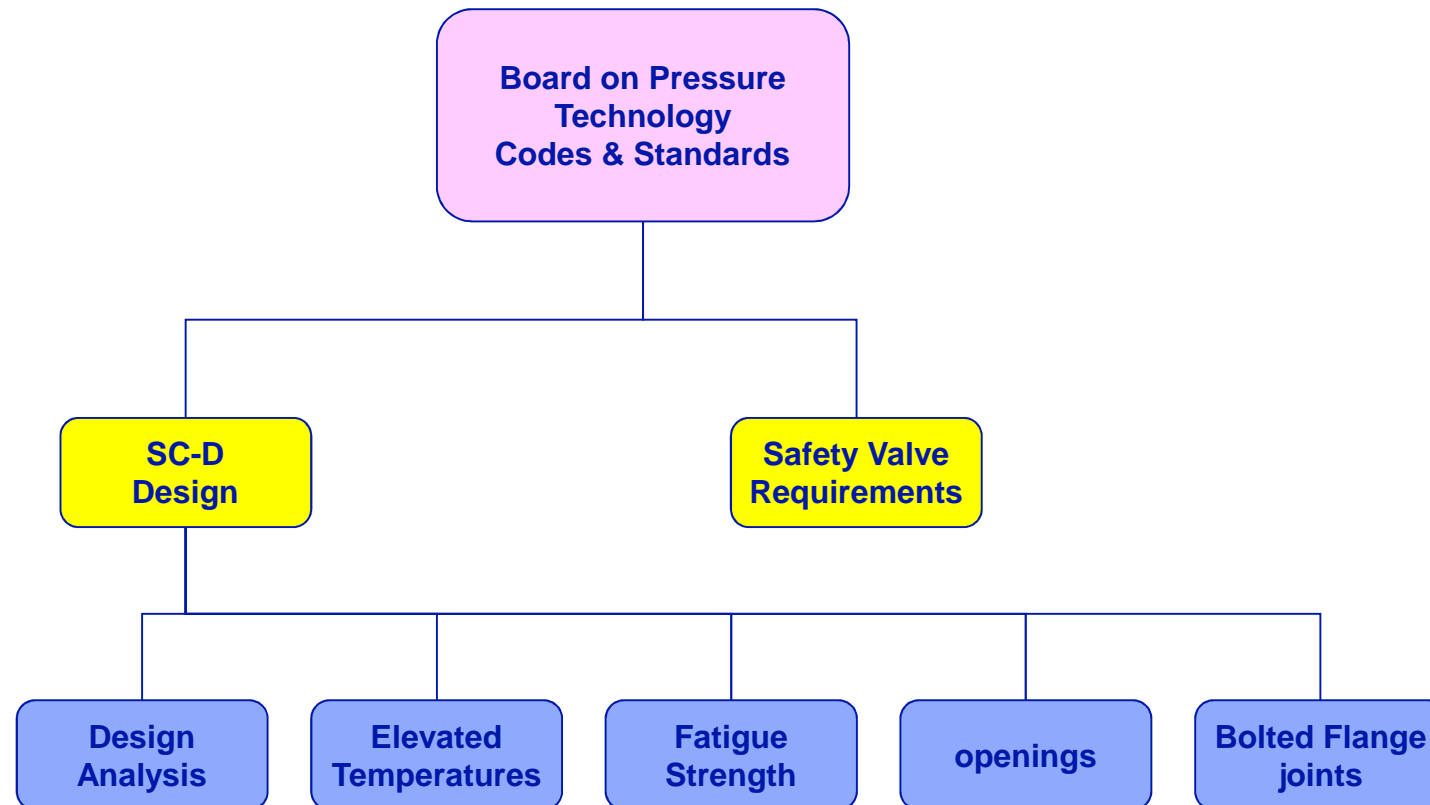
ASME BPV-I 2011



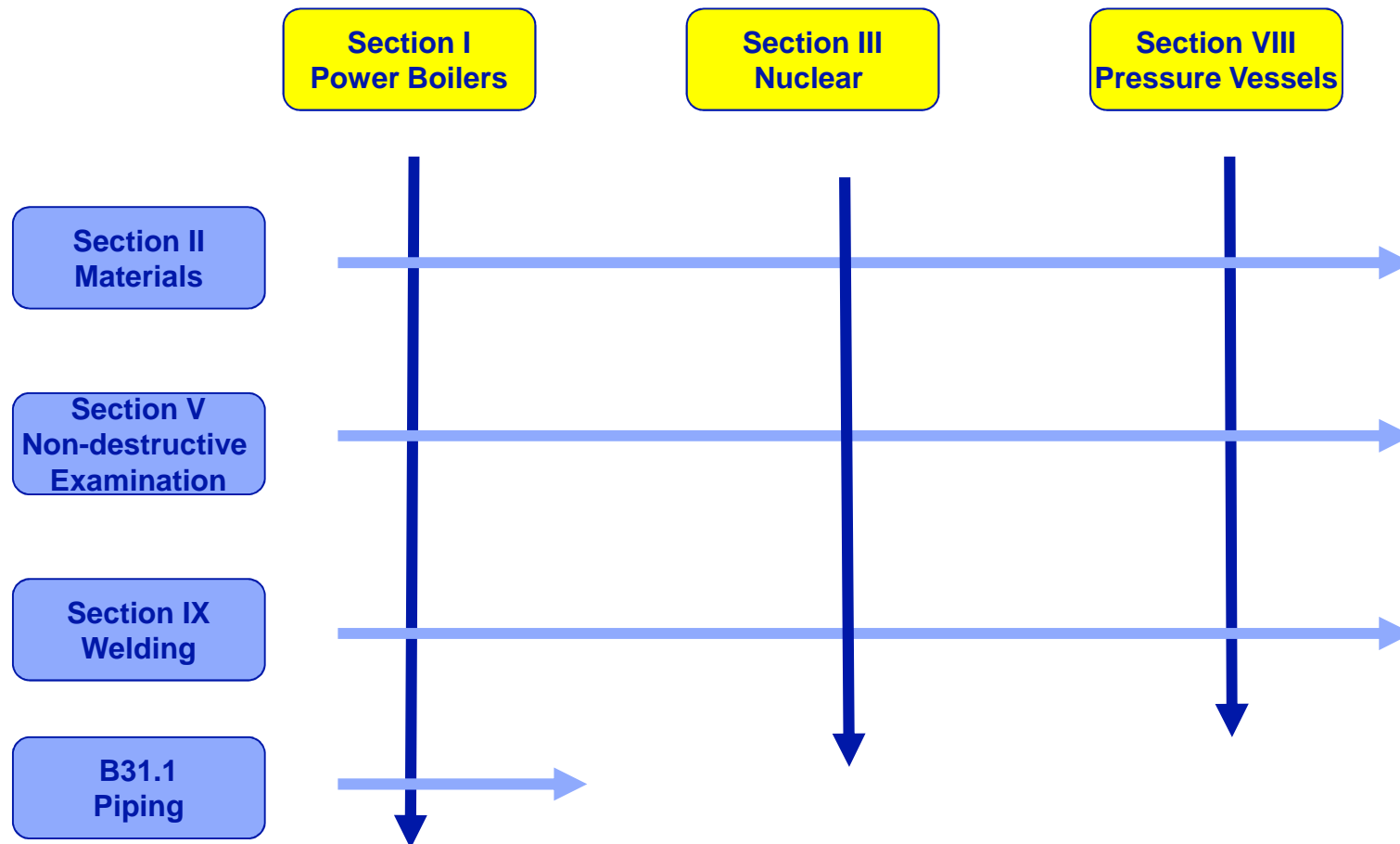
Committee Structure



Committee Structure



Reference Standards



ASME Section I – Power Boilers

Contents

Preamble

PG – General requirements

PW – Boilers fabricated by welding

PR – Boilers fabricated by Riveting (use 1971 Code)

PB – Boilers fabricated by Brazing

PWT – watertube boilers

PFT – firetube boilers

PFH – Optional requirements for feedwater heaters

PMB – Miniature boilers

PEB – Electric boilers

PVG – Organic fluid vapourisers

Appendices

Interpretations

Code Cases

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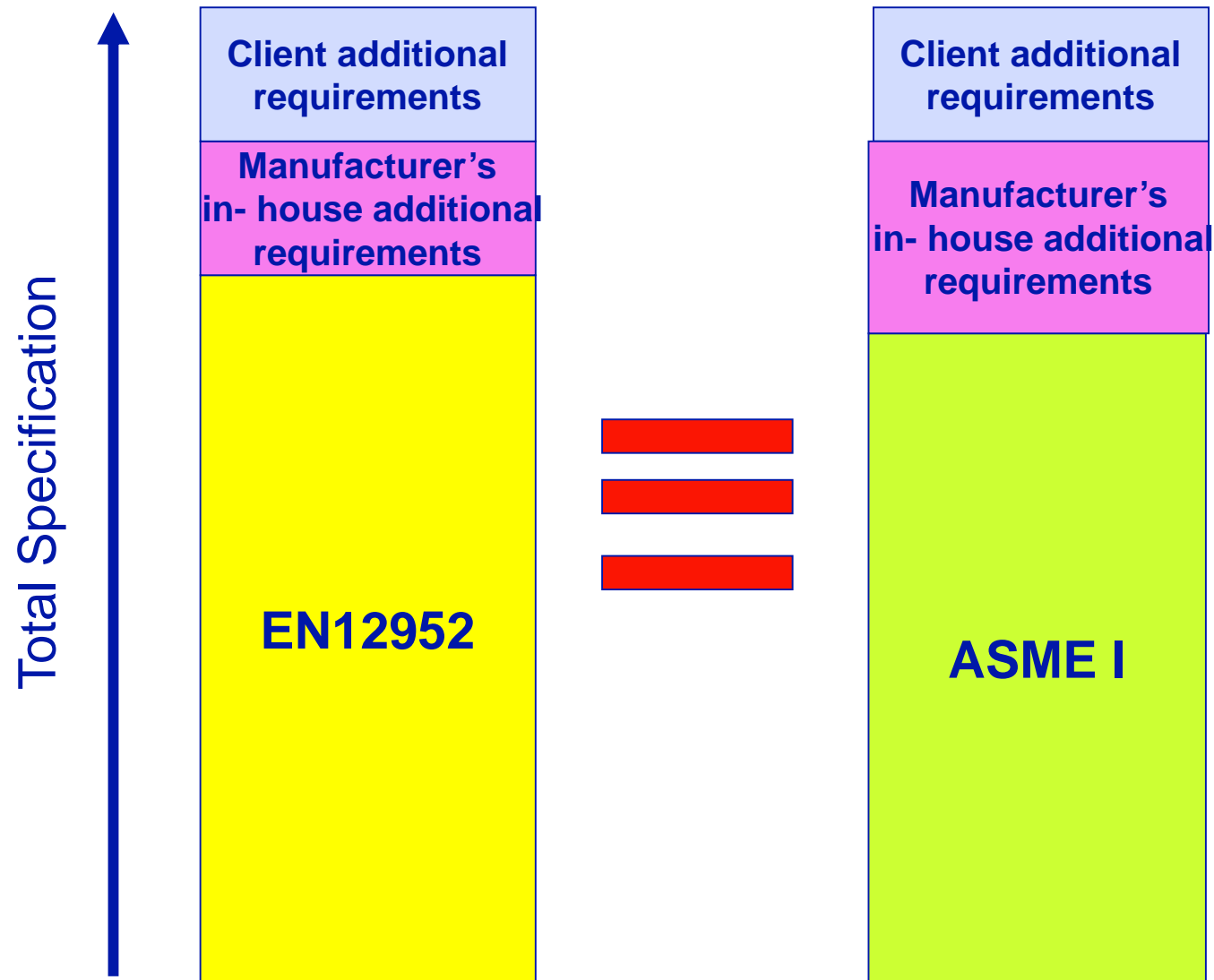
The Code does not contain rules to cover all details of design and construction. Where complete details are not given, it is intended that the manufacturer, subject to acceptance of the Authorised Inspector, shall provide details of design and construction which will be as safe as otherwise provided by the rules of the Code.

In the US this tends to result in most boilers being built to ASME plus additional requirements of the main manufacturers but when the Code is used outwith the US then the same level of additional requirements may not necessarily be recognised.

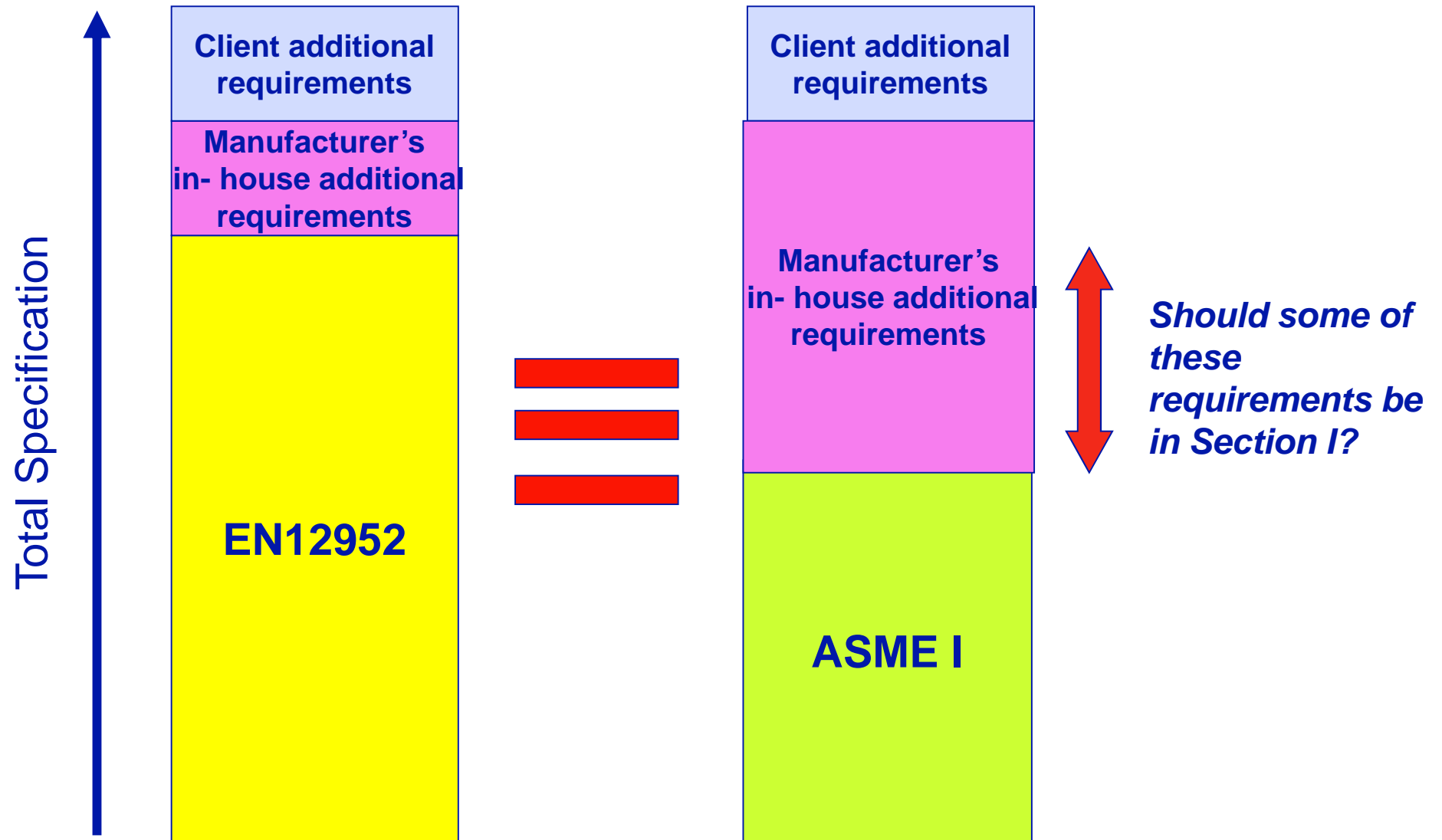
EN12952 compared to ASME Section I

- EN12952 was developed to comply with the Pressure Equipment Directive (PED)
- It is more prescriptive and specific than ASME Section I and in general represents current European working practice
- Being a relatively new Code EN12952 (10+ years old) it is very logical and structured
- ASME Section I has developed over a long period of time with numerous additions and deletions
- Involvement by the Notified Body is defined in the PED and is based on the level of risk of the component

