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COMPARATIVE STUDY OF DESIGN OF PIPING SUPPORTS CLASS 1, 2 AND 3 CONSIDERING GERMAN CODE KTA AND ASME III – NF.

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ABSTRACT

The objective of this paper is developing a comparative study of the design criteria for class 1, 2, 3 piping supports considering the American Code ASME Section III – NF and the German Code KTA 3205.1 to the Primary Circuit, KTA 3205.2 to the others systems and KTA 3205.3 series-production standards supports of a PWR nuclear power plant. An additional purpose of the paper is a general analysis of the main design concepts of the American Code ASME Boiler and Pressure Vessel Code, Section III, Division 1 and German Nuclear Design Code KTA that was performed in order to aid the comparative study proposed. The relevance of this study is to show the differences between codes ASME and KTA since they were applied in the design of the Nuclear Power Plants Angra 1 and Angra 2, and to the design of Angra 3, which is at the moment under construction. It is also considered their use in the design of nuclear installations such as RMB – Reator MultiPropósito Brasileiro and LABGENE – Laboratório de Geração Nucleoelétrica.

1. INTRODUCTION

The objective of this paper is developing a comparative study of design criteria for class 1, 2, 3 piping supports considering the American Code ASME code Section III – NF and the German Codes KTA 3205.1 to the Primary Circuit, KTA 3205.2 to the others systems and KTA 3205.3 series-production standard supports of a nuclear power plant. The paper compares the prescriptions of “Design by Analysis” and “Design by Rule” from ASME, with “Analysis of the Mechanical Behavior” and “Component Specific Analysis of the Mechanical Behavior” from KTA, and also compares the equations for piping design of both codes.

A general description of the German KTA standards is presented in [1]. Also the differences between ASME standards [2]-[8] and KTA standards [9]-[20] are analyzed in [21]. The comparison between KTA 3201.2 and ASME NB standards applied to the Primary Circuit design is summarized in [22] and included in section 3 of the paper. The main aspects of the piping support design were discussed in section 4 and an example of a piping support hardware calculation was presented in section 5. Some comments and conclusions are addressed in section 6.

2. NOMENCLATURE

A	additional thickness to account for material corrosion (ASME)
c_1	Absolute value of the minus tolerance of wall thickness (KTA)
c_2	value accounting for wall thickness reduction due to mechanical wear (KTA)
C	Coefficient of friction
D_O	outside diameter of pipe (ASME)
d_a	outside diameter of pipe (KTA)
E	Young modulus
Fb	allowable stress (bending)
I	Moment of inertia
N	Normal force
L	Span of supports
P	design pressure (ASME and KTA)
R_{mRT}	minimum tensile strength at room temperature (KTA)
R_{mT}	minimum tensile strength above room temperature (KTA)
$R_{p0.2RT}$	minimum yield strength at room temperature (KTA)
$R_{p0.2T}$	minimum yield strength above room temperature (KTA)
RT	room temperature (ASME and KTA)
S	allowable stress (ASME class 2 and class 3)
S_m	allowable stress (ASME and KTA)
S_T	minimum tensile strength at room temperature (ASME)
$S_T R_T$	minimum tensile strength above room temperature (ASME)
S_y	minimum yield strength at room temperature (ASME)
$S_y R_y$	minimum yield strength above room temperature (ASME)
s_o	calculated wall thickness (KTA)
s_n	nominal wall thickness (KTA)
S_u	ultimate tensile strength
T	temperature
t_m	minimum required wall thickness (ASME)
y	parameter to adjust the Boardman equation to the Lamé equation (ASME)
ν	Poisson`s ratio
α	Thermal expansion coefficient

3. ASME SECTION III VERSUS KTA

3.1. General

The American Society of Mechanical Engineers (ASME) is a professional membership organization with experts in all areas of mechanical engineering. The ASME committees issue codes and standards focusing mechanical engineering providing rules and recommendations to apply in the design, fabrication, installation and inspection of pressure vessels, pumps, valves, piping and supports.

The organization of the ASME code for instance, ASME Section III division 1 that defines rules to build a nuclear power plant components, presents the division in Subsections, and each Subsection is organized in Articles, as shown in Table 1.

Table 1: ASME III organization

DIVISION 1	ARTICLES
Subsection NB - Class 1 Components /2/ Subsection NC - Class 2 Components /3/ Subsection ND - Class 3 Components /4/ Subsection NE - Class MC Components /5/ Subsection NF - Supports /6/	1000 - Introduction or Scope 2000 - Material 3000 - Design 4000 - Fabrication and Installation 5000 - Examination 6000 - Testing 7000 - Overpressure Protection 8000 - Nameplates, Stamping

The Nuclear Safety Standards Commission (KTA) has the task to issue nuclear safety standards to the design of German nuclear power plants components. KTA design rules were derived from ASME code, while adding some design rules from German industry experience.

