BOA Group

SEVENTH FRAMEWORK PROGRAMME

Seismic-**I**nitiated events risk mitigation in **LE**ad –cooled **R**eactors

SILER

How to isolate an NPP – interface components:

Metal Bellows Expansion joints

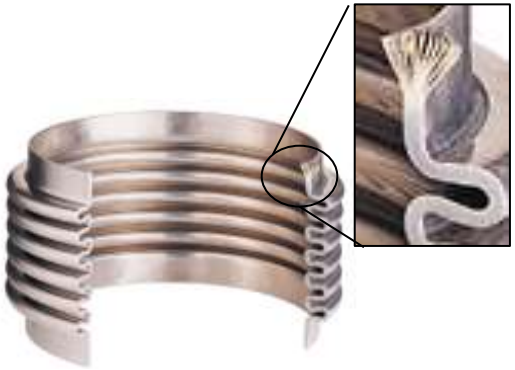
Your Flexible Solutions Partner

What are Metal Bellows Expansion Joints

Metal Bellows Expansion joints are corrugated, **leak proof** tubes that are capable to **withstanding pressure** at cryogenic as well as elevated temperatures and that are **flexible** to compensate movements or vibration.

The key element is the **metal bellows** which comes in various shapes, number of layers (plies), and materials.

Single ply “U” shaped



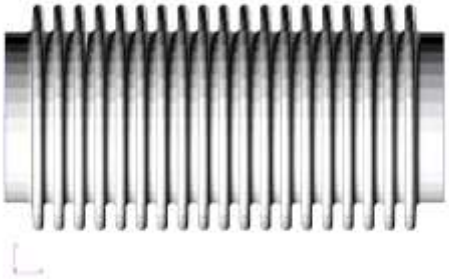
Multy ply “U” shaped

2 – ply testable

Single ply toroid-(Omega) shaped

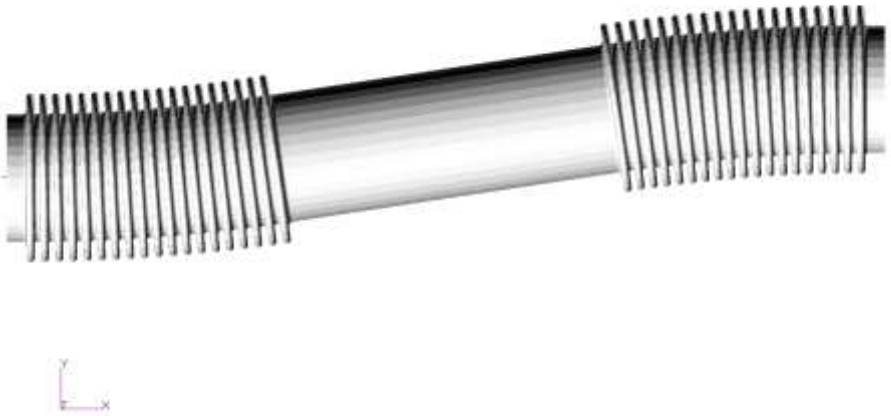
How do expansion joints (metal bellows) work (Movement compensation in one plane)