ASME and EN12952 – Steady State Conditions



ASME and EN12952 – High Temperature Cyclic Loading



Example of Additional Requirements - Non-destructive examination

ASME Section I

The main method of non-destructive examination is still radiography although ultrasonic recently allowed

All longitudinal and circumferential welds above a specified nominal diameter or thickness are mandatory

There is no requirement to carry out NDE on welds below these sizes e.g. tube butt welds, or on branch connections or on load carrying attachments

European Boiler Standard

Acceptance criteria for surface imperfections for MT or PT examination

In general UT is preferred to RT

10% RT on tube butt welds to include sample of each welder's work

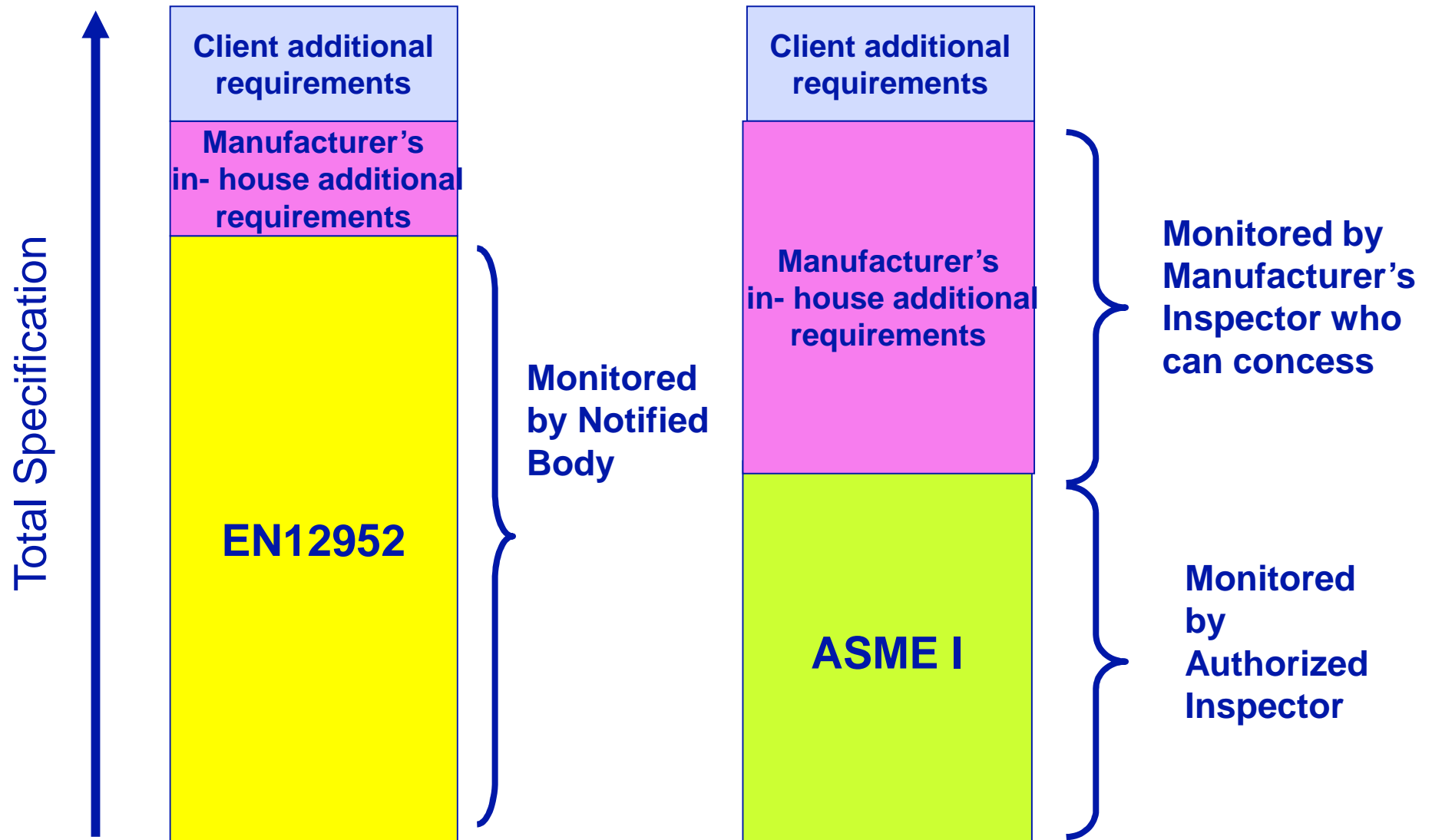
100% UT on branch connections with thk $>1\frac{1}{2}$ " (10% for less than this)

100% MT or PT on load carrying attachments

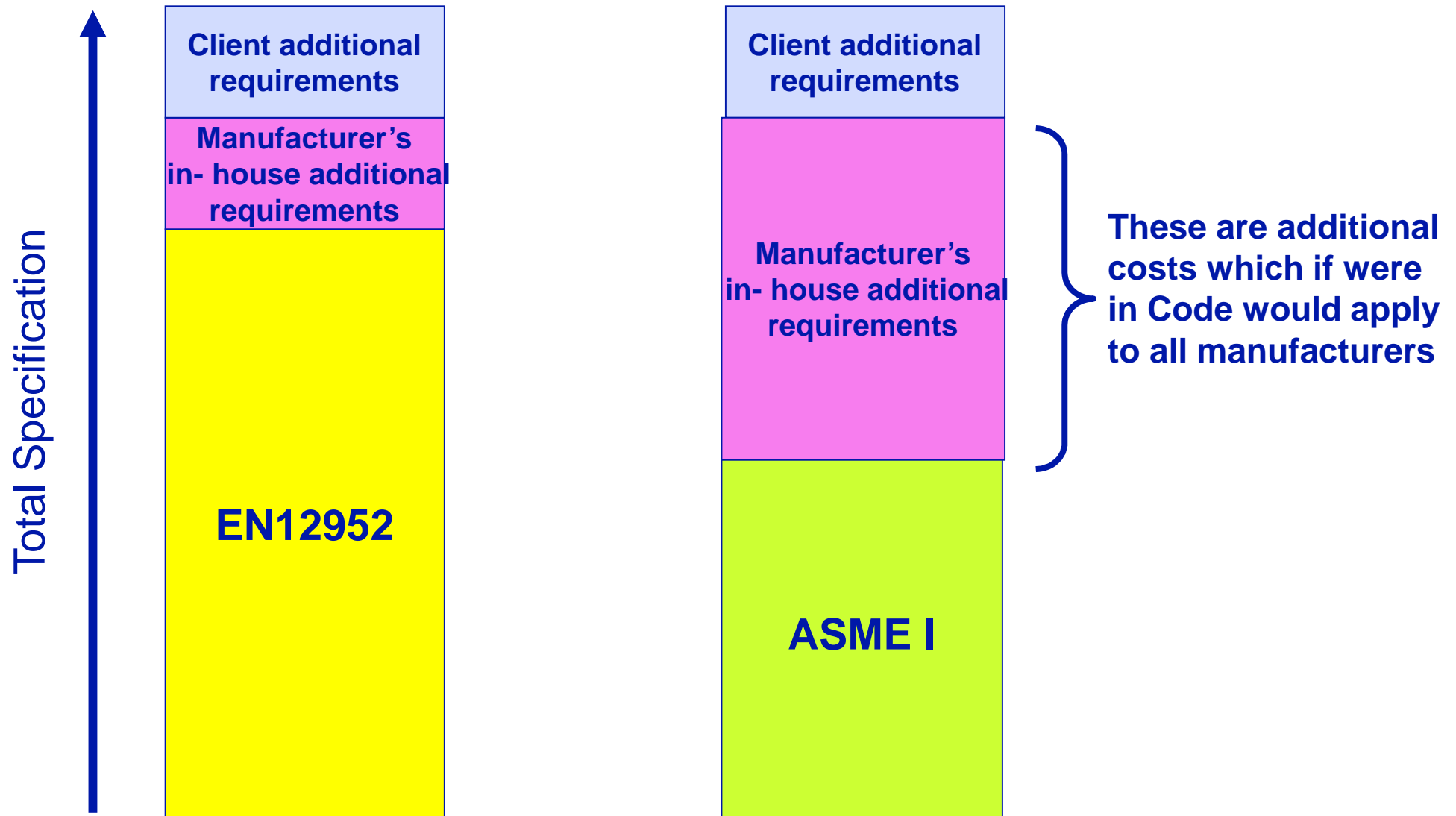
***Some of these are often incorporated in the
Manufacturer's Specification***



ASME and EN12952



ASME and EN12952



Contents of EN12952

The European boiler standard EN 12952 is in 16 parts

First 6 parts are mainly equivalent to contents of ASME I

1 – General

2 – Materials

3 – Design

4 – In-service boiler life expectancy calculations

5 – Workmanship and Construction

6 – Inspection, documentation and marking

EN12952 – 5 Annex F – Competency of Boiler Manufacturers

It is the responsibility of the boiler purchaser to place the order for boiler plant with a competent boiler manufacturer to ensure adequate quality is obtained when the boiler is put in operation in accordance with the manufacturers instructions.

Annex F is an informative Annex identifying criteria whereby a judgement can be made as to the competency of a boiler manufacturer's organisation and controls.

The principles of ISO 9001 have been used as a basis but is specific to boiler plant and the guidelines include criteria covering design, materials, fabrication, erection, commissioning, examination and inspection.

A Competency Declaration Form is completed by the Manufacturer

EN12952 – 5 Annex F – Competency of Boiler Manufacturers

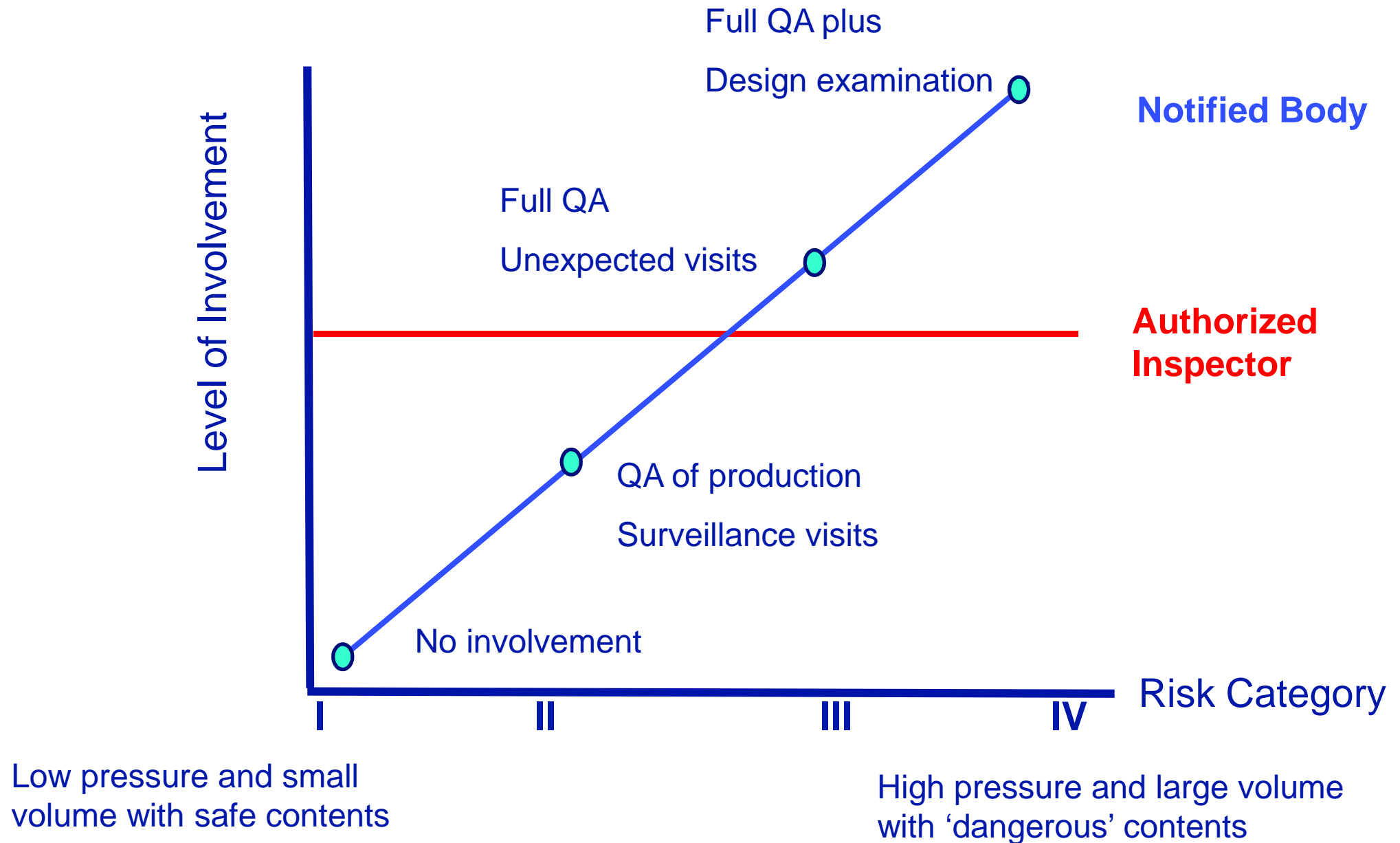
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Level of Involvement of Inspection Body