There are 92 KTA standards [21] to cover protection, transportation and safe operation of nuclear power plants. Concerning the mechanical design, there are 9 safety standards: KTA 3101.3 [10], KTA 3201.2 [11], KTA 3204 [12], KTA 3205.1 [13], KTA 3205.2 [14], KTA 3205.3 [15], KTA 3211.2 [16]-[17], KTA 3401.2 [18], KTA 3902 [19] and KTA 3905 [20].

The design concepts of KTA standards are applied to the systems of the plant. For instance, the KTA 3201.2 provides design rules for pressure and activity retaining boundaries of components and piping systems of the primary circuits, while KTA 3211.2 provides design rules for the others systems. KTA standards apply, also, for specific systems of power plants and contain rules and regulations for subjects like material or in-service inspection. A typical KTA division of subjects is presented in Table 2, although not all KTA Standards are organized in this manner.

Table 2: KTA 3201 and 3211 organization

KTA 3201 (3211)	
Volume	Sections
32xx.1 - Details material 32xx.2 - Outlines design and analysis 32xx.3 - Contains rules for manufacturing 32xx.4 - Covers in-service inspection and operational monitoring	1. Scope 2. General principles 3. Load case classes as well as design, service and test loadings and limits 4. Effects on the components due to mechanical and thermal loadings, corrosion, erosion and irradiation 5. Design 6. Dimensioning 7. Analysis of mechanical behavior 8. Component-specific analysis of mechanical behavior 9. Type and extend of verification strength and pertinent documents to be submitted Annexes

The main difference between ASME and KTA is that the German code deals with the system of the plants, and the American code has a broader scope and is not restricted to a systems or types of power plants. The equivalence between KTA design standards and ASME Section III, Division 1 Subsections can be established as given in Table 3.

Table 3: ASME versus KTA equivalence

ASME Section III, Div. 1 Subsections	KTA Standard
NB (Class 1 Components)	KTA 3201.2 and KTA 3211.2
NC (Class 2 Components)	KTA 3211.2
ND (Class 3 Components)	KTA 3211.2
NE (Class MC Components)	KTA 3401.2
NF (Supports)	Primary System: KTA 3201.2 Sections 5.3.6 and 8.5 for integral areas of component support structures KTA 3205.1 for non-integral areas Other than Primary System: KTA 3211.2 Sections 5.3.6 and 8.5 for integral areas of component support structures KTA 3205.2 for non-integral areas KTA 3205.3 for standard supports

3.2. Design Pressure

The ASME and KTA codes apply the concept that the wall thickness of a straight pipe calculated with design pressure determines which pipe schedule is needed. The components and fittings have to be specified according to the pipe schedule. This is because the burst pressure of a tested product is greater than that of a straight pipe of the same schedule.

ASME code outlines for design pressure of piping in NB-3132, NC-3132 and ND-3132, the equation for calculating the required wall thickness of a straight pipe, as:

$$t_m = \frac{PD_o}{2(S_m + Py)} + A \qquad (1)$$

The allowable stress S_m for Class 1 has to be replaced by S in the equation (1) for Class 2 & 3. When the factor y is 0.4, the equation (1) is called Boardman equation, and is an approximation of the Lamé equation, which calculates the elastic hoop stress of a thick-walled cylinder under internal pressure.

KTA formula for design pressure of straight pipes is:

$$s_o = \frac{d_a P}{2S_m + P} \qquad (2)$$

As in ASME code, the allowable stress S_m for Class 1 must be replaced by S in the equation (2) for Class 2 & 3.

The nominal wall thickness s_n is then calculated by: $$s_n = s_o + c_1 + c_2 \quad (3)$$

The calculated minimum wall thickness with equation (1), ASME code, and equation (3), KTA standard considering c_1 as the minimum value of the minus tolerance, are nearly identical, differing by less than 1%.

3.3. Design by Analysis

Design rules for Design by Analysis are defined in NB-3200 and NC-3200, for class 1 and class 2 components respectively. There is no Subsection ND-3200, so, a general analysis can only be performed with NB and NC. Design basis of ASME is described in NCA-2140.

In order to develop a specific component design, it is required that all loadings applied to the plant conditions are already defined to be considered in it. The design condition, the service levels and its correlation to the plant condition (normal, upset, emergency and faulted) and test loadings are defined in ASME and KTA as showed in Table 4.

Table 4: Service loadings - ASME and KTA

PLANT CONDITIONS			ASME (NCA-2140)	KTA (3201.2/3211.2)
Design	-	-	2142.4(a)	3.3.2
Service	Level A	normal operation	2142.4(b)(1)	3.3.3.2
	Level B	abnormal operation	2142.4(b)(2)	3.3.3.3
	Level C	emergency	2142.4(b)(3)	3.3.3.4
	Level D	faulted conditions	2142.4(b)(4)	3.3.3.5
Test	Level P	test conditions	2142.4(d)	3.3.3.6

The structural integrity for design, service and test loadings has to be proved. The stress intensity S_m (class 1) and S (class 2 & 3) have to be used to calculate the design, service and test limits with one of the analysis methods listed bellow:

1. elastic analysis
2. limit analysis
3. collapse load analysis
4. plastic analysis
5. shakedown analysis

The theory of failure for combining stress, stress intensity or equivalent stress, is the so called Tresca`s maximum shear stress theory and is used as proof of structural integrity to both codes ASME and KTA.