Axial movement



Angular rotation

Lateral movement

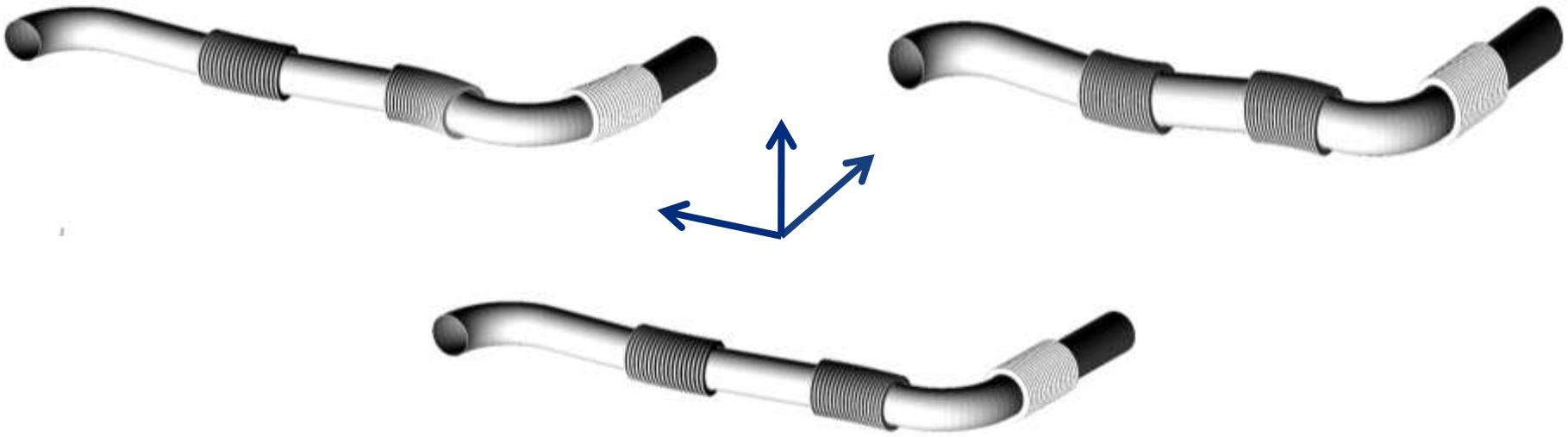


Movement compensation in 2 planes

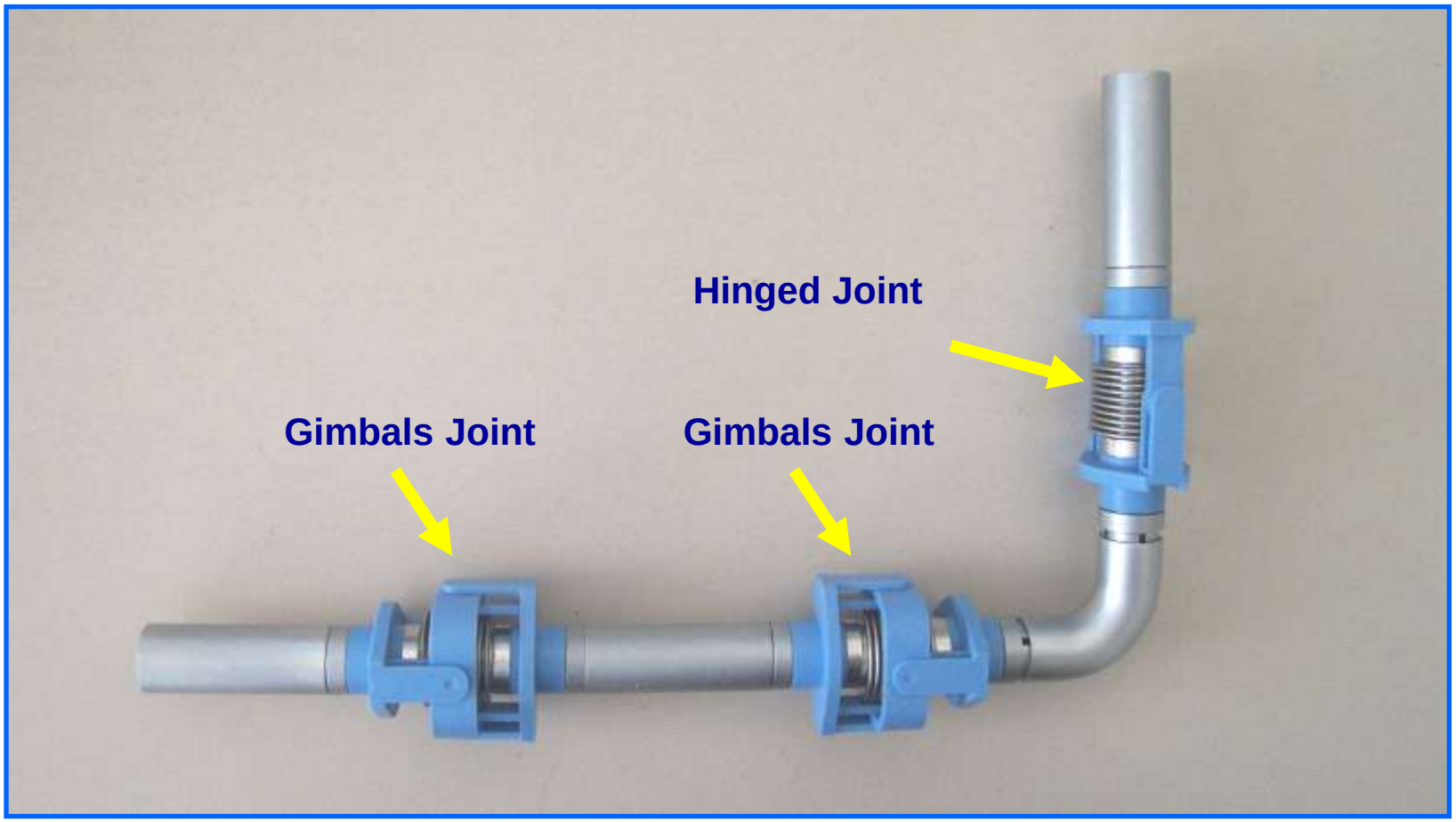
Cardanic rotation

Universal

Movement compensation in 3 planes (typical expansion joint system)