EN12952 – 3 : Design & Calculation of Pressure Parts

General rules for calculating thickness of shells, heads, etc

PLUS

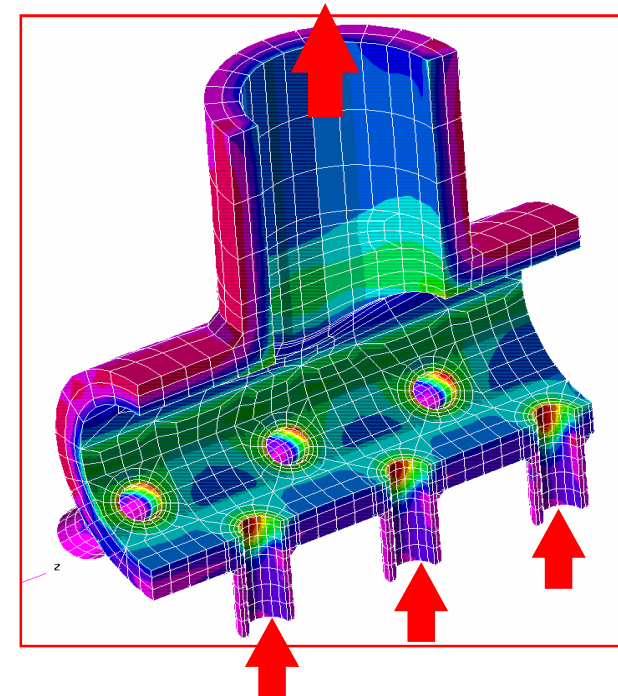
Exemption rules for fatigue analysis

Stress analysis for fatigue analysis

Calculation of stresses in tube bends

Fatigue cracking – design to allow fluctuating stress

Examples for calculating the effects of fatigue



General production requirements for welding

The welding on site of widely differing materials e.g. austenitic to ferritic materials should be avoided whenever possible.

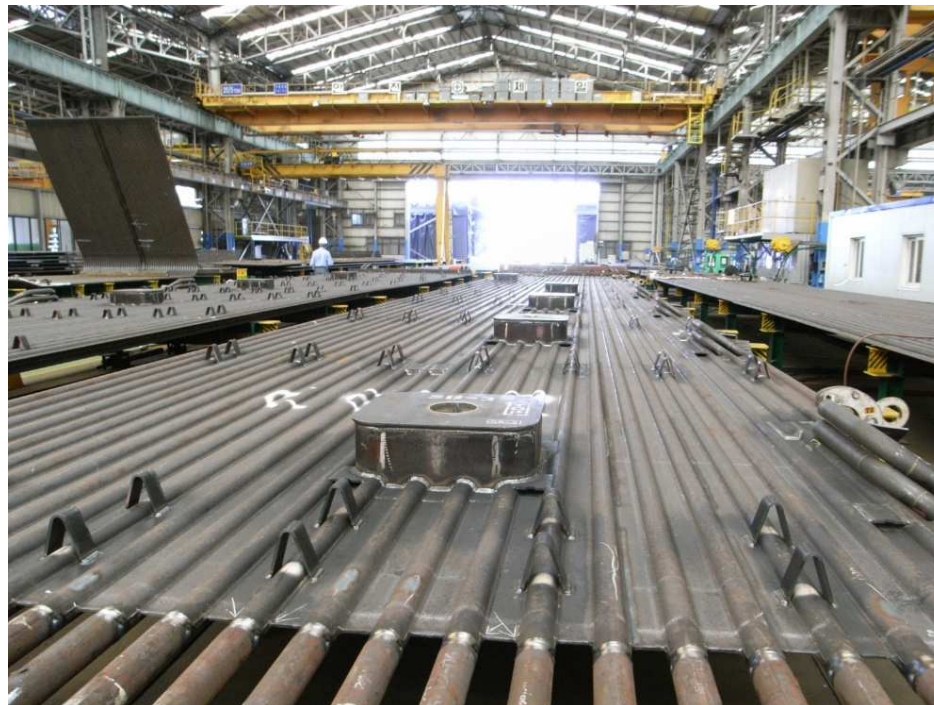
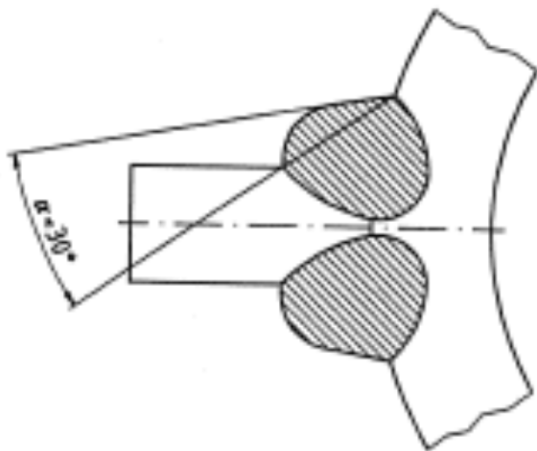
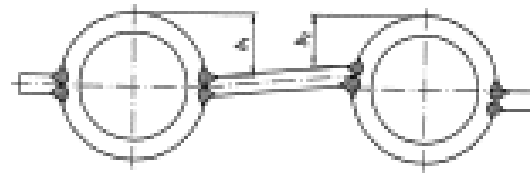
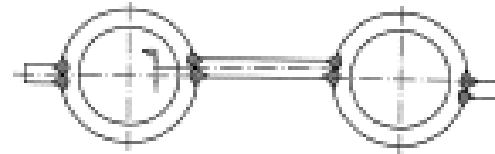
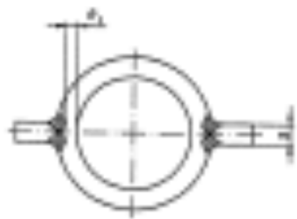
It is recognized that there may be difficulty in complying strictly with the requirements for the root gap. Minor modifications imposed by practical considerations shall be permitted, providing the manufacturer can ensure that the safety of the boiler is not impaired.

Temporary attachments to pressure parts should be kept to a minimum and should be removed prior to first pressurization.

Particular attention shall be paid to the quality of tack welds and where necessary the ends of these shall be dressed to facilitate proper fusion if they are to be incorporated into the root run. Any cracked tack welds shall be completely removed.

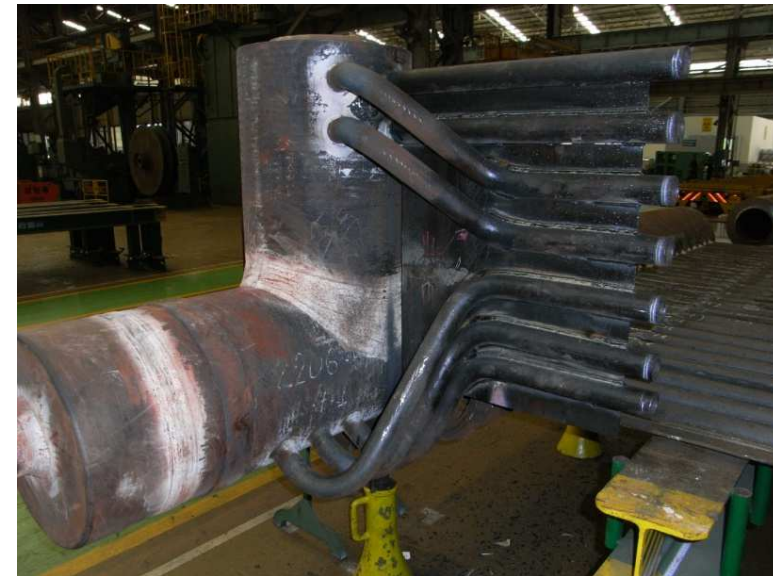
Again most of these are often incorporated in Manufacturer's Specification

Membrane welding tolerances – typical sketches



NDE of Header Welds

Type of Weld	Surface	Volumetric
Circumferential Welds	100%	100%
<u>Pressure connection welds</u>		
Thk>25mm (full pen)	100%	100%
15mm < thk < 25mm (full pen)	100%	10%
All other welds, incl. seal welds	10%	-
<u>Attachment welds</u>		
Load carrying	100%	-
Non-load carrying	10%	-
End plate welds	100%	100% (UT)



EN12952 – Part 4 :In-service boiler life expectancy calculations

Unique to international boiler Codes

Informative Annexes of calculation of creep and fatigue damage based on German methodology

The calculations are not required to be carried out by the manufacturer as part of his responsibilities within EN12952

The calculations may be carried out using transposed design equations using the measured wall thickness .

The results may be used as a guideline for the decision to inspect a component for fatigue cracks or to inspect for creep pores by the replica method or any other suitable method.



Standards for ultra super-critical boiler plant

EN12952 meets the requirements for new plant operating in cyclic mode but doesn't cover creep fatigue interaction at the design stage

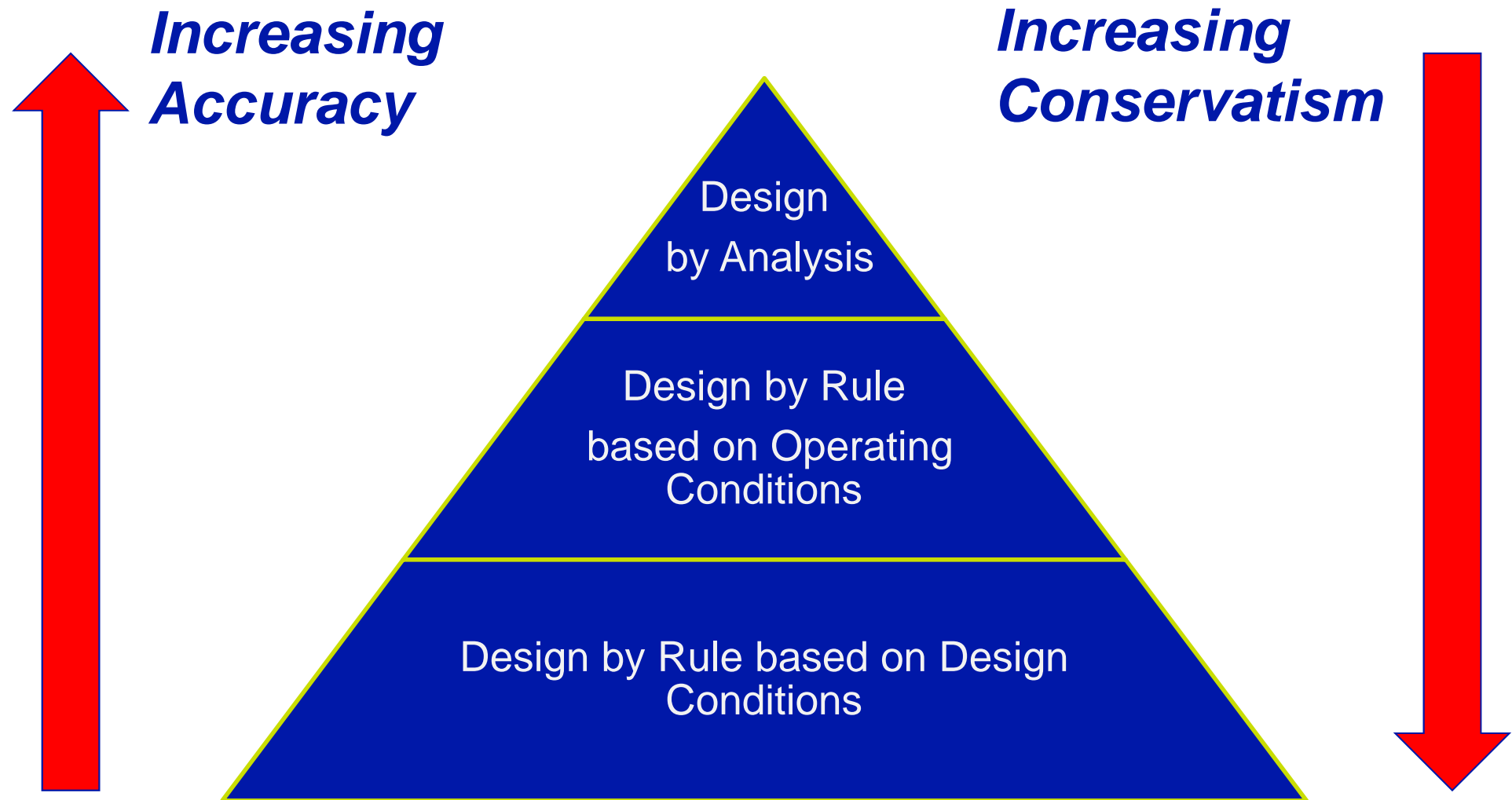
ASME are developing a new Part' to ASME Section I to cover a similar scope to EN12952.

Evaluation of Needs of a new Part for ASME Section I'

In general Section I was originally developed for industrial boilers through to sub-critical boilers operating at relatively low temperatures and pressures under steady state conditions.