Design rules for “General Analysis of the Mechanical Behavior” are defined in Section 7 of KTA 3201.2 for Primary Circuit components and KTA 3211.2 for component of the others systems. The section 7.7 “Stress Analysis” provides the design rules, which are the same as

ASME code. It means that the design, service and test conditions and the analysis methods are the same as defined in the earlier paragraph.

3.4. Design by Rule

Design rules for component specific analysis, class 1 & 3, of ASME are defined in Subsection NB, NC and ND 3300-3600. For class 2 pressure vessels, ASME provides alternative design rules in NC-3200, in addition to those of NC-3300. In the KTA standards, KTA 3201.2 and KTA 3211.2, the design rules are defined in Sec. 8.2, Sec. 8.3, Sec. 8.4 and Sec. 8.5.

The design criteria for a specific component in ASME and KTA are quite the same.

The Table 5 gives a resume of paragraph and/or sections that have to be applied in the design based on ASME and KTA.

Table 5: ASME versus KTA equivalence

Component	CLASS 1		CLASS 2 & 3		
	NB	KTA 3201.2	NC	ND	KTA 3211.2
Vessel	NB-3300	Sec. 8.2	NB-3200	NB-3300	Sec. 8.2
Pumps	NB-3400	-	NB-3400	NB-3400	Sec. 8.3
Valves	NB-3500	Sec. 8.3	NB-3500	NB-3500	Sec. 8.4
Piping	NB-3600	Sec. 8.4	NB-3600	NB-3600	Sec. 8.5

3.5. Materials

ASME Section II provides all information for the design analysis regarding materials properties. The criteria to calculate S_m, for class 1 design, are in the TABLE 1-100 of Mandatory Appendix 1 (criteria for establishing allowable stress values for tables 1A and 1B) and to calculate S, for class 2 & 3 design, are in the TABLE 2-100(a) of Mandatory Appendix 2 (criteria for establishing allowable stress values for tables 2A and 2B) of ASME Section II, Part D [8]. The tables 1A/2A/1B/2B show the values of allowable stress even in high temperature. It is because ASME code takes into account the effects of the creep rate to determine the allowable stresses.

KTA does not have a general section dedicated to materials like ASME Section II. The regulations are not the same in the different KTA standards. For example, in KTA 3211.2, for class 1, 2 & 3 outside Primary Circuit design, the materials which are permitted are listed in KTA 3211.1. In the case of KTA 3201.2, standard for class 1 Primary Circuit design, the allowable materials are listed in KTA 3201.1. The stress intensities allowable S_m for class 1 and S for class 2 &3 are calculated with TABLE 6.6-1 of KTA 3211.2 based on the material properties, which are provided in Annex A of KTA 3211.1. KTA limits the design temperature to 400 ºC because the effects of the creep rate, but there are materials that are allowed to be used at higher temperature.

The safety factor of ASME and KTA are different for class 2 & 3. KTA S-value divides the tensile strength by 4.0 and the ASME by 3.5, as shown at the Table 6. So, the safety margins for tensile strength are 14% higher in KTA, while for yield strength is 7% higher than those of ASME. Therefore, KTA is slightly conservative compared to ASME. For class 1 components, the safety margins are similar.
The allowable stresses are chosen as the minimum values considering the conditions at Room Temperature and Above Room Temperature as shown in the Table 6.

Table 6: ASME versus KTA – allowable stresses

Strength		CLASS 1			CLASS 2 & 3		
		ASME	KTA 3211.2		ASME	KTA 3211.2	
		(NB)	ferritic	austenitic	(NC & ND)	ferritic	austenitic
Tensile	at RT	$S_T/3.0$	$R_{mRT}/3.0$	$R_{mRT}/3.0$	$S_T/3.5$	$R_{mRT}/4.0$	$R_{mRT}/4.0$
	above RT	$1.1S_TR_T\ /3.0$	$R_{mT}/2.7$	$R_{mT}/2.7$	$1.1S_TR_T\ /3.5$	-	-
Yield	at RT	$2/3\ S_y$	-	$R_{p0.2RT}/1.5$	$2/3\ S_y$	$R_{p0.2RT}/1.6$	$R_{p0.2RT}/1.6$
	above RT	$2/3\ S_yR_y$ or $0.9\ S_yR_y$	$R_{p0.2T}/1.5$	$R_{p0.2T}/1.1$ or $R_{p0.2T}/1.5$	$2/3\ S_yR_y$ or $0.9\ S_yR_y$	$R_{p0.2T}/1.6$	$R_{p0.2T}/1.1$ or $R_{p0.2T}/1.5$

4. PIPING SUPPORT DESIGN ACCORDING TO ASME & KTA

The structural integrity of a piping system is ensured by providing minimum piping wall thickness (controlling the hoop stress) and an adequate design of supports for holding the pipe in place (controlling the longitudinal stress). In a mathematical model to perform the stress analysis of a piping system every point is associated with six degrees of freedom (DOF): three translations and three rotations. Without restriction, the pipe can move and rotate in the x, y and z directions, but if the movement is not allowed, loads will arise in the restricted directions.