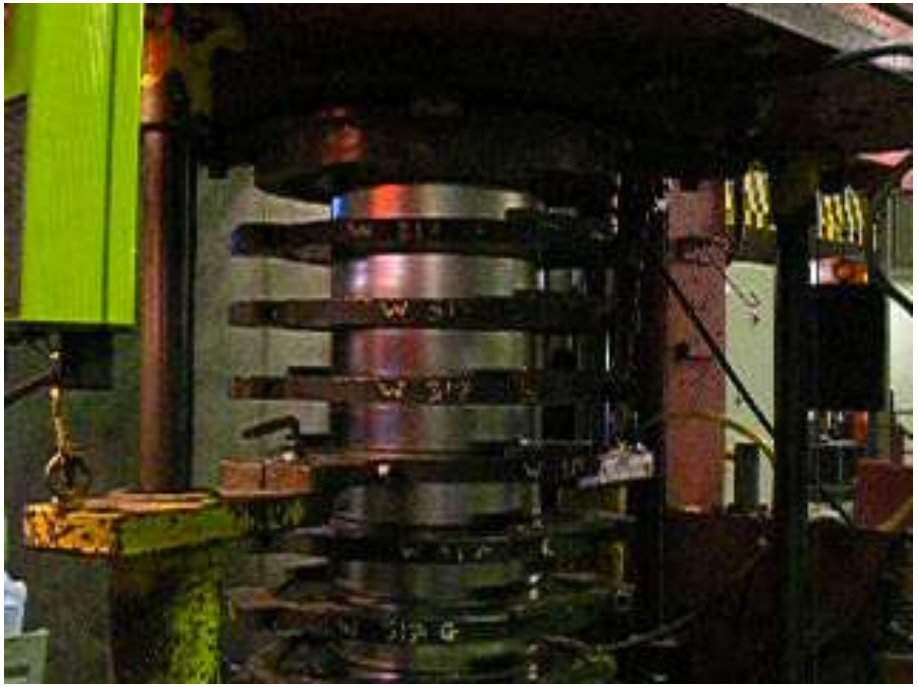
Typical 3 Pin Gimbals (cardanic) system



Bellows manufacturing method

The BOA Group primarily utilizes **hydraulic forming** because :

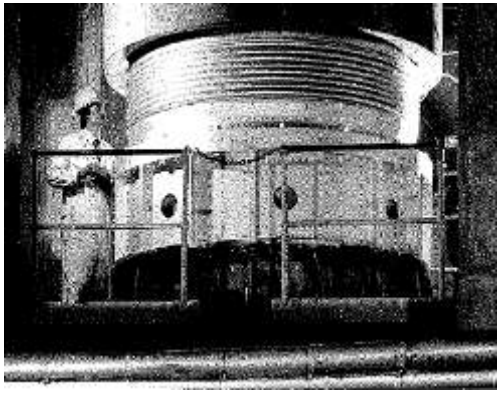
- It offers the **most homogenous** form of metal forming
- It guarantees the **highest precision**
- It causes the **least amount of cold hardening**

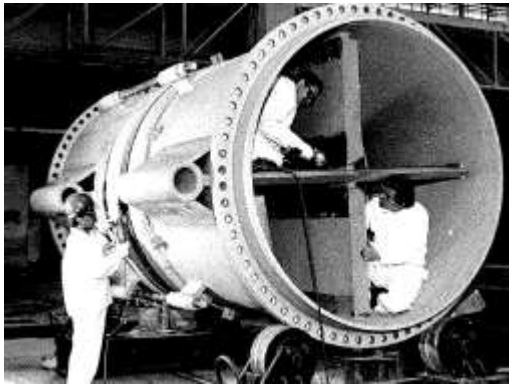


Diameters range from 25 mm to 7000 mm and larger

Previous expansion joint installations in NPP

In primary loops of Magnox reactors such as NPS Sizewell A, Bradwell, Dungeness A, Tokai Mura1and Chinon 3.

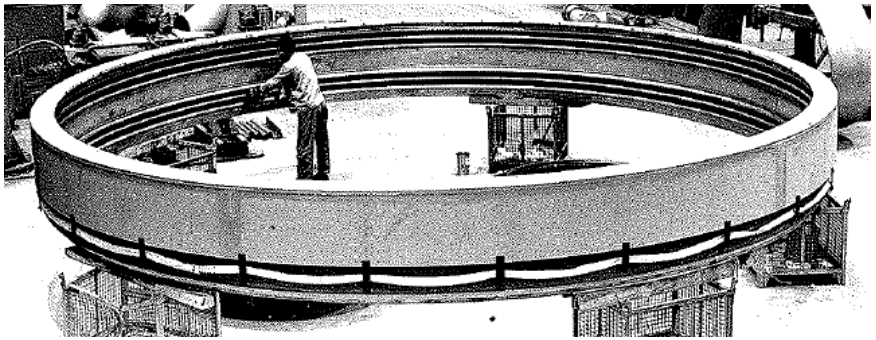




Installed to primarily compensate for thermal expansion in piping system.
Design pressure: 20 bar
Design temperature: approx. 450° C

Previous expansion joint installations in NPP

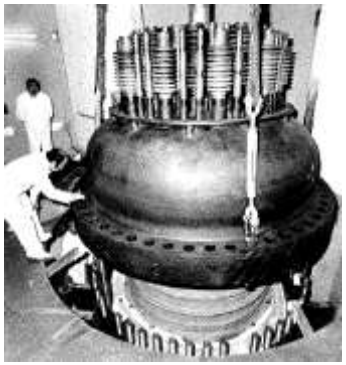
Refuelling systems such as NPS Leipstadt



Installed to primarily compensate for thermal expansion and also for movements which would be incurred in case of aircraft impact.