Current and future boilers operate at higher temperatures and pressures under cyclic loading require a more detailed assessment and examination to:

- allow Design By Analysis with associated other requirements
- develop a sensible approach to creep-fatigue interaction
- define the extent of NDE and corresponding acceptance criteria
- take account of steam side oxidation, erosion and corrosion
- consider the role of the AI to be based on risk



Failure modes

Design shall consider the following failure modes:

Short Term Failures due to the application of non-cyclic loads which lead to immediate failure e.g. brittle fracture, ductile failures, instability, etc

Long Term Failures due to application of non-cyclic loads which lead to delayed failure e.g. creep rupture, erosion, corrosion, environmentally assisted cracking, etc

Cyclic Failures e.g. progressive plastic deformation, fatigue, etc

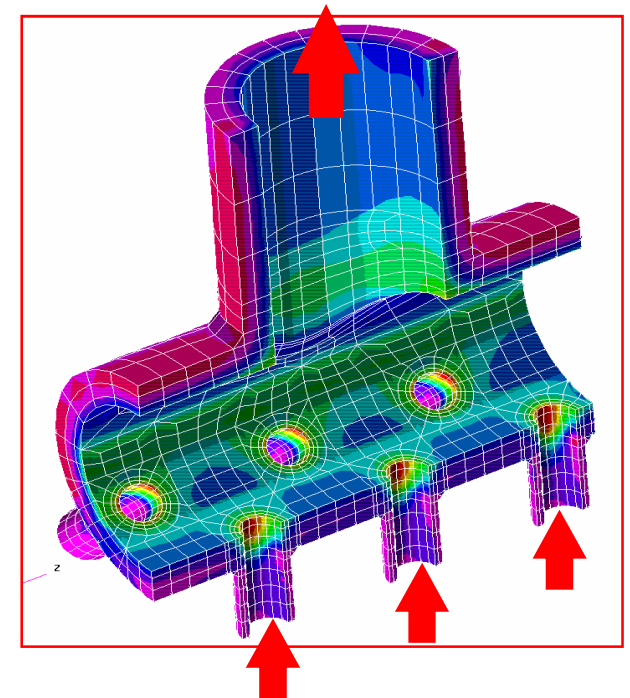
Explicit & Implicit Design

Explicit Design

Rules or requirements that directly affect how the Standard addresses the specific failure mode e.g. formula for sizing wall thickness for resisting ductile burst.

Implicit Design

Where design tables, empirically based rules or other approaches are used and the derivation is not obvious. e.g. may be a combination of material control, design margins, temperature limits, etc



Other Requirements

Fabrication

Details relevant to selected failure modes e.g. control of cylindrical ovality, weld profiles, control of tolerances, etc.

Material

Control of YS/UTS ratios, provisions for addressing strain hardening, application of heat treatment, etc

Examination

NDT or visual inspection relevant to each failure mode, NDT levels correlated to design factors, etc

Testing

Provisions for final testing with specific information on normal test pressures



Creep Life – Inquiry I-89-30

Question:

Does the ASME Boiler and Pressure Vessel Committee establish a specific design life for components designed to Section I?

Reply:

No



Creep Life – Inquiry IID – 95-01

Question:

Do the criteria of Appendix 1 of Section II, Part D, for establishing stress values in Table 1A and 1B, imply an explicit design life for Section I construction, using the allowable stresses in Tables 1A and 1B for materials permitted for Section I construction?

Reply:

No.

There is neither an explicit nor an implicit design life associated with the allowable stresses in Tables 1A and 1B for Section I construction. The criteria of Appendix 1 of Section II, Part D, have been established with the intention that sufficient margin is provided in the allowable stresses to preclude failure during normal operation for any reasonable life of boilers constructed according to Section I rules.

Modernization is more than just incorporating Design by Analysis

Design by Analysis

Design by Rule
same as
VIII Div 2

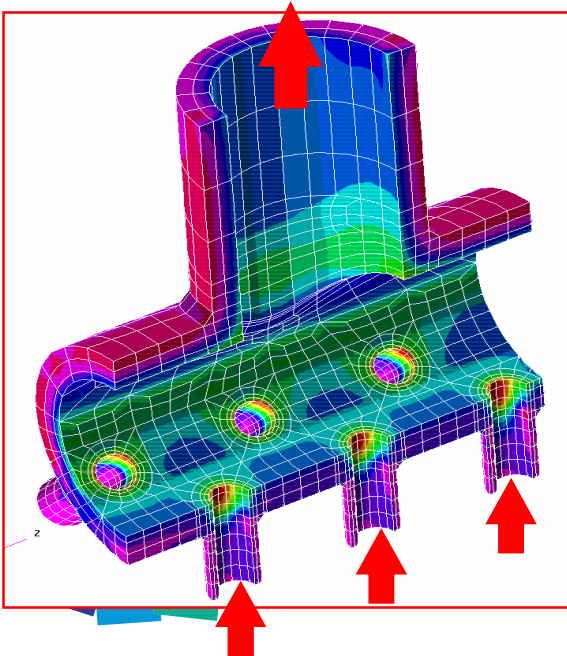
Users Design Spec

Material data for creep
life and fatigue curves

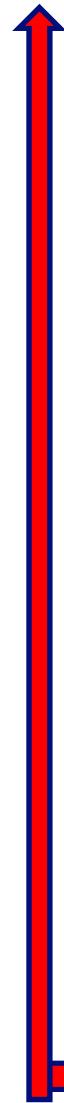
Restrictions on weld
geom

Additional NDE

Flaw Acceptance
criteria



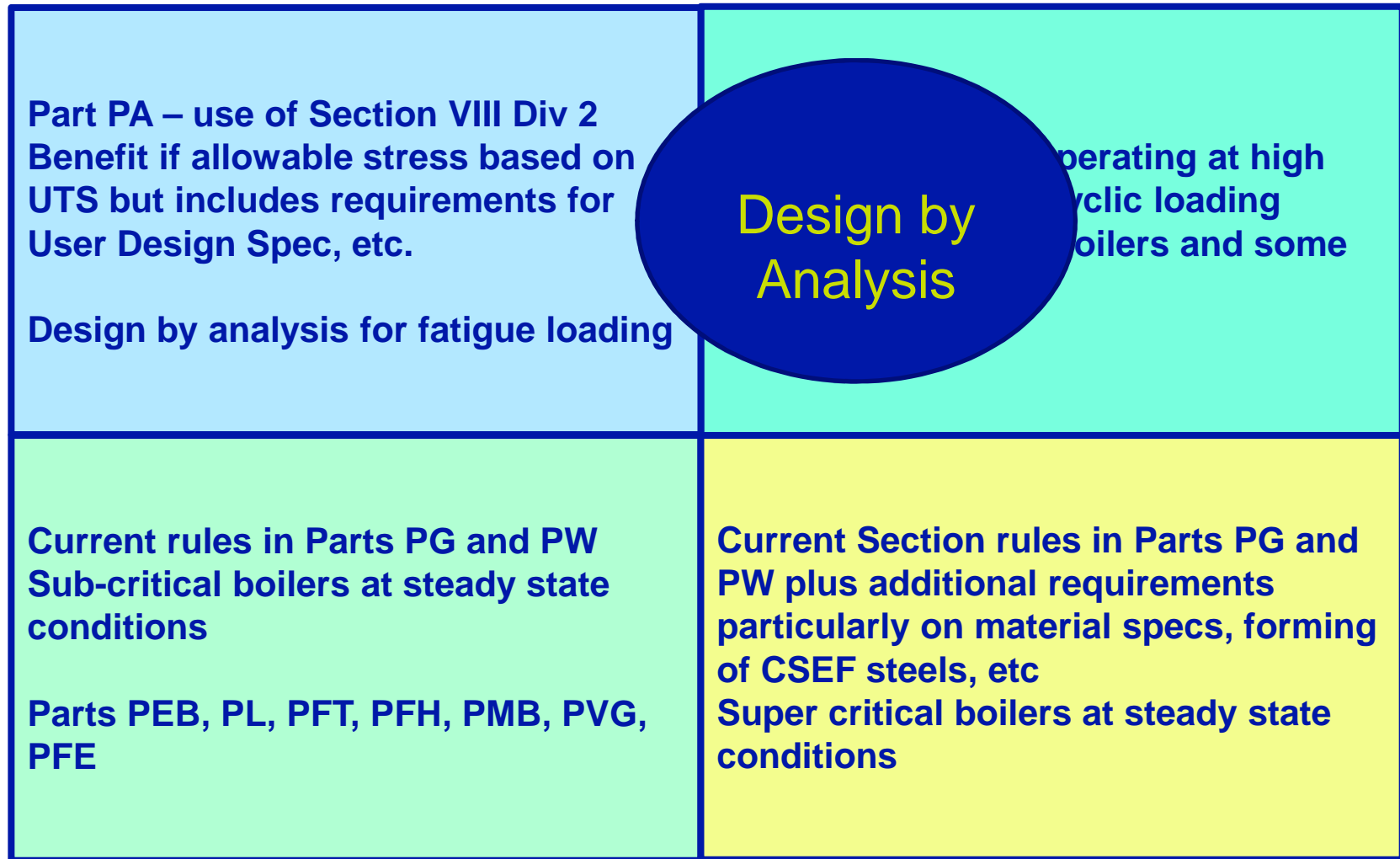
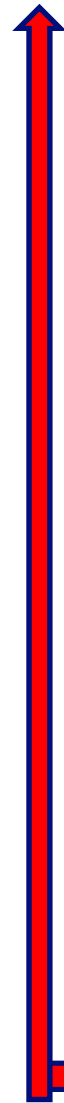
**Increasing
cycles**



<p>Part PA – use of Section VIII Div 2 Benefit if allowable stress based on UTS but includes requirements for User Design Spec, etc.</p> <p>Design by analysis for fatigue loading</p>	<p>New Part for plant operating at high temperature under cyclic loading Ultra Super Critical boilers and some HRSGs</p>
<p>Current rules in Parts PG and PW Sub-critical boilers at steady state conditions</p> <p>Parts PEB, PL, PFT, PFH, PMB, PVG, PFE</p>	<p>Current Section rules in Parts PG and PW plus additional requirements particularly on material specs, forming of CSEF steels, etc Super critical boilers at steady state conditions</p>

**Increasing
temperature**

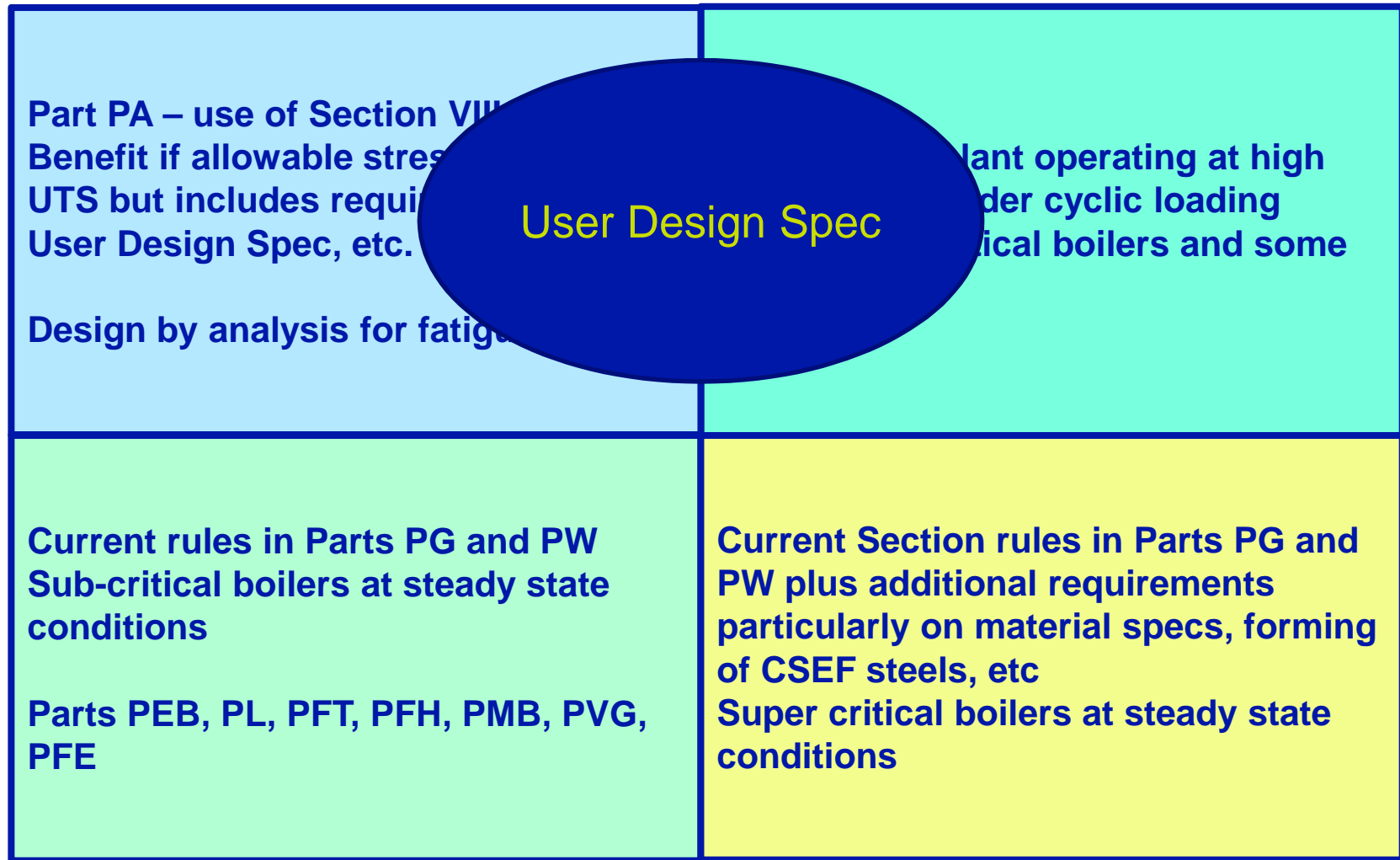
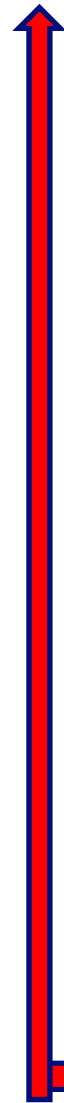
**Increasing
cycles**