Piping Support is a generic designation used to describe an assembly of structural elements, which restrict one or more degrees of freedom of the piping system, resulting in loads that are transmitted to the building structure. By this approach, the type and function of the piping support are established and summarized in the Table 7.

A non-rigid piping support is a non linear type of support that restrains the movement in the downward direction and is applied to sustain the piping weight and the loads acting in the same direction. A dynamic support is a type of support that restrains only dynamic loads due to earthquakes, water hammer, relief valve discharge, etc.

Piping support can be built with several structural configurations, usually named “Piping Support Hardware”, which depends on the:

- function of the support;
- distance between the pipe and building structure;
- available space in order to arrange the structural elements of the piping support.

Table 7: Types of supports versus restricted DOF versus Function

Restricted DOF	TYPE	Function / Devices
1	rigid	hanger, restraint, strut, guide and stop
	non-rigid	variable spring, constant spring
	dynamic	snubber
2	rigid	(hanger or restraint or strut) + guide
		double guide
3	rigid	(hanger or restraint or strut) + guide + stop
		double guide + stop
	dynamic	viscodamper
6	rigid	anchor (fixed point)

A piping support hardware is an assembly of mechanical parts such as beams, columns, brace, connectors, pins, bolts, nuts and are designed taking into account the conditions described in the previous paragraph and is connected to the building structure.

Typical piping supports hardware arrangements usually applied in nuclear power plants designed by ASME or KTA code are showed in the Fig. 1 and Fig. 2.

4.1. Jurisdictional Boundary

The jurisdictional boundaries between pipe x pipe support hardware and pipe support hardware x building structures are treated in a similar way according to ASME and KTA code. These are shown in Fig. 1 and Fig. 2 and summarized in Table 8:

Table 8: Definition of jurisdictional boundary

Boundary	ASME	KTA
Pipe x Support	NF-1130 and requirements of NB-1132, NC-1132 or ND-1132 for piping class 1, 2 or 3	KTA 3201.2 section 8.5.1.2 and KTA 3211.2 item 8.6.2 for non-integral areas of a support applied to primary system and others systems
Support x Building Structure	NF-1130 and requirements of concrete or metallic building structure	KTA 3201.2 item 8.5.1.2 and KTA 3211.2 item 8.6.2 for non-integral areas of a support and requirements of concrete or metallic building structure

Integral area of a support is that part rigidly connected to the pipe. A lug, for instance, is an integral area of the support and has to be analyzed with the pipe.

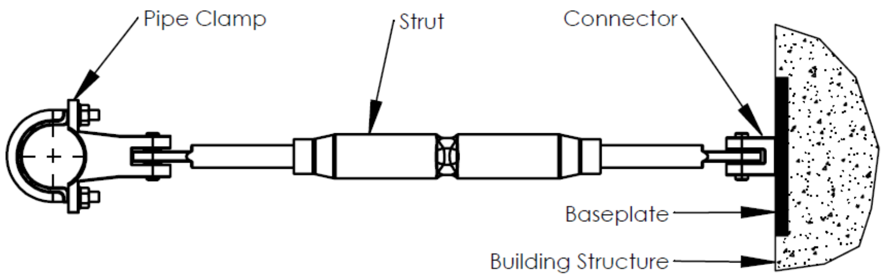

Figure 1: Jurisdictional boundary versus function – one-directional type

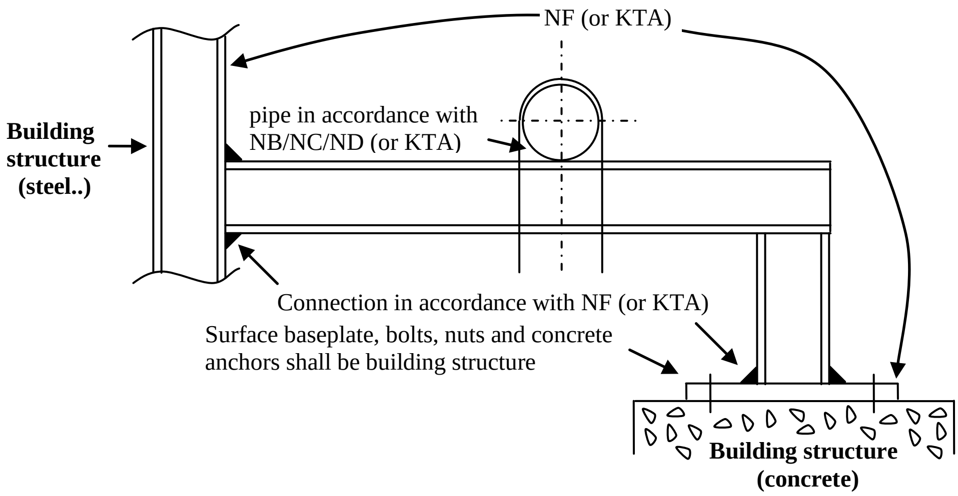

Figure 2: Jurisdictional boundary versus function - two-directional type

4.2. Support Design

The mechanical design of any structure, for instance a support, in a Nuclear Power Plant, performed with ASME or KTA, establishes procedures and rules meeting the safety of the plant. It means that "the safety criteria", i.e., the Component Stability, the Structural Integrity and the Functional Capability, are established as defense in depth by ASME and KTA.