Previous expansion joint installations in NPP

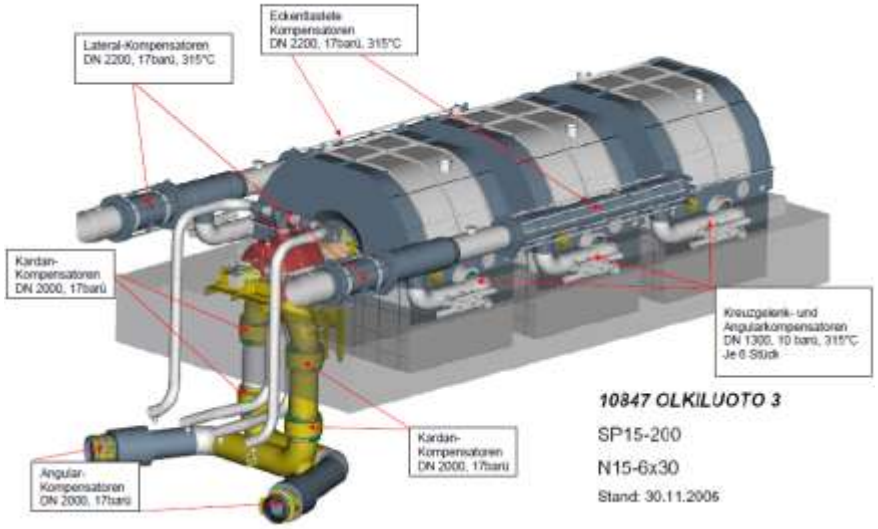
In Containment penetrations of practically all European PWR & LWR Reactor penetration.



Installed to primarily compensate for thermal expansion of piping and also for movements which would be incurred in case of aircraft impact.
Design pressure: low
Design temperature: low

Previous expansion joint installations in NPP

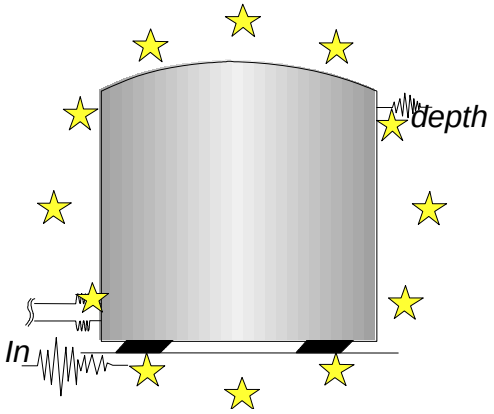
In various steam and extraction piping systems of the steam turbine of OLKILUOTO III



Installed to compensate for thermal expansion.

Previous studies on seismic applications

Indepth Project

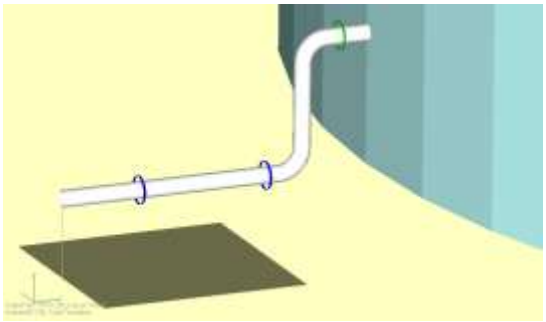
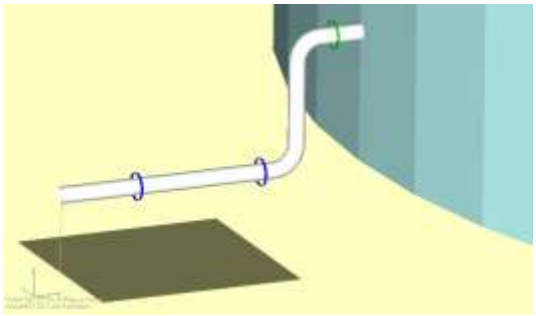
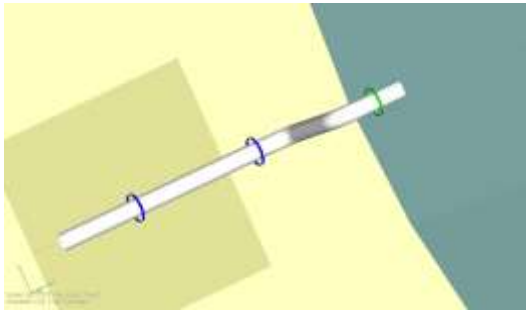
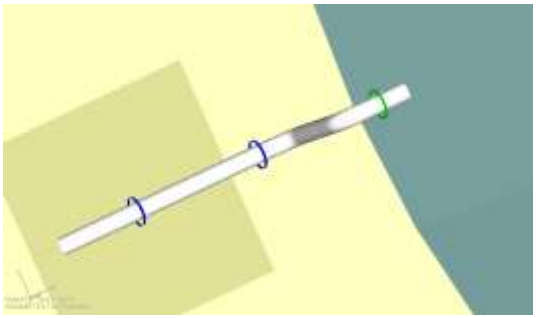