**Design by
Analysis**

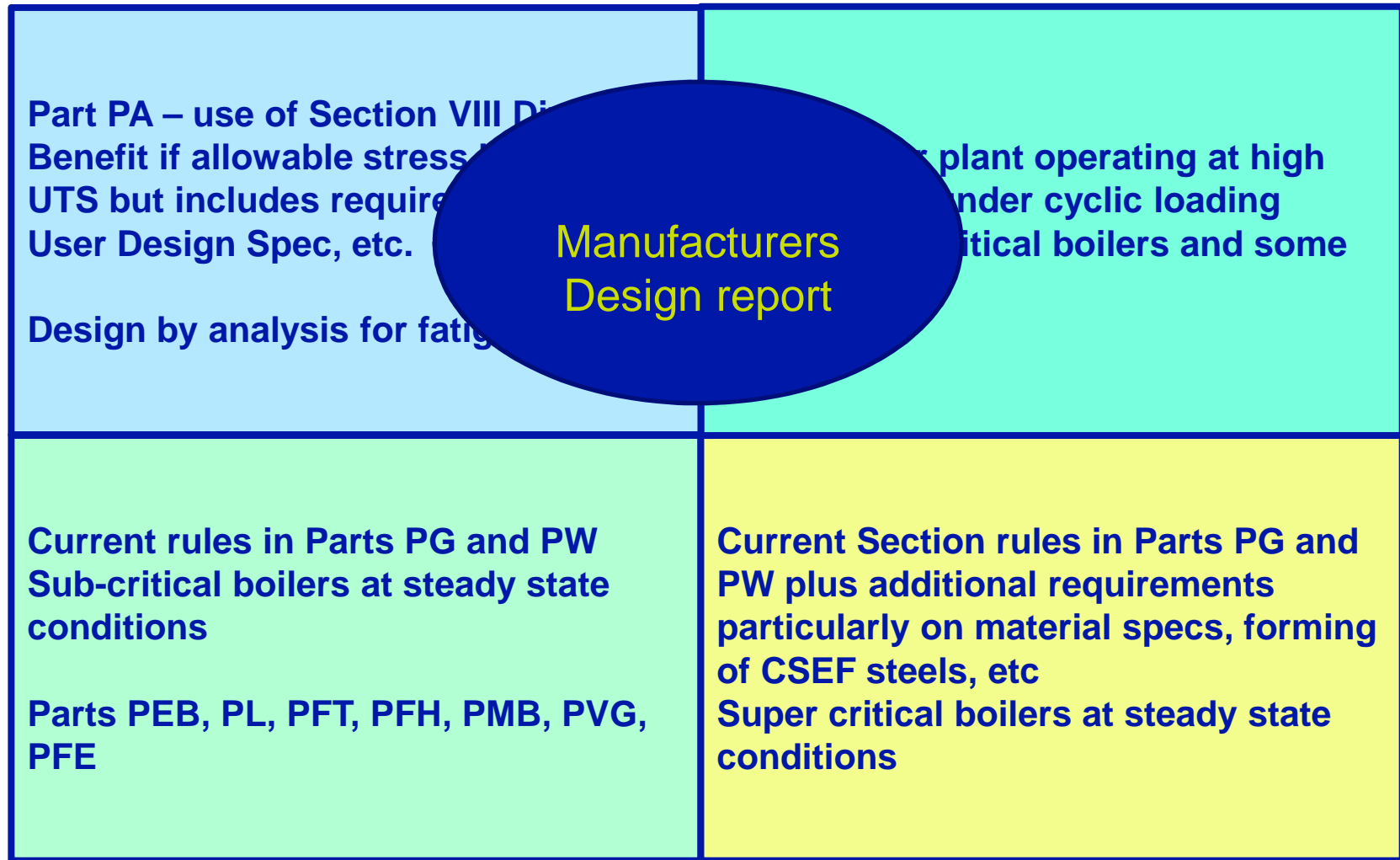
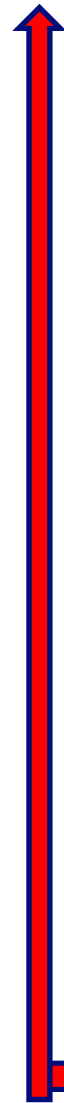
**Increasing
temperature**

**Increasing
cycles**



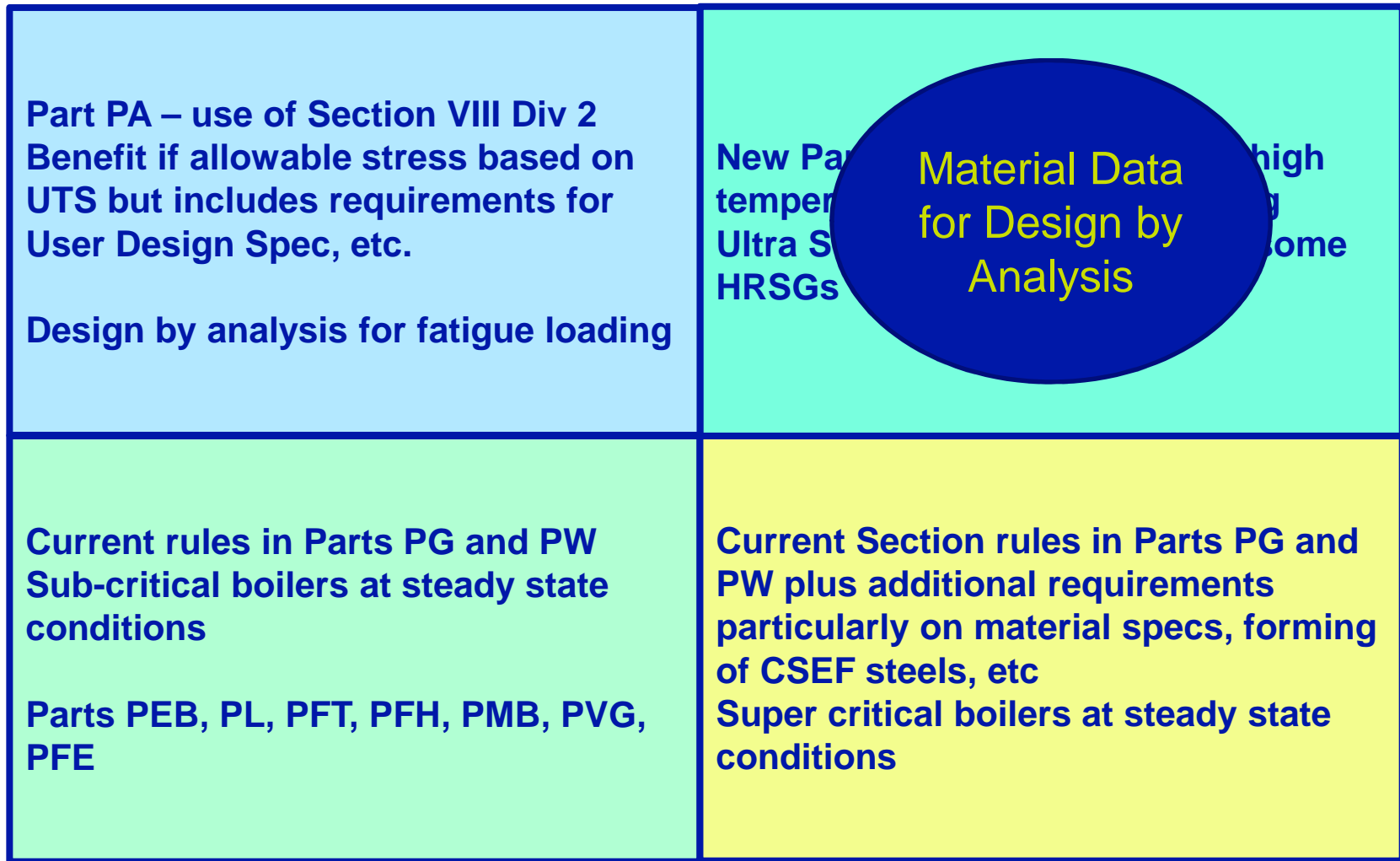
**Increasing
temperature**

**Increasing
cycles**



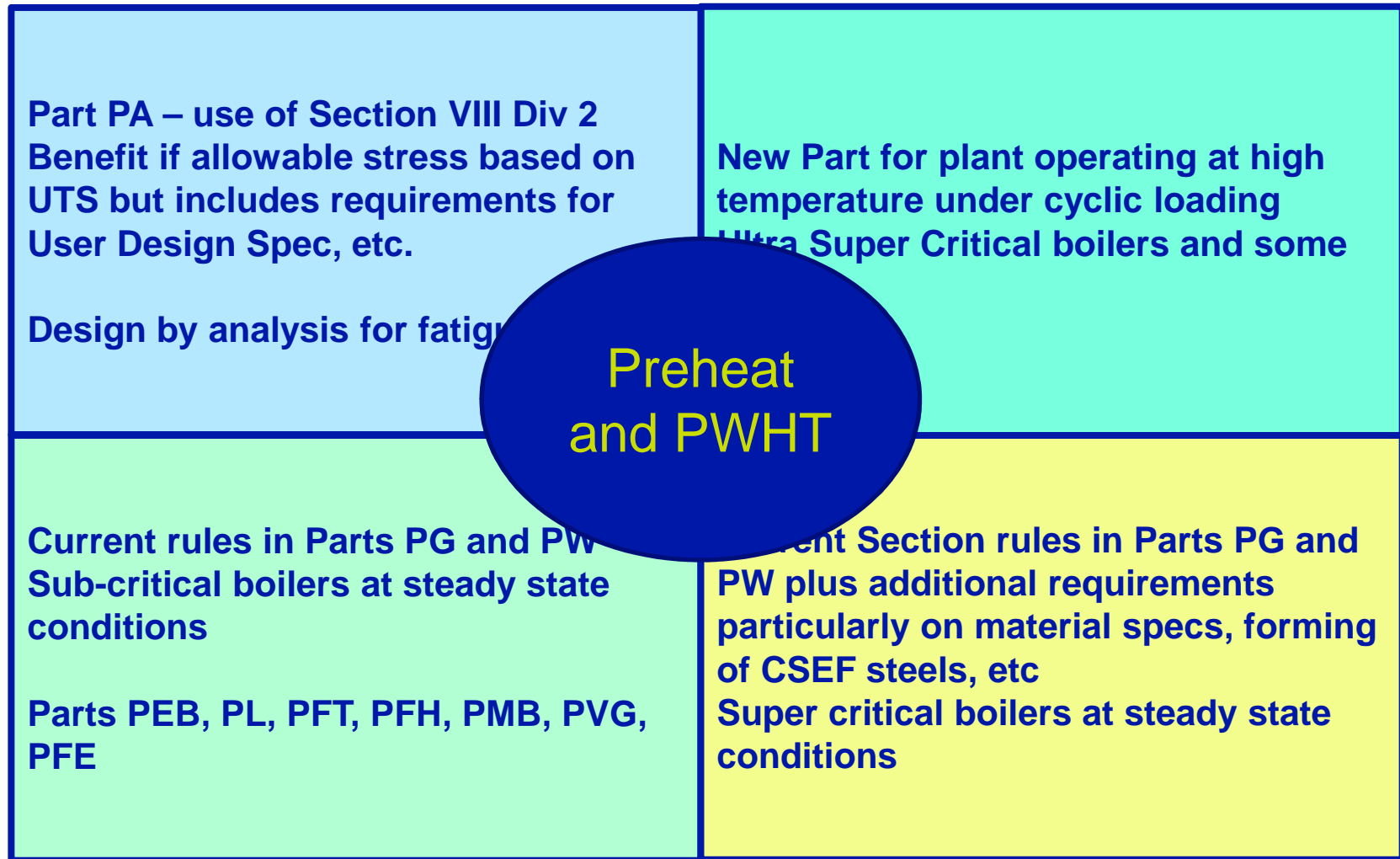
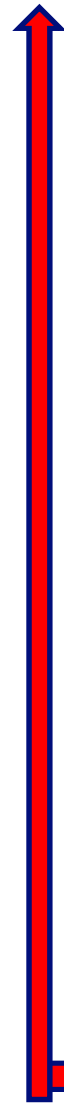
**Increasing
temperature**

**Increasing
cycles**



**Increasing
temperature**

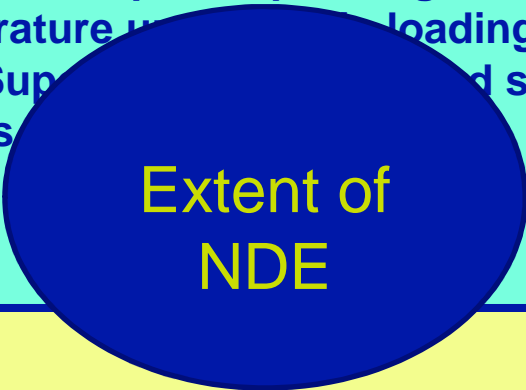
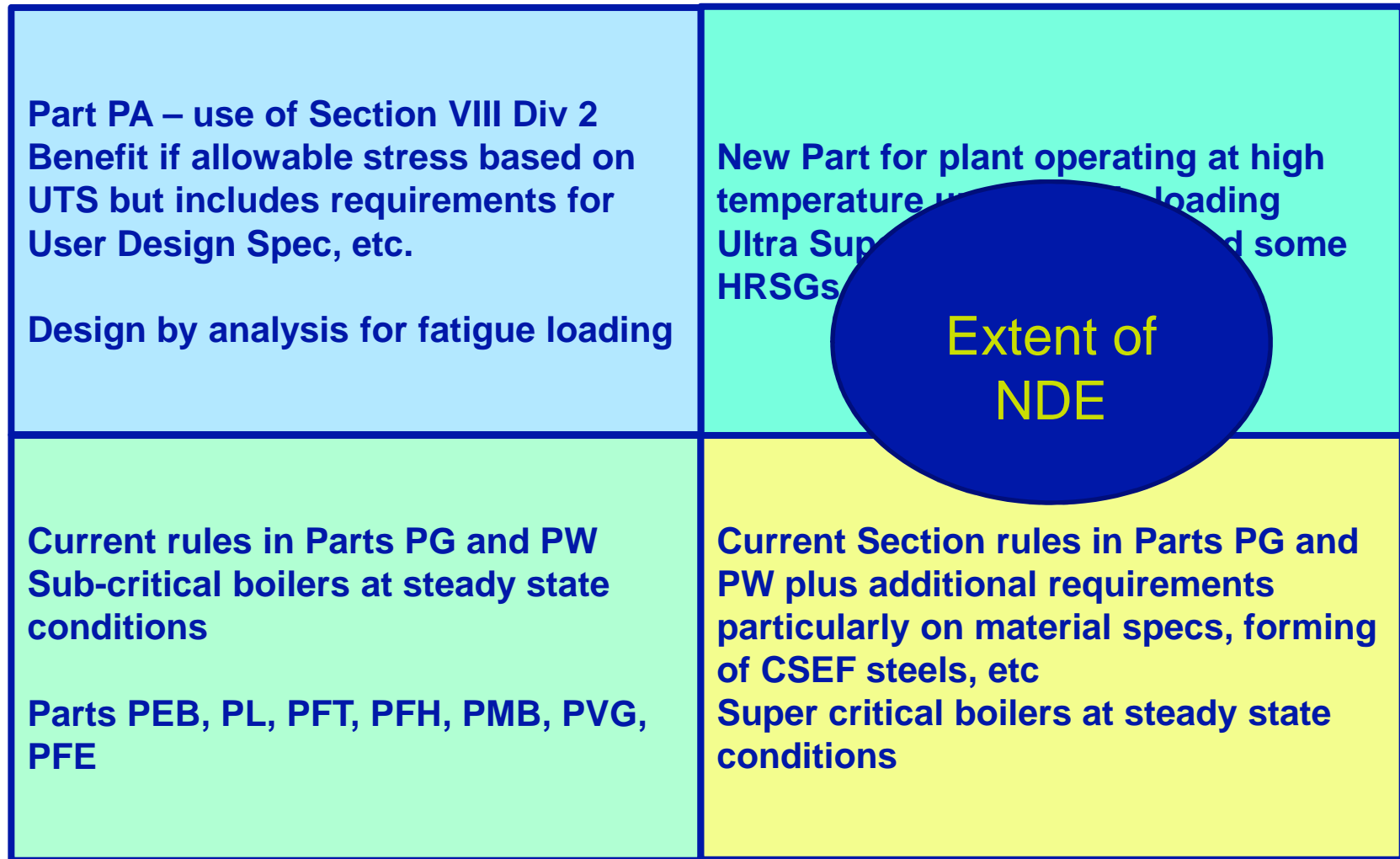
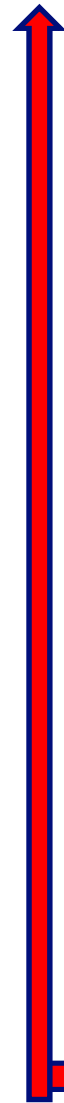
**Increasing
cycles**