The ASME III NF-1200 classifies the supports taking into account the function, the type of structure to be supported and the feasibility of series productions, like:

- **plate and shell type supports** – a support such as a skirt or saddle fabricated from plate and shell elements and normally applied in components;
- **linear type support** – a support acting only in one degree of freedom, such as tension and compression struts, beams and columns subjected to bending, trusses, frames, arches and cables;
- **standard supports** – supports described in MSS-SP-58 [23], which was developed and approved by Manufactures Standardization Society of the Valve and Fittings industry, and some of them is listed :
    - o rigid supports consisting of anchors, guides, restraints, rolling or sliding supports and rod-type hangers;

- constant and variable type spring hangers;
- snubbers;
- sway braces and vibration dampeners;
- structural attachments such as ears, shoes, lugs, rings, clamps, slings, straps and clevises.

A stress analysis of supports, according to NCA-3550 [2] and NF-3133, including their mechanical parts, has to be performed as well as KTA establishes the proof of integrity by calculation, considering the design of supports according to the system they belong. The design of a piping support is performed in both ASME NF and KTA with one of the three design procedures: Design by Analysis, Experimental Stress Analysis or Load Rating. Piping support hardware arrangement to support a safety class 1 piping system must attend the requirements of NF-3320 and in case of number of cyclic loading > 20.000, a fatigue analysis, as described in NF-3330, must be performed. The KTA code demands also a fatigue analysis as shown in Table 9.

Table 9: KTA code: stress analysis versus fatigue analysis

Primary Circuit	KTA-3205.1	Stress analysis	Section 5(e)
		Fatigue analysis	Section 7.3.7
Others systems	KTA-3205.2	Stress analysis	Section 5.1(a)
		Fatigue analysis	Section 5.1(4)
Standard supports	KTA-3205.3	Stress analysis	Section 3.3 (l) & 5.2
		Fatigue analysis	Section 5.1

The fatigue analysis of a piping support is performed applying the transients of level A and B with the procedure of NF-3330 and the transients of loading level H and HZ of KTA, and it is the same procedure applied to analyze a piping system. The methods to perform the fatigue analysis in both codes are “elastic fatigue analysis” and “simplified elastic plastic fatigue analysis”. In KTA 3201.2, section 7.8.3 and 7.8.4, the two methods are described.

4.3. Support and Piping Design

The external area of the piping and the support structure hardware at the restrained point touch each other and, because of this, any aspects of the direct contact between surfaces and design parameters of piping and supports structure has to be analyzed. This way, in a structural viewpoint, we outline the most relevant parameters, such as stiffness, friction forces, gap and localized pipe stress of the design applied to the contact surface between piping and supports.

4.3.1. Stiffness

Normally, a stress analysis of a pipeline is performed and the resulting loads on pipe restrictions are forwarded to a team which develops a support design. This independent behavior between a piping design and support design is grounded in the assumption that the support has a quasi rigid behavior.

According to WRC-353 [24], this decoupling is valid since:

- piping support hardware stiffness in the direction of load: $K_{\text{sup}} \geq 200 \; \frac{E\,I}{L^3}$
- maximum deflection of 1.6 mm in the direction of load, for combining loads in the abnormal operation service (Level B).

4.3.2. Friction forces

Frictions forces are generated by the movement of the piping system, between the pipe and any piping support hardware, during heat up and cool down of the plant operation, in the unrestrained directions. It is recommended to include theses forces in support design, in the combination deadweight and thermal loading.

The friction forces are computed as: $F_{friction} = C \times N$

4.3.3. Gaps

The definition of the gaps is important to improve the distribution of the loads of the contact area and avoid stress concentration at any point at the contact area between pipe and support. A total gap recommended to a frame type support design in the cold conditions is 3.2 mm in the direction of load. For supports located near rotating equipment nozzle or for supports type “stop” near to “relief valves” the gap is limited to 1.6 mm. Gaps recommended by [24]. This prescribed gap must be enough to assure that the pipe hot conditions allow free radial expansion of the pipe.

4.3.4. Localized pipe stress

Any piping attachment to transmit load or restrict motion may cause, in most case, some degree of localized stress in the pipe wall. As a general rule, clamps, U-bolts and bearing on structural members produce stresses in the pipe and they are classified as secondary stresses in nature and, according to WRC-353 [24], can be neglected. Others type of support which function is, for instance, to restrain an axial movement or to impose an anchor in the middle of a straight pipe, produces primary stresses. A special care must be taken when applying clamps and U-bolts in thin-walled piping (Schedule 10) because an excessive installation torque may cause high localized stresses and excessive deformation.