Indepth Project

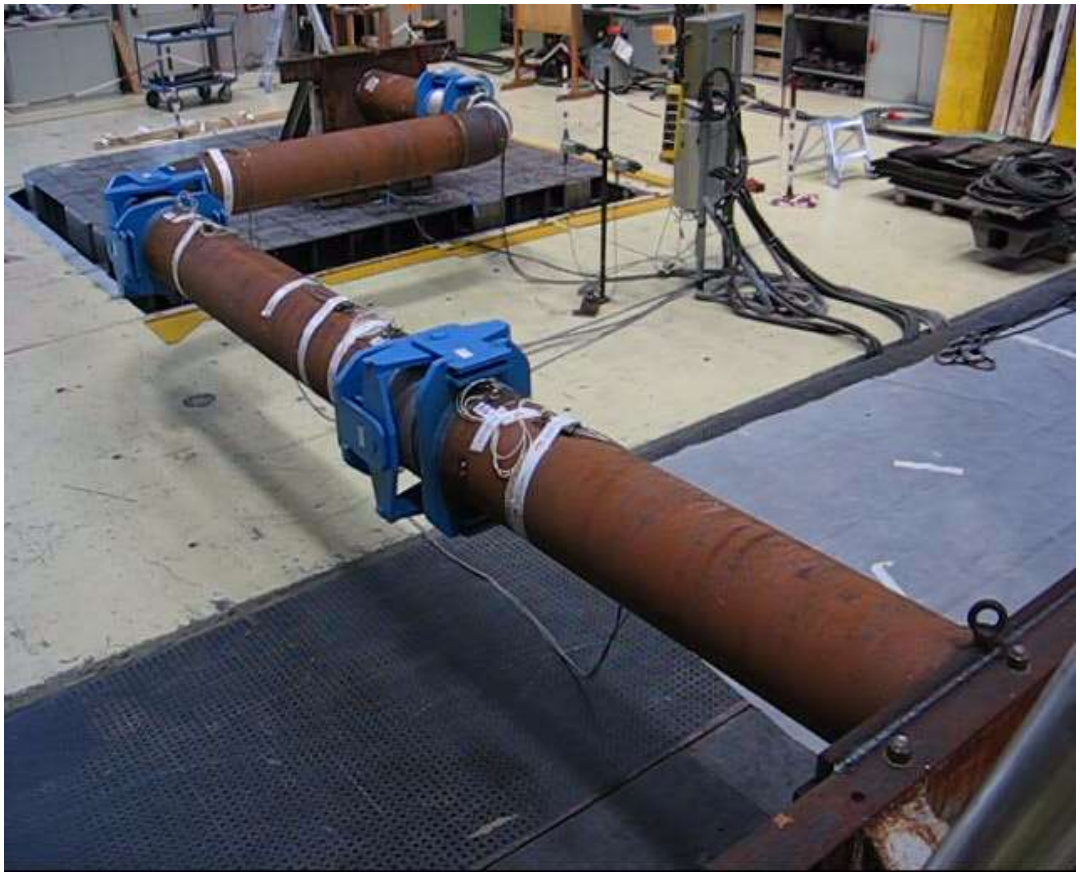
Development of INnovative DEvices for Seismic Protection of PeTrocHemical Facilities

.....especially storage tanks .

Previous studies on seismic applications-simulation

	Non isolated	Isolated
Tank P 5151		
Axial displacement		
Transversal displacement		

Previous studies on seismic applications- validation



Dynamic tests were performed at CESI on a full scale (DN 300mm) 3-pin Z system in order to validate calculated data.

Test results are published in CESI Report and reach the conclusion that:

...practically no excitation reached the second end of the pipe.