**Preheat
and PWHT**

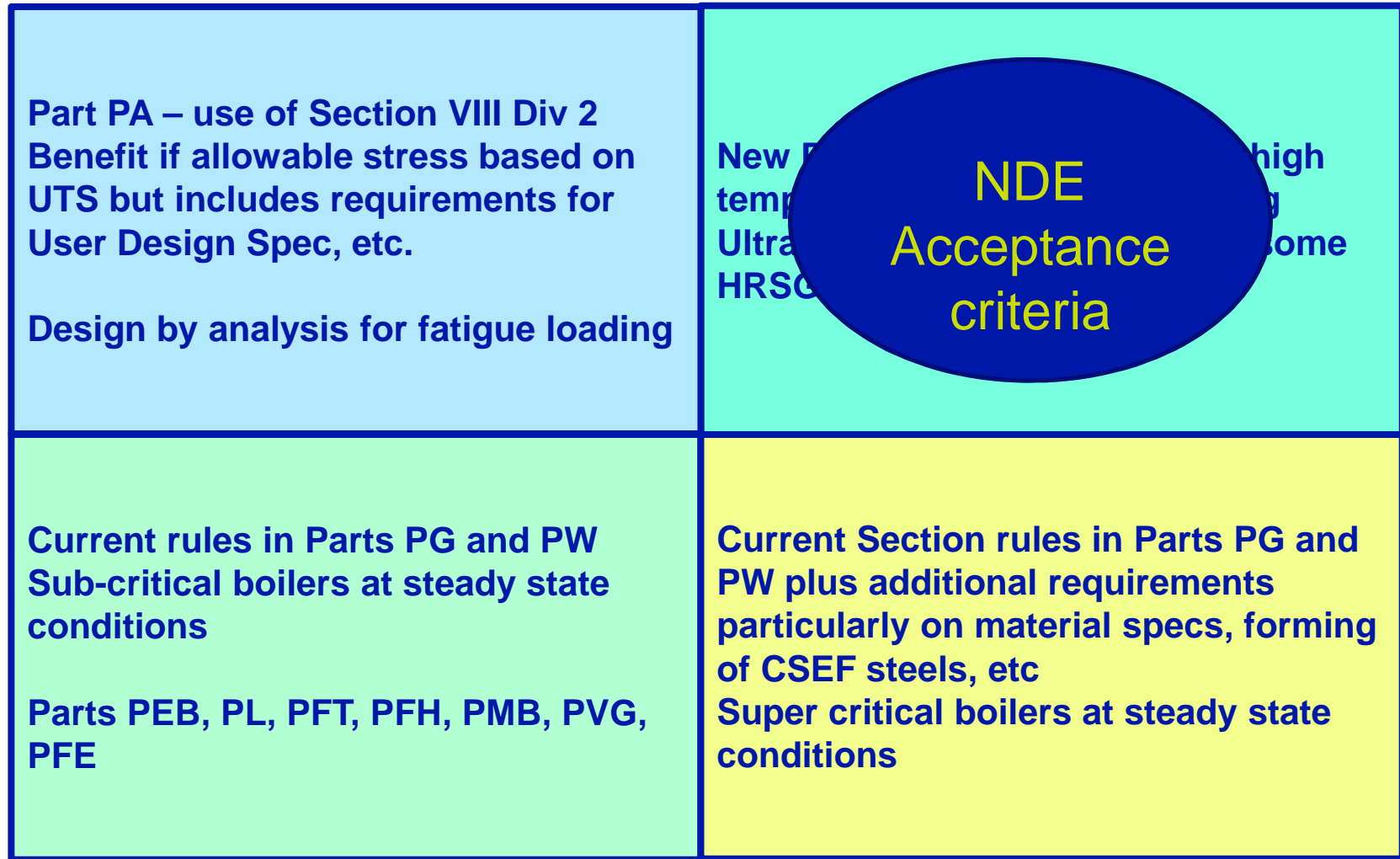
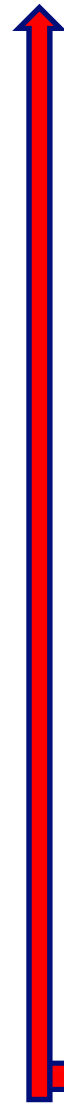
**Increasing
temperature**

**Increasing
cycles**



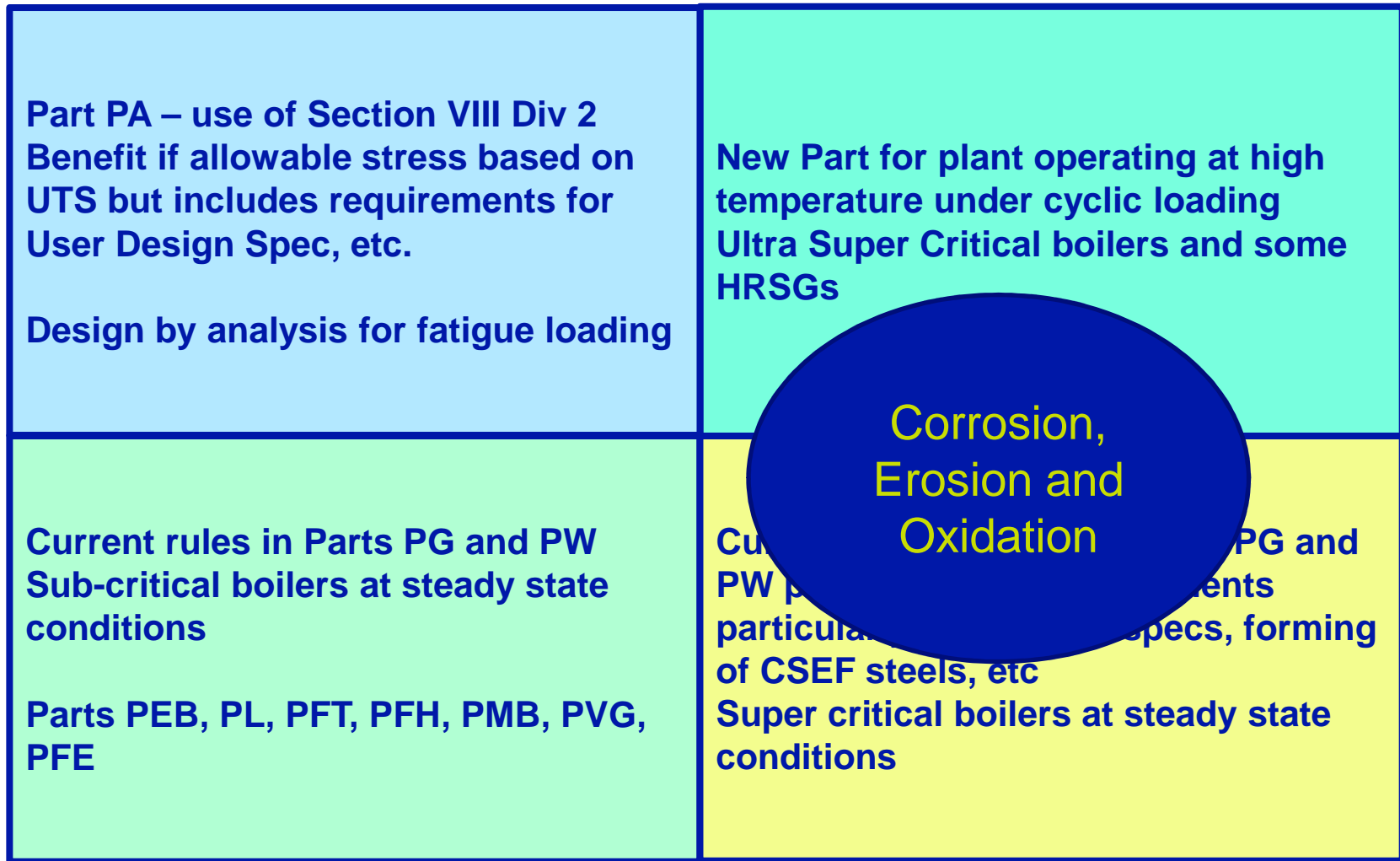
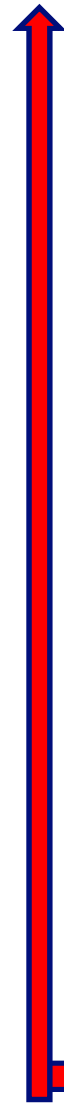
**Increasing
temperature**

**Increasing
cycles**



**Increasing
temperature**

**Increasing
cycles**



**Corrosion,
Erosion and
Oxidation**

**Increasing
temperature**

Design by Analysis Methods

In general Section I of the ASME Boiler Code was originally developed for industrial boilers through to sub-critical boilers operating at relatively low temperatures and pressures under steady state conditions. Current and future boilers do and will operate at higher temperatures and pressures under cyclic loading requiring a more detailed assessment and examination to ensure safe and reliable operation.

Design by Analysis (DBA) methods will be fundamental to the assessment process for key boiler components. It is intended that the Code will incorporate several DBA methods, ranging in complexity, to allow the user some flexibility to select the method appropriate to the design conditions.

The methods currently being considered include an elastic approach based on Section VIII Division 2, an inelastic approach based on the Omega method from API 579, the Section VIII Division 2 Code Case 2843 based on the Section III Part NH rules utilizing the strain deformation method and a new Section III Code Case based on the EN 13445 approach.



Design by Analysis Methods

Method 1 : Elastic Approach (based on Section VIII Division 2 – new Part 5.6)

Part 5.6 is organized with each sub-paragraph addressing one of the potential failure modes that are addressed in the rest of part 5: rupture, buckling, creep/fatigue interaction, and ratchetting.

The procedure evaluates protection against stress rupture from primary loading using elastic stress analysis.

It also includes a fatigue screening method.

This procedure is based on the computation and categorization of equivalent stress at a location in a component, and to determine the acceptability of the resulting stress state at each point in time of the operating cycle. Alternatively, if the controlling temperature and loading conditions can be identified, a single calculation may be used to determine acceptability.



Design by Analysis Methods

Method 1 : Elastic Approach (based on Section VIII Division 2, New Part 5.6)

Stress Rupture is addressed in a 7 step process:

STEP 1 – Define the loads and load combinations, evaluating those associated with “load-controlled” loads (e.g. pressure or weight) and “strain-controlled” loads (e.g. thermal gradients or imposed displacements). Tables 5.1 and 5.3 give guidance.

STEP 2 – At the location of interest calculate the stress tensor (6 components of stress) and assign to either (1) General primary membrane, (2) Local primary membrane, (3) Primary bending, or (4) Secondary as defined by Figure 5.1 (Noting that Service Stress is currently not considered).

STEP 3 – Sum the stress tensors for each stress category

STEP 4 – Determine the principal stress for each stress tensor and compute the equivalent stress

STEP 5 – Apply appropriate weld strength reduction factor

STEP 6 – Determine the time dependent allowable stress

STEP 7 – Evaluate protection against plastic collapse (time independent regime) or stress rupture (time dependent regime)



Design by Analysis Methods in the Modernized Code

Method 1 : Elastic Approach (based on Section VIII Division 2, New Part 5.6)

Creep Buckling – is considered for external pressure, generally utilizing the isochronous stress-strain curve approach of Annex 3G.

Creep-Fatigue Interaction – To use this Part of the Code a fatigue screening process must be undertaken to demonstrate no creep-fatigue interaction.

Two fatigue screening criteria which must be met (1) the number of full-range pressure cycles must not exceed 250 and (2) the total number of cycles (including full-range and significant pressure cycles and significant temperature cycles) must not exceed 500.

If both these criteria are met then a detailed creep-fatigue analysis is not required.

Creep Ratchetting – the summation of local primary membrane, primary bending and secondary stress must be kept within the cold to hot stress range.