4.4. Loads Combinations and Limits

The “Service Limit” and “Loading Level” combination, defined in ASME and KTA respectively, are the way that these codes correlate the loads and combinations with the operational conditions of the plant. The Table 10 shows the relationship among the “Service Limit”, “Loading Level” and the design criteria usually inherent at the design of a nuclear power plant.

Table 10: Service limit versus loading level x design criteria

Service Limit	Loading Level	Design Criteria
A / B	H / HZ	Fully suitable for intended use
C	HS1	Fulfillment of stability requirements and maintenance of required functions, limited deformation, generally re-usable
D	HS2/HS3	Gross plastic deformation permitted, re-use not intended

The combinations of the loads, according to ASME and KTA codes, describing the load cases that normally arise in the design of a nuclear power plant, are shown in Table 11.

Table 11: Service limit (ASME) versus loading level (KTA)

Service Limit	Loading Level	Loads combination	OBS
Normal (A)	H	Deadweight	NF & KTA
		Deadweight + thermal	
Upset (B)	HZ	Normal + relief valve discharge	NF & KTA
		Normal + earthquake (OBE) + relief valve discharge	NF
		Normal + earthquake (DBE*1) + relief valve discharge	KTA
		Normal + water hammer	NF & KTA
Emergency (C)	HS1	Normal + earthquake (SSE) + relief valve discharge	NF
		Normal + earthquake (DBE*1) + relief valve discharge	KTA
Faulted (D)	HS2/HS3	Normal + earthquake (SSE) + pipe rupture	NF & KTA

***1)** – KTA 2201.4 [9]

The allowable stress for normal, shear, bending, combined and equivalent stresses to NF linear type supports class 1, 2 and 3, as well as KTA supports are summarized in Table 12.

Table 12: Allowable stresses for linear type support design – ASME & KTA

STRESS	ASME-NF	KTA
Normal (tension)	0.60 Sy	0.66 Sy
Shear	0.40 Sy	0.38 Sy
Bending	0.66 Sy	0.66 Sy
Bearing	0.90 Sy	1.17 Sy
Combined	$\frac{fa}{Ft}+\frac{fby}{Fby}+\frac{fbz}{Fbz}\leq 1.0$	-
Equivalent	-	$\sqrt{\sigma_{normal}^2 + 3\,x\,\tau_{shear}^2} \leq 0.77\,Sy$

The applied service limits (A, B, C and D) and loading levels (H, HZ and HS) are defined as a function of allowable stress, Table NF-3623(b)-1, NF-3225-1 and appendix F-1334 for ASME-NF, and section 7.2.7.1 and 7.2.5 of KTA 3205.1. The Table 13 shows all these limits for a linear type support.

Table 13: Factors to the limits for linear type supports

STRESS	ASME - NF				KTA		
	Design	Level A	Level B	Level D *3)	H	HZ	HS
Normal (tension)	1.0	1.0	1.33 *1)	1.86 *4)	1.0	1.15	1.5
Shear	1.0	1.0	1.33 *2)	1.86 *5)	1.0	1.15	1.5
Bending	1.0	1.0	1.33	1.86	1.0	1.15	1.5
Equivalent	-	-	-	-	1.0	1.04	1.2

***1) -** not exceed (1,5*Sh); ***2) –** not exceed (0,3*Sy, Sy from weld material) or (0,42*Su, Su from base material); ***3) -** as item **F-1334.4(a)** from **appendix F**, adjust factor **"K"** for: fragile or ductile steel ***4) -** not exceed [1,2*Sy] and [0,7*Su]; ***5) -** not exceed [0,72*Sy] and [0,42*Su]

The allowable stress for an elastic fatigue analysis of a piping support is defined by KTA 3201.2 as 3 x Sm. The ASME code outlines in NF-3330 the procedure to define the allowable stresses, as showed in Table 14.

Table 14: ASME procedure to define allowable stresses

Loading condition	Geometry	Stress category	Allowable stresses
Table NF-3332.2-1	Figure NF-3332.3-1	Table NF-3332.3-1	Table NF-3332.2-1

5. EXAMPLE

The purpose of this section of the paper is to present a structural analysis of a piping support according to the rules of NF and KTA in order to point out the differences between the codes.

Fig. 3 shows the three dimensional and the side view of a typical piping support hardware, which provides supporting to a class 2 DN80 piping system.