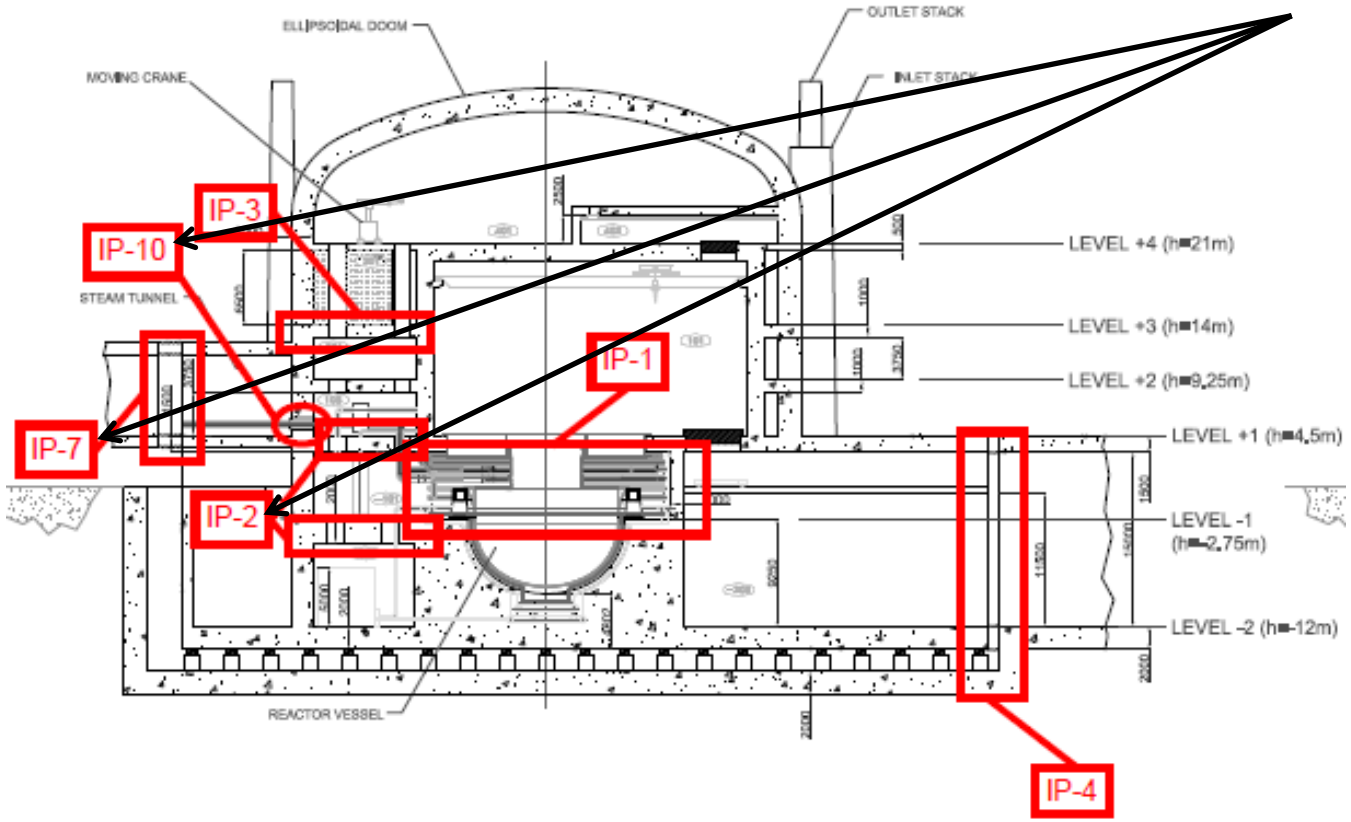
...the three joints completely filtered and absorbed the input motion.

Interface points on LFR (extract)

Item	ID	Isolated elements	Interface Description	Level
Concrete vessel support	IP #1	Reactor Building & Reactor Buildings plus Surrounding Area	The reactor vessel is lying on a big solid reinforced concrete structure. A circular steel support anchored to the concrete bears the vessel.	L+1
Main steam and feed water pipelines	IP #2	Reactor Building & Reactor Buildings plus Surrounding Area	Joint at the main steam and feed water pipelines pass through a concrete slab at Level +1	L+1
DHR elevated pools	IP #3	Reactor Building & Reactor Buildings plus Surrounding Area	At level +3 there are 4 DHR pools.	L+3
Equipment exit tunnel	IP #4	Reactor Building & Reactor Buildings plus Surrounding Area	Joint at the Equipment tunnel that connects the Reactor Building to the Radwaste Building. The tunnel is split in two parts, one belonging to the Reactor Building and the other to the Radwaste building.	L-2 L-1
Spent fuel hatch	IP #5	Reactor Building & Reactor Buildings plus Surrounding Area	Joint at the Spent Fuel hatch that connects the Reactor Building to the Radwaste Building. The tunnel is split in two parts, one belonging to the Reactor Building and the other to the Radwaste building.	L-2 L-1
Fresh fuel hatch	IP #6	Reactor Building & Reactor Buildings plus Surrounding Area	Joint at the Fresh Fuel hatch that connects the Reactor Building to the Fuel Building. The tunnel is split in two parts, one belonging to the Reactor Building and the other to the Fuel building.	L-2 L-1
Main steam and feed water pipelines	IP #7	Reactor Building & Reactor Buildings plus Surrounding Area	Joint at the main steam and feed water pipelines tunnel that connects the Reactor Building to the Turbine Building.	L+1
Pipe connections to DHR-2 external pools	IP #8	Reactor Building Alone	Pipe connecting the DHR-2 external pools to the reactor vessel pass through the walls of the Reactor Building.	L+1