Design by Analysis Methods

Method 1 : Elastic Approach (based on Section VIII Division 2, New Part 5.6)

Stress Category	Primary			Secondary Membrane plus Bending	Peak
	General Membrane	Local Membrane	Bending		
Description (see Annex 2D and VIII 2, Part 5)	Average primary stress across solid section. Excludes discontinuities and concentrations. Produced only by mechanical loads.	Average stress across any solid section. Considers discontinuities but not concentrations. Produced only by mechanical loads.	Component of primary stress proportional to distance from centroid of solid section. Excludes discontinuities and concentrations. Produced only by mechanical loads.	Self-equilibrating stress necessary to satisfy continuity of structure. Occurs at structural discontinuities. Can be caused by mechanical load or by differential thermal expansion. Excludes local stress concentrations.	<ol style="list-style-type: none"> Increment added to primary or secondary stress by a concentration (notch). Certain thermal stresses which may cause fatigue but not distortion of vessel shape.
Symbol	P_m	P_L	P_b	Q	F

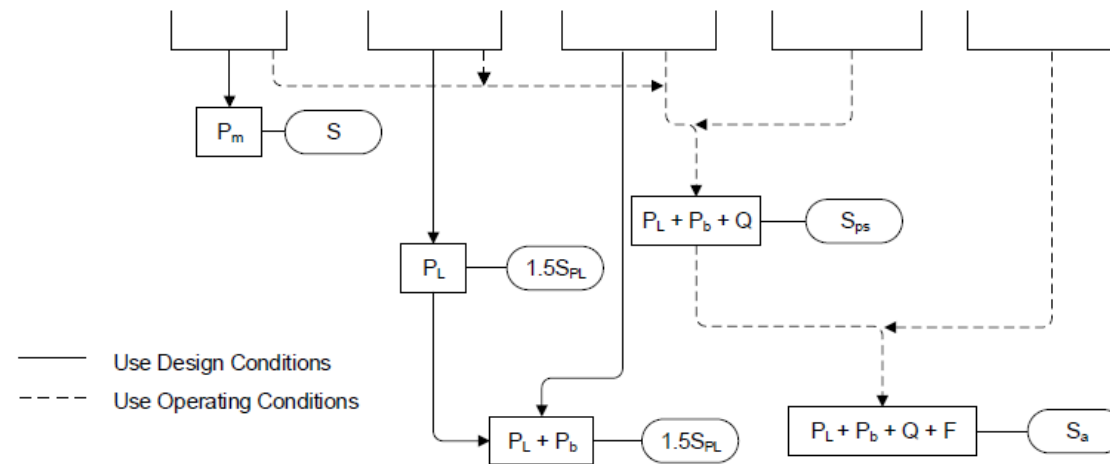


Figure 5.1 – Stress Categories and Limits of Equivalent Stress

Design by Analysis Methods

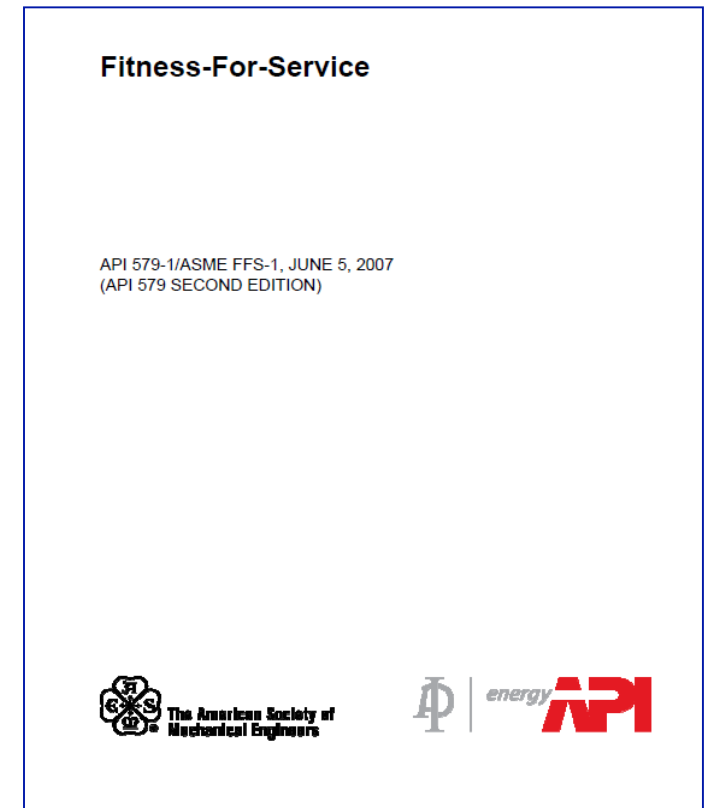
Method 2 Inelastic Approach (based on the Omega method from API 579)

5 failure modes are evaluated:

- 1) Protection against plastic collapse
- 2) Protection against local failure
- 3) Protection against collapse from buckling
- 4) Protection against failure from Cyclic Loading
- 5) Protection against Creep and/or Creep-Fatigue

Modes 1 through 4 are covered by Annex B1

Mode 5 is covered by Part 10



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Design by Analysis Methods

Method 2 Inelastic Approach (based on the Omega method from API 579)

Level 3 Assessment

For Creep Rupture Assessment it is a 12 Step Process:

1. Determine the load history (can be design or service based)
2. For each cycle determine the time increments
3. For each time increment determine the temperature
4. Carry out stress analysis to determine stress components
5. Determine protection against plastic collapse
6. Determine principal stresses and effective stress
7. Determine remaining life
8. Repeat Steps 3 through 7 for each time increment.
9. Calculate accumulated creep damage
10. Repeat Steps 2 through 9 for each cycle
11. Calculate the total creep damage for all cycles
12. Compare with allowable creep damage, limited to 0.8.

Accumulated creep strain is also evaluated.

Fitness-For-Service

API 579-1/ASME FFS-1, JUNE 5, 2007
(API 579 SECOND EDITION)



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Design by Analysis Methods

Method 2 Inelastic Approach (based on the Omega method from API 579)

This method requires:

- use of an elastic-plastic material model
- Consider the effects of non-linear geometry
- Calculate the plastic collapse load (the load that causes overall structural instability)

Material data is taken from the MPC Project Omega Data (Annex F of FFS-1)

API 579-1/ASME FFS-1 2007 Fitness-For-Service

Table F.30 – MPC Project Omega Creep Data					
Material	Notes	Strain Rate Parameter – $\dot{\epsilon}_0$		Omega Parameter Ω	
Carbon Steel	• See Notes 1 and 2	A_0	-16.3	B_0	-1.0
		A_1	38060	B_1	3060.0
		A_2	-9165	B_2	135.0
		A_3	1200	B_3	-760.0
		A_4	-600	B_4	247.0

$${}^nL = \frac{1}{\dot{\epsilon}_{co} \Omega_m} \quad (10.13)$$

where

$$\log_{10} \dot{\epsilon}_{co} = - \left\{ (A_o + \Delta_{\Omega}^{sr}) + \left[\frac{1}{460 + {}^nT} \right] [A_1 + A_2 S_l + A_3 S_l^2 + A_4 S_l^3] \right\} \quad (10.14)$$

$$\Omega_m = \Omega_n^{\delta_{\Omega} + 1} + \alpha_{\Omega} \cdot n_{BN} \quad (10.15)$$

$$\Omega_n = \max \left[(\Omega - n_{BN}), 3.0 \right] \quad (10.16)$$

$$\log_{10} \Omega = (B_o + \Delta_{\Omega}^{st}) + \left[\frac{1}{460 + {}^nT} \right] [B_1 + B_2 S_l + B_3 S_l^2 + B_4 S_l^3] \quad (10.17)$$

Design by Analysis Methods

Method 3 – Elastic Approach Utilizing Section VIII Division 2 Code Case 2843 (based on the Section III Part NH rules utilizing the strain deformation method)

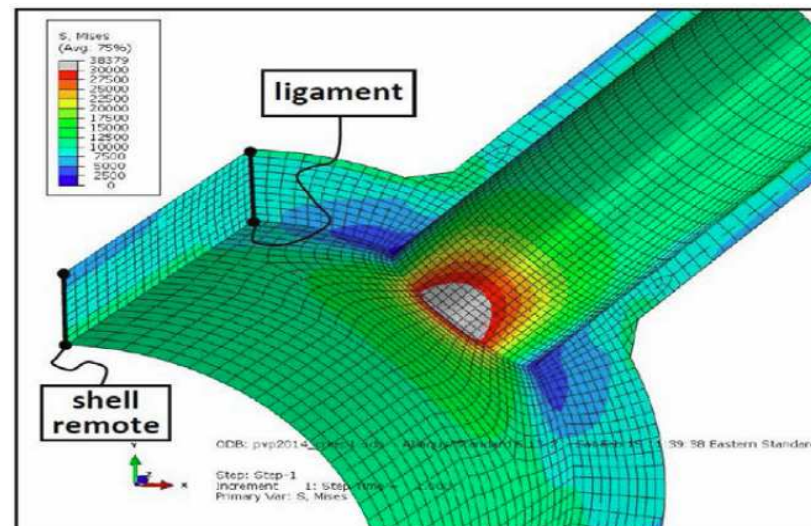
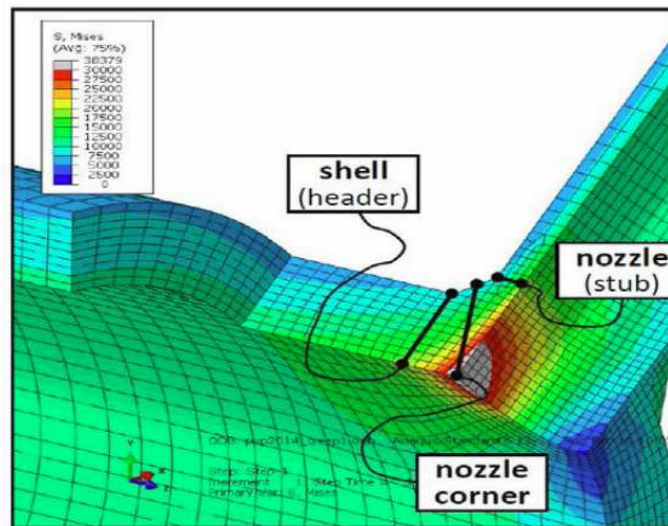
This recently published Code Case includes for time dependent cases.

It uses load controlled limits and strain controlled limits.

Load controlled limits to ensure stress levels are maintained below code allowable values.

Strain controlled limits to ensure protection against ratcheting

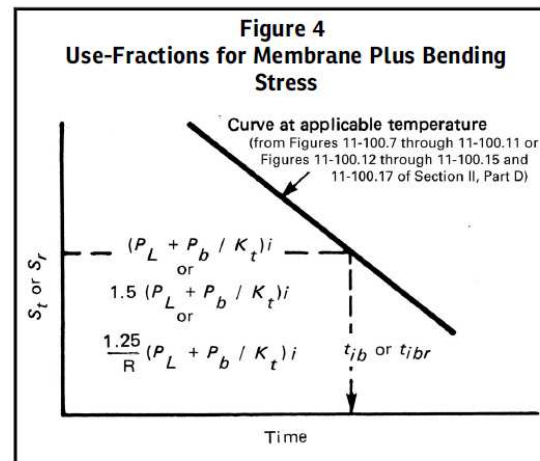
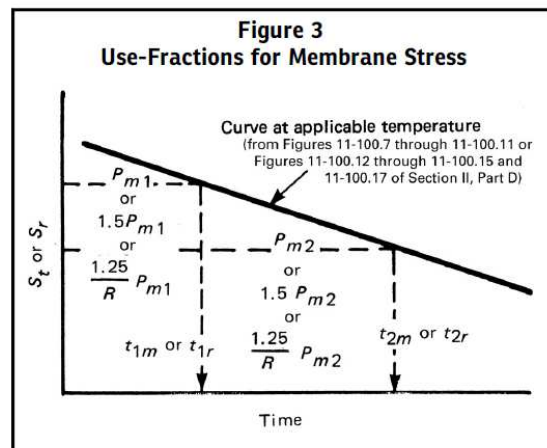
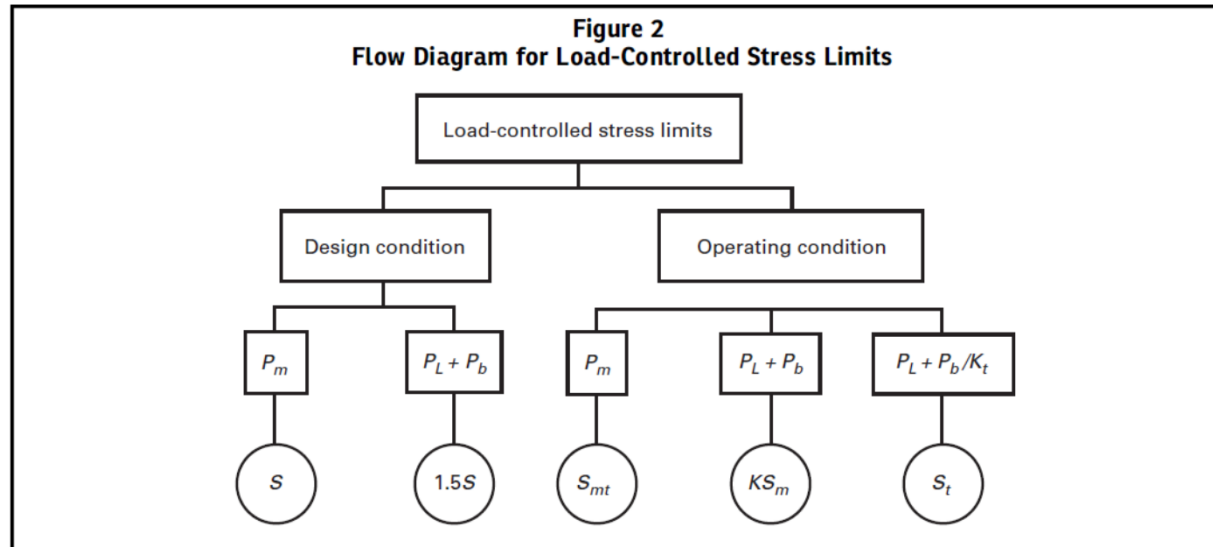
The Code Case also addresses creep-fatigue criterion which brings in the lifetime specification for components.



Design by Analysis Methods

Method 3 – Elastic Approach Utilizing Section VIII Division 2 Code Case 2843 (based on the Section III Part NH rules utilizing the strain deformation method)

As with the Section VIII Division 2 Part 5 the different loads and combinations are assessed for adequacy.

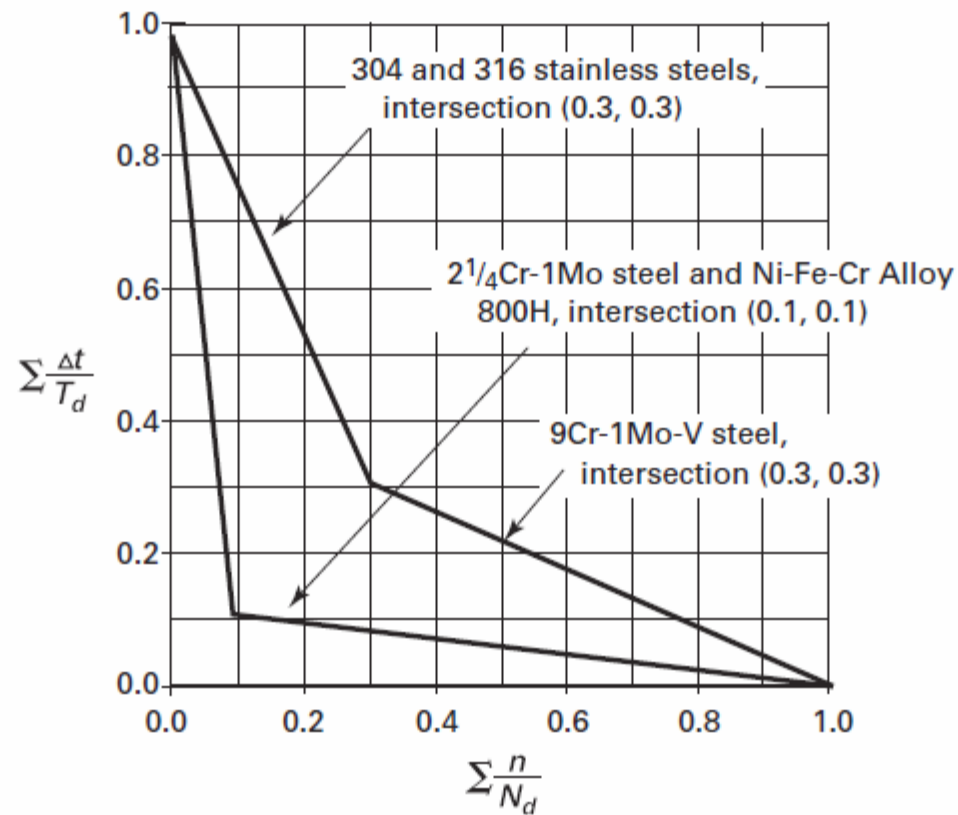


Design by Analysis Methods

Method 3 – Elastic Approach Utilizing Section VIII Division 2 Code Case 2843 (based on the Section III Part NH rules utilizing the strain deformation method)

Creep-Fatigue is evaluated using a modified interaction diagram from Section III Part NH.

