framatome

Thermal Sleeve Wear

Enhance the safety of your plant and extend the lifetime of its reactor vessel head with Framatome qualified and field-proven solutions

Your performance
is **our** everyday **commitment**

Challenge

In the last few years, an increasing number of industry events have revealed thermal sleeve wear issues as a result of flow-induced vibrations. Thermal sleeve flange wear is evidenced by a lowering of the thermal sleeve relative to the rest of the closure head. In certain cases, wear has led to the thermal sleeve flange interfering with movement of the control rod drive mechanism (CRDM) and **ultimately failure of the thermal sleeve.**

Thermal Sleeve Events


French plant


U.S. plant


French plant

Framatome approach:
The right fix at the right time

Framatome thermal sleeve maintenance solutions enable plant operators to manage wear issues with tailored options for replacement and mitigation, while providing a predictable outage schedule and significant cost savings.

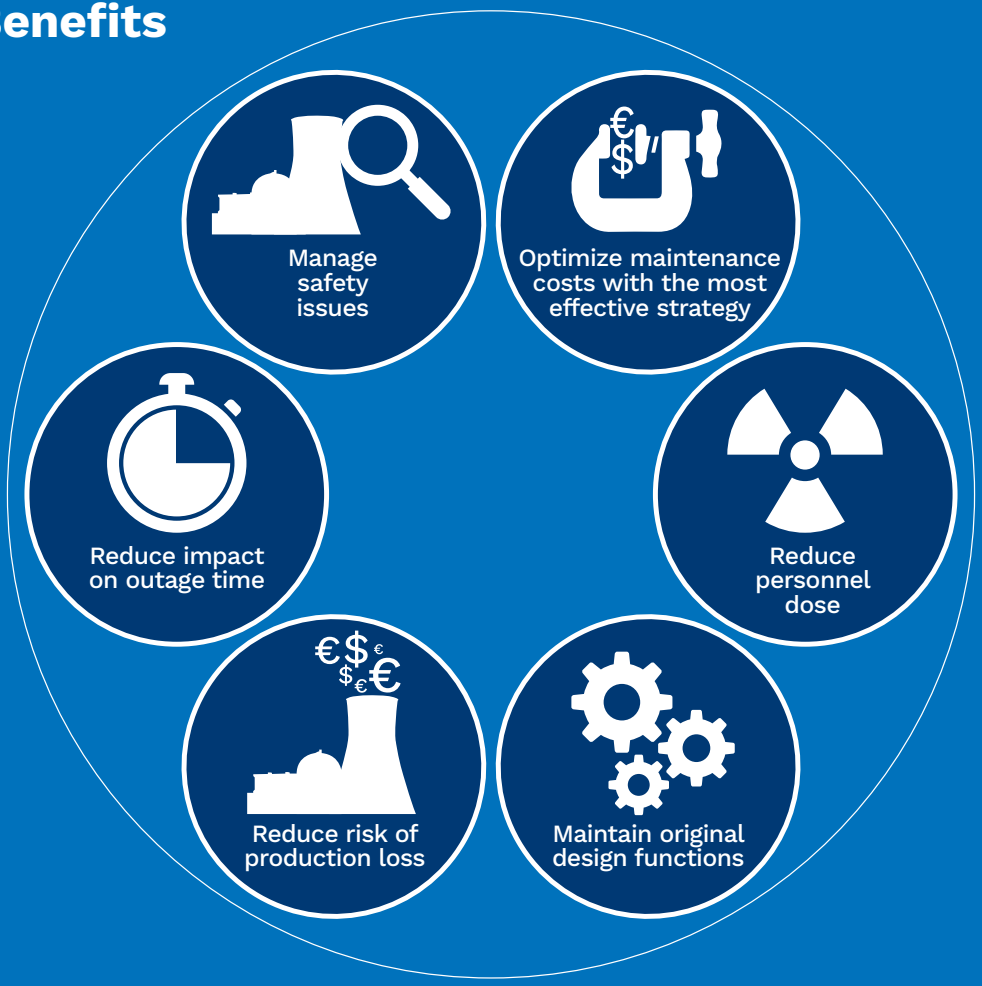
The only permanent solution available.

Unique global integrated support

Engineering and Safety	Inspections	Permanent Solutions	Repair and Replacement
• Define wear criteria • Propose mitigation measures • Support to interface with safety authorities through Framatome and EDF safety studies	• Altimetry measurements (borescope, photogrammetry, laser scanner) • Ultrasonic testing (UT) for thickness measurement • Borescope to check surface state of the adapter and thermal sleeve	• Install spacer by Framatome to stop wear • Cut thermal sleeve without replacement if not mandatory for CRDM	• Repair and replacement of thermal sleeve from under the head • Repair and replacement of thermal sleeve from above the head

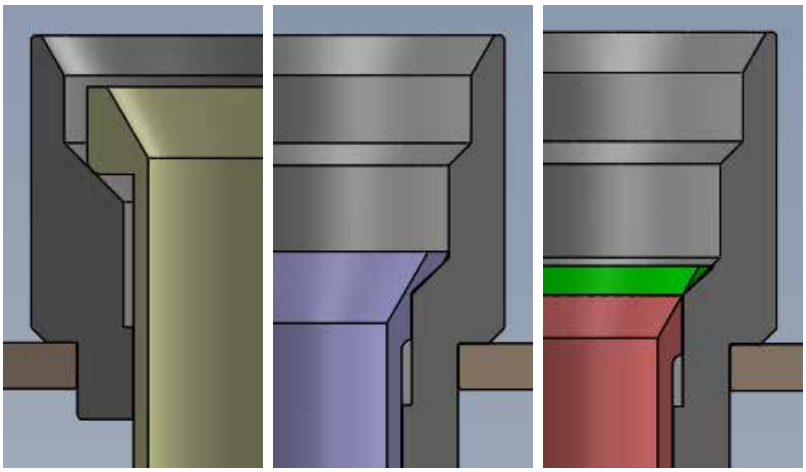
Control and qualify plant restart

Utility Benefits