Interface points on LFR

Main-steam
&
Feed -water



Basic design requirements

Main-steam piping:

- Pipesize: DN 400 o.D. 406,4 Sched. 120
- Pipe material: SA 335 Gr. P 11
- Operating pressure: 180 Bar
- Operating temperature: 450° C
- Flow velocity: 50,89 m/sec

Feed-water piping:

- Pipesize: DN 400 o.D. 406,4 Sched. 120
- Pipe material: SA 335 Gr. P 11
- Operating pressure: 200 Bar
- Operating temperature: 335° C
- Flow velocity: 7,33 m/sec

General requirement:

- Displacement (design seismic movement): + / - 700 mm
- Displacement (beyond design) + / - 900 mm

The **SILER** challenge
(What differentiates SILER from previous applications in NPP?)

- Extreme pressures……..up to 180 bar, 200 bar respectively
- Relatively high temperatures ……up to 450° C
- Extreme displacements……..+ / -700mm, + / - 900 mm resp.

The **SILER** challenge (Major criteria)

- **Suitable bellows material**
  - Sufficient strength at design temperature to retain pressure
  - Sufficient ductility to cope with dynamic loads
  - Suitable chemical properties to allow welding
  - Sufficient elongation to allow forming
  - General acceptance for use in NPP
- **Forming capability**
  - Sufficient capacity of hydro-former
- **Sufficient flexibility**
  - Sufficient angular rotation to compensate for the extreme movements within the available space

Preliminary Design Analysis

Data sheet

General informations

Customer	SFZ
Quotation / Item :	NA_SILER_DN400_180_B_A
Nominal Diameter :	400
Customer ref. :	-
PED CE – Equipment type :	-
PED CE – Fluid type :	-
PED CE – Fluid group :	-
PED CE – Considered Volume (l)	-
PED CE – Categorie	-
Notice Language * :	English
Construction code	-

Calculation data :	A	B	C	D
Design pressure : Bars	200,0	180,0	200,0	-
Test pressure : Bars				
Max Design temp : Deg°C	335	450	335	-
Min Design temp : Deg°C	-10	-10	-10	-
Movement : Axial comp. mm	-	-	12,0	-
Ext.	-	-	-	-
Lateral mm	-	-	-	-
	-	-	-	-
Angular °	3,0	3,0	-	-
	-	-	-	-
N cycles guaranteed :	1000	1000	1000	-
Stiffness : Axial N/mm	6242	5916	6242	-
Lateral N/mm	40176	38394	40176	-
Angular N/m/°	3255	3110	3255	-
Pressure thrust (Design P) T	375	338	375	-

Bellow

Calculation code :	EJMA
Category / Weld joint factor :	1,00
Material :	SB 443 N06625
N. bellows : x N. convolutions	1 x 3
N. plies : x Thickness :	1 x 3,0

Connection	Welding end		Flange :	
Delivered by :	SFZ			
Type (NP) :	-	-	-	-
Material :	SB 443 N06625		-	-
External diameter : mm	440	440	-	-
Thickness : mm	30	30	-	-
Chamfer	-	-	-	-

Accessories

Shipping bars	-	Tie rods	-	Stroke ind.	-
Internal sleeve	-	Hinge	-		
Shroud	-	Gimbal	-		

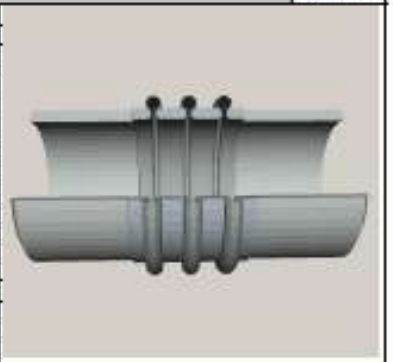
Quality Control and Manufacturer Data Report Documents

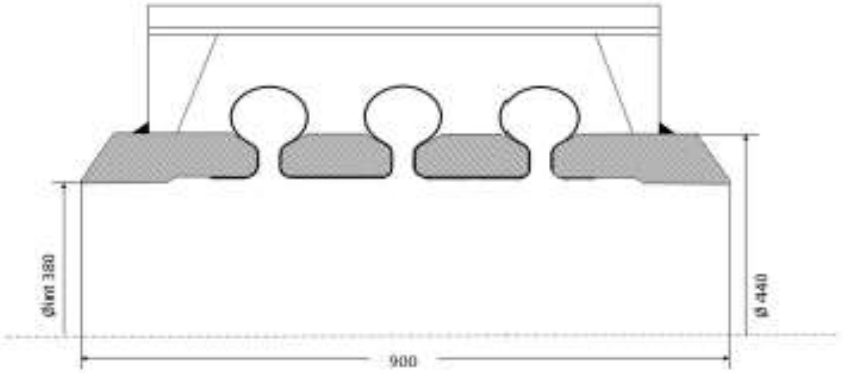
(I : Intervention A : Approval C : Customer / DN : Organism / X : Applicable)