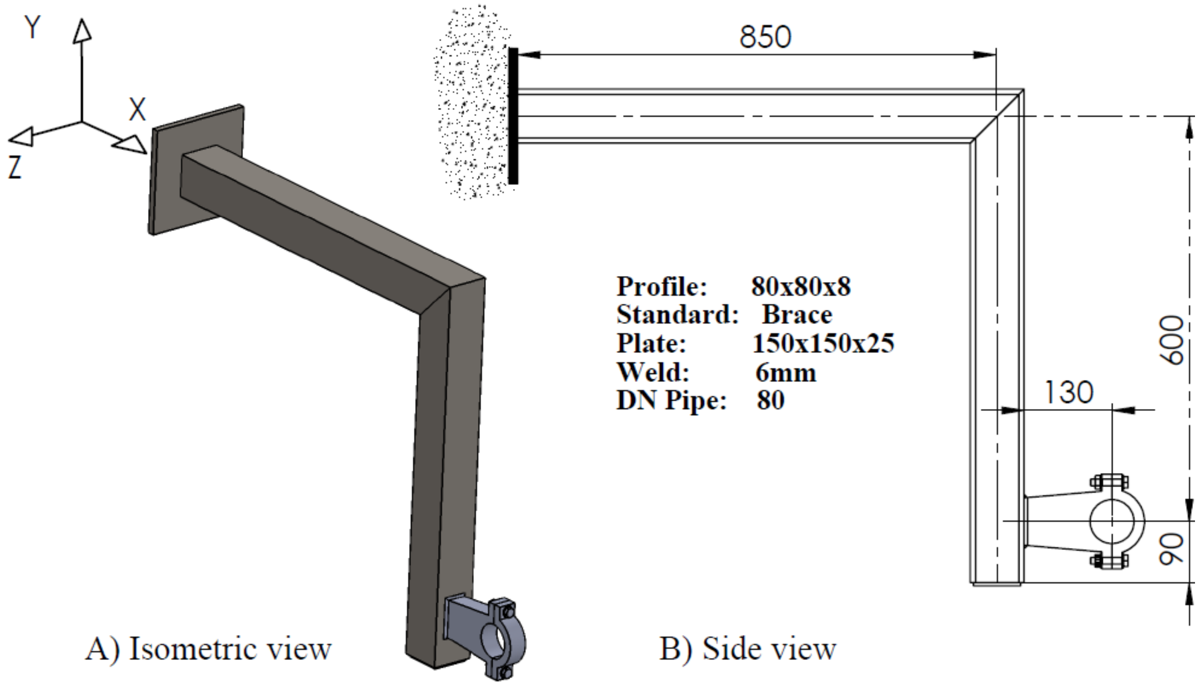

Figure 3: Typical piping support hardware

The main dimensions are shown in Fig. 3. Materials properties of piping support structure used in both codes are presented in Table 15:

Table 15: Materials properties – ASME x KTA

Material	Code	T (ºC)	ν	α (mm/mºC)	E (MPa)	Su (MPa)	Sy (MPa)	Sh (MPa)
SA36	ASME	150	0,3	1,2 E-05	195000	400	250	114
Rst37.2	KTA	145	0,3	1,2 E-05	205800	340	235	-

Table 16 shows load cases and typical values to piping stress analysis. The same value of OBE load case from ASME code was adopted to load case DBE in KTA.

Table 16: Loads – ASME x KTA

Load case	ASME			KTA		
	Fx(N)	Fy(N)	Fz(N)	Fx(N)	Fy(N)	Fz(N)
Dead Weight (W)	104	2	-	104	2	-
Thermal Expansion (T)	185	280	-	185	280	-
Operational Basis Earthquake (OBE)	±35	±20	-	-	-	-
Design Basis Earthquake (DBE)	-	-		±35	±20	
Shutdown Safety Earthquake (SSE)	±55	±30	-	±55	±30	-

5.1. Structural Model

The stress analysis of the piping support hardware shown in Fig. 3 is performed developing a structural model of the support with the finite element computer software ANSYS [25]. The finite element "SOLID95" was used to model the support geometry, resulting in twenty nodes with three degree of freedom by node (displacements: Ux, Uy and Uz). The generated mesh of the structural model can be seen in Fig. 4.