Figure 15
Creep-Fatigue Damage Envelope



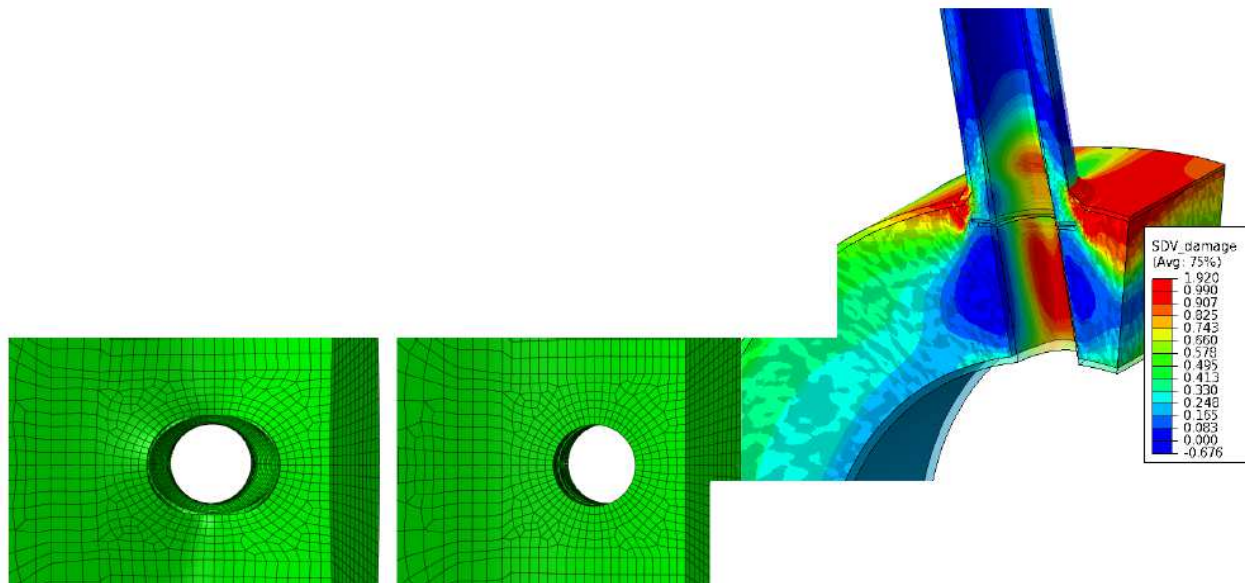
Design by Analysis Methods

Method 3 – Elastic Approach Utilizing Section VIII Division 2 Code Case 2843 (based on the Section III Part NH rules utilizing the strain deformation method)

Currently there is a comparison of CC 2843 with Section I Design being undertaken.

Section I makes use of wall thickness or pressure capacity equations for component sizing, supplemented by rules for compensation of openings.

CC 2843 uses a combination of hand calculations for basic stresses (termed General Primary Stresses) and finite element analysis (FEA) with linearized through-thickness stress results at key locations (Local Primary as well as Secondary and Peak stresses and limits) which take the place of compensation rules. It also requires a definition of a specific design life, in addition to consideration of both Design and Operating cases.



Design by Analysis Methods

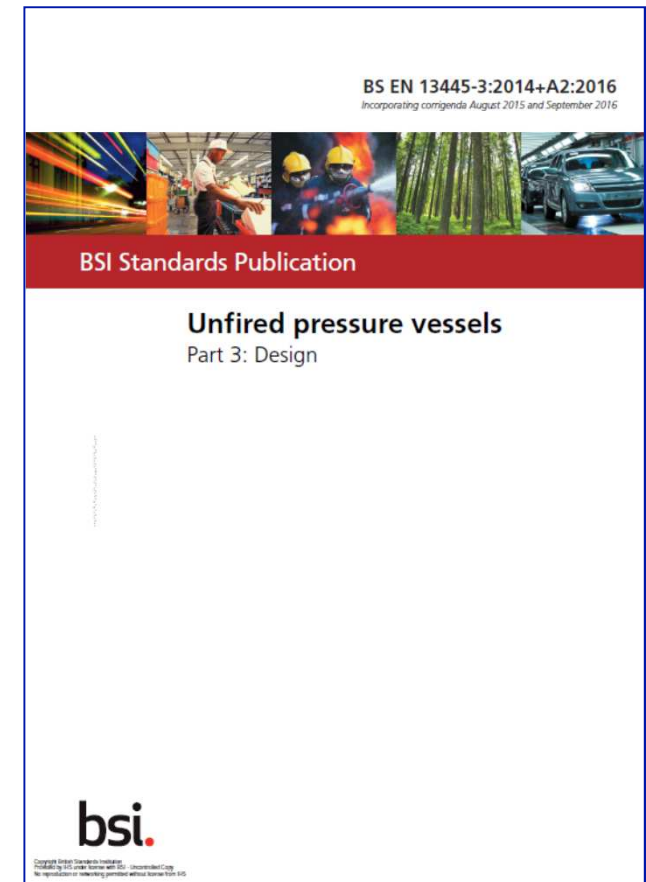
Method 4 – Simplified Inelastic Approach Utilizing a Draft Section III Code Case (based on EN 13445)

This final case is still being investigated for Section I use and was recommended by the authors of the ASME funded research project for Section I Modernization – STP-PT-070 “Design Guidelines for the Effects of Creep, Fatigue and Creep-Fatigue Interaction”.

It is the method mandated by EN12952 for design by analysis as defined in EN 13445 Annex B

It assumes material is sufficiently ductile / creep ductile

It characterizes design (ultimate) loads and also service load conditions.



Design by Analysis Methods

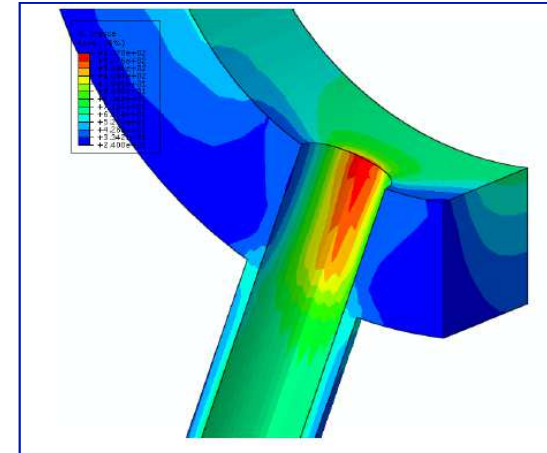
Method 4 – Simplified Inelastic Approach Utilizing a Draft Section III Code Case (based on EN 13445)

Design Checks for Time Independent Conditions:

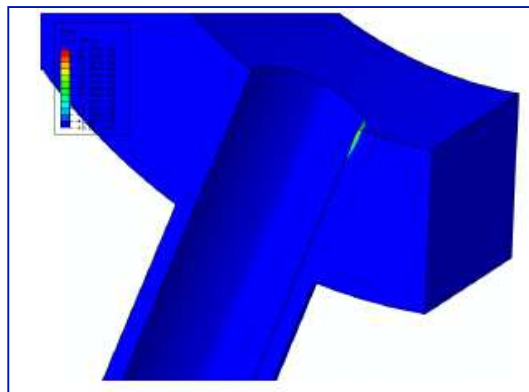
- Gross Plastic Deformation
- Progressive Plastic Deformation (Ratchetting)
- Instability
- Fatigue
- Static Equilibrium

Design Checks for Time Dependent Conditions

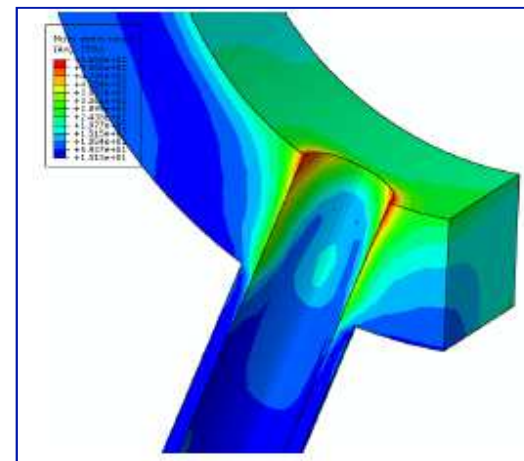
- Creep Rupture
- Excessive Creep strain
- Creep-Fatigue Interaction



Tresca elastic Stress



Plastic Strain



Von Mises stress range

Design by Analysis Methods

Method 4 – Simplified Inelastic Approach Utilizing a Draft Section III Code Case (based on EN 13445)

Model Basis:

- Gross Plastic Deformation check – linear-Elastic ideal plastic law using Tresca's yield condition (maximum shear stress).
- Progressive Plastic Deformation (Ratchetting), Creep Rupture and Excessive Creep Strain checks a linear-elastic ideal plastic law is used with von Mises' yield condition (maximum distortion energy)
- Instability check – either a linear-elastic or linear-elastic ideal-plastic law
- Fatigue check - a linear-elastic law

Note von Mises yield condition may be used for the Gross Plastic Deformation check if the strength parameter is modified by $\sqrt{3} / 2$

Additional Requirements

Additional requirements to be addressed to ensure a safe, reliable design is produced, such as:

- ✓ Material Properties
- ✓ Creep-Fatigue Flaw Growth parameters
- ✓ NDE Levels and Criteria



Material Data

A proposed Research Project: Elevated Temperature Material Property Compilation for Design-by-Analysis has now been approved for funding by ASME ST LLC and should start mid 2017.

It is currently formed to look at the following materials data and materials for boiler components as well as nuclear and petro-chem type applications:



Material data

- Creep rupture, average and minimum
- Creep ductility
- Creep strain vs. time curves
- Elevated temperature yield, tensile strength and physical properties
- Elevated temperature continuous cycling fatigue curves
- Elevated temperature hold time fatigue curves

Primary Materials:

- Grade 91
- Type 304H
- Type 347H
- Grade 22
- Grade 92
- Grade 22V
- Grade 9 (9Cr)
- Alloy 617
- Carbon Steel (SA-516, SA-299)
- C-1/2Mo
- SA-533/SA-508
- Type 316H
- 5Cr
- Alloy 800H
- Grade 11
- A709

Secondary Materials:

- Grade 23
- Type 321H
- 3Cr
- Type 410
- Grade 12
- 12Cr
- B16, B7 bolting
- B8 bolting
- Grade 660
- Alloy 601
- Inconel bolting



Flaw acceptance criteria

Creep-Fatigue Flaw Growth Analysis to Support Elevated Temperature Flaw Size Acceptance Criteria.

The scope of this project is to analyze a matrix of typical elevated temperature components using recognized creep-fatigue flaw growth analysis methods and data.

The key deliverable will be the largest initial flaw size for each case that satisfies the specified transient operating conditions (temperature, pressure, time, cycles).

This information will then be used in developing rational flaw acceptance criteria for equipment operating in the creep regime and is a necessary extension to the current Section I Code Case 2235 for using ultrasonic test methods in lieu of radiography, and directly supports Section I modernization.



Flaw Growth Analysis

Creep-Fatigue Flaw Growth Analysis to Support Elevated Temperature Flaw Size Acceptance Criteria.

Specified Inputs:

Operating Duration: 200,000 hours (22.8 years)

Operating Conditions:

Cold Starts (> 48 hours shutdown) = 100

Warm Start (8 to 48 hours shutdown) = 1,000

Hot Start (<8 hours shutdown) = 6,000

Stresses:

Pressure-induced

Welding residual equal to 35% of average 0.2% yield strength

Thermal

Transient conditions have been included (start-up, shutdown curves) intended to be representative of a typical ultra-supercritical (USC) power plant.



Flaw Growth Criteria

Analysis Methods:

API 579-1/ASME FFS-1 Part 10 (including Annex F material models and data)
EDF Recommended Procedure R5 V4/5 (including R66 material models and data)
Electric Power Research Institute BLESS Code (including embedded material models and data)

Configurations:

To be girth welds (Superheater and Reheater tube, Superheater and Reheater header)

Materials :

To be Grade 22, Grade 91, Type 304H, Grade 23

Flaw Orientations to be:

Circumferential and Longitudinal

Flaw Locations to be Inside surface, Outside surface, Mid-wall (subsurface)

Flaw Geometries: to be Infinite length/full circumferential and 6:1 (2c vs. a) semi-elliptical

This creates 192 flaw analysis cases (per analysis method).

Acceptance criteria should be consistent with the given analysis method. If no acceptance criteria are given, then failure shall be defined as either a flaw growing to 75% through-wall at its deepest point or gross rupture due to loss of section.



The benefits of participating in Code Committees

- Interact with the foremost technical experts from around the world
- Create personal network of contacts for valuable technical advice on standards
- Develop awareness of technical issues in their industry-how others are dealing with them
- Become knowledgeable of requirements in industry standards and how they are applied
- Ensures that the interests, practices and experience of the organization are considered in developing and updating code requirements

Summary Overview

EN12952

- is more prescriptive and specific than ASME Section I and in general represents current European working practice
- is a harmonised standard under the Pressure equipment Directive
- tends to be only used in Europe

ASME I

- normally has additional requirements by the Manufacturer to a similar level to those of EN12952
- Some of these additional requirements will be in a new Part
- Used worldwide
- Now allows materials other than just ASME and ASTM



Thank You