Drawings	-	Impact Test	-
Calculation sheet	-	Temperature Tensile Te	-
Quality plan	-	US	-
Welding book	-	Heat treatment :	-
PQR + WPQ	-	Dye penetrant test **	-
WPS	-	Hellium test	-
Bellow material certificate	-	P.M.I.	-
Connection material certif.	-	Hardness	-
Test coupon	-	Micro sand blasting	-
Longi. Bellow seams Xray	-	Pressure test	-
Longi. W.E. seams Xray	-	Inspection	-
Circumf. seams Xray	-	Std. Painting	-
		Plate	-

Estimate dimension (for shipping)

Max. external Diam. :	mm	550
Min internal Diam. :	mm	380
Approximative length	mm	900
Estimate weight :	Kgrs	250



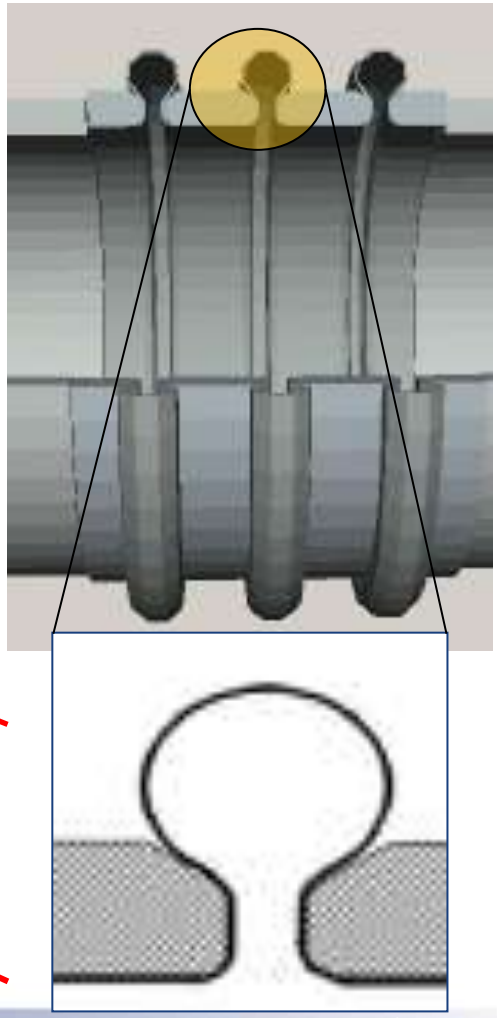


Made by	Date	Number	Quantity	Principle sketch
max.michotti	04/05/2012	FP_SILER_DN400 rev 180_B_A	1	** Except bellow longi. Weld The customer guarantees the compatibility of the material with the fluid and its by-products

SFZ
8, rue des Frères LUMIERE, F-69680 CHASSIEU, France
Tel : (33) 472 47 02 00 , Fax : (33) 472 47 02 01,
E-mail : info@sfz.fr

Preliminary Design Analysis

Calculation data :			A	B	C	D
Design pressure :		Bars	200,0	180,0	200,0	-
Test pressure :		Bars	-			
Max Design temp :		Deg C	335	450	335	-
Min Design temp :		Deg C	-10	-10	-10	-
Movement :	Axial comp.	mm	-	-	12,0	-
	Ext.		-	-	-	-
	Lateral	mm	-	-	-	-
			-	-	-	-
	Angular	°	3,0	3,0	-	-
			-	-	-	-
N cycles guaranteed :			1000	1000	1000	-
Stiffness :	Axial	N/mm	6242	5965	6242	-
	Lateral	N/mm	40176	38394	40176	-
	Angular	Nm/°	3255	3110	3255	-
Pressure thrust (Design P) :		T	375	338	375	-
Bellow						
Calculation code :			EJMA			
Category / Weld joint factor :			1,00			
Material :			SB 443 N06625			
N. bellows: x N. convolutions			1 x 3			
N. plies : x Thickness :			1 x 3,0			



Preliminary conclusion

- Inconel 625(LCF) provides sufficient strength to withstanding the required operating pressures at the applicable operating temperatures
- Subject bellows provide sufficient flexibility to allow an angular rotation to the magnitude of approximately 3 degrees.
- The bellows material provides sufficient elongation to permit the forming of the desired toroid bellows profile
- Subject profile can be formed with current hydraulic press.

Next steps

- Refine bellows profile to optimize pressure / displacement capability
- Verify compliance with applicable codes
- Identify hardware requirements in consideration of pipe routing and permissible parameters at the connecting points of the systems.
- Create expansion joint (-system) model to run simulation of seismic event
- Manufacture prototype for dynamic testing

Thank you for your attention