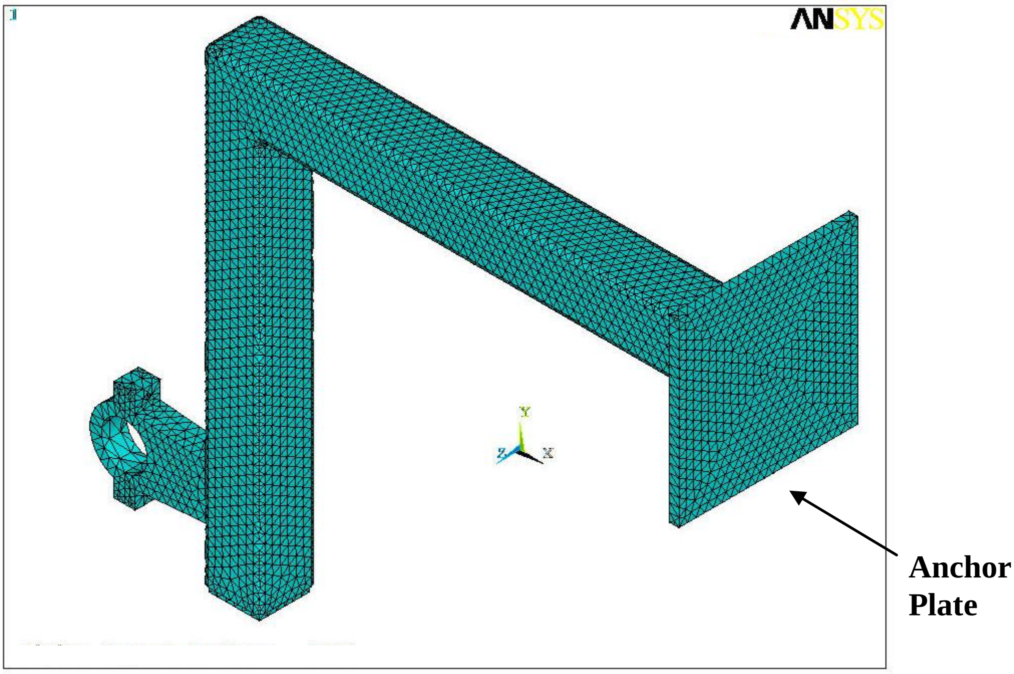

Figure 4: Piping support hardware – finite element mesh

The displacements in directions X, Y and Z were restricted in the anchor plate that connects the piping support hardware to the building structure in order to represent the restraining boundary conditions. Loads resulting from the load cases combinations in the connection of the piping support hardware with the pipe were applied, according to the Table 17. The values of the forces in direction Z are calculated as: $Fz = 0.3\sqrt{Fx^2 + Fy^2}$.

Table 17: Load combinations– ASME & KTA

Service Level	Load case combination	Fx (N)		Fy (N)		Fz (N)	
		max.	min.	max.	min.	max.	min.
Design / Level A	W / W+ T	289	104	282	2	121	-
Level B	W±OBE : W+T±OBE	324	69	302	-18	133	-
Level C	W±SSE : W+T±DBE	-	-	-	-	-	-
Level D	W±SSE / W+T±SSE	344	49	312	-28	139	-

Once the structural model is built, the boundary conditions and the load cases are defined, then a numerical simulation with the computer program ANSYS can be performed.

5.2. Results

The results of the computational simulation to normal, bending, shear, combined, equivalent stresses and the stress limits of the used material steel SA-36 (NF) and Rst 37.2 (KTA) are summarized in Table 18.

Table 18: Stress results and combinations – ASME & KTA (MPa)

NF (KTA)		Normal		Bending		Shear		Combined / Equivalent	
		Calc	Limit	Calc	Limit	Calc	Limit	Calc	Limit
Nível A (H)	NF	21.5	150,0	13.4	165,0	9.3	100,0	0.22	≤ 1.0
	KTA		155,0		165,0		89,0	26.8	180,0 MPa
Nível B (HZ)	NF	23.0	171,0	14.6	219,0	10.2	133,0	0.20	≤ 1.0
	KTA		178,0		189,0		102,4	29.0	187,0 MPa
Nível D (HS)	NF	23.3	279,0	15.3	306,0	10.7	168,0	0.14	≤ 1.0
	KTA		232.5		247,5		133,5	30.1	216,0 MPa

The resulting stresses are below the recommended limits of ASME-NF and KTA.

It can be noticed in Table 18, that the allowable limits for the materials SA-36 (NF) and Rst 37.2 (KTA), commonly employed in piping hardware supports in USA and Germany, show meaningful differences at the fault condition, level D of NF and level HS of KTA.

The maximum deflection in the load direction is 0.5 mm for upset condition and it is smaller than 1.6 mm, as suggested by WRC-353 [24].

The stiffness of the piping hardware support was:

$$\begin{cases} \text{Axis X} \Rightarrow 1.4 \times 10^6 \text{ N/m} \\ \text{Axis Y} \Rightarrow 1.5 \times 10^6 \text{ N/m} \\ \text{Axis Z} \Rightarrow 0.6 \times 10^6 \text{ N/m} \end{cases}$$

6. CONCLUSIONS

The design of a piping support applicable to nuclear power plants can be developed according to ASME-NF, as done to the ANGRA1 NPP or according to KTA, partially adopted, to the ANGRA2 NPP in Brasil. The main features of both codes were assessed and it can be addressed that:

- Rules for calculation and recommendations are quite similar in both codes;
- The used materials are different in both codes. They have, in general, different ultimate and yielding limits;
- The allowable limits for design condition, operational conditions and tests prescribed in KTA and NF are relatively closed to each other, except for faulted condition, which, in this case, is quite different.

- The layout of piping support hardware depends on the feasibility in the building, but the mechanical parts are quite different:
    - Structural elements cross sections are different (AISC & DIN), they have different geometry and materials. In ANGRA1 NPP the profile "I" is commonly applied to the supports while in ANGRA2 NPP the profile "□" is usually applied;
    - Anchor plates are different;
    - Standard mechanical parts like strut, sway braces, etc, are different;

It is important to mention that, despite the differences, the checked configurations developed using both approaches result in designs that attend the requirements regarding the component stability, the structural integrity and the functional capability.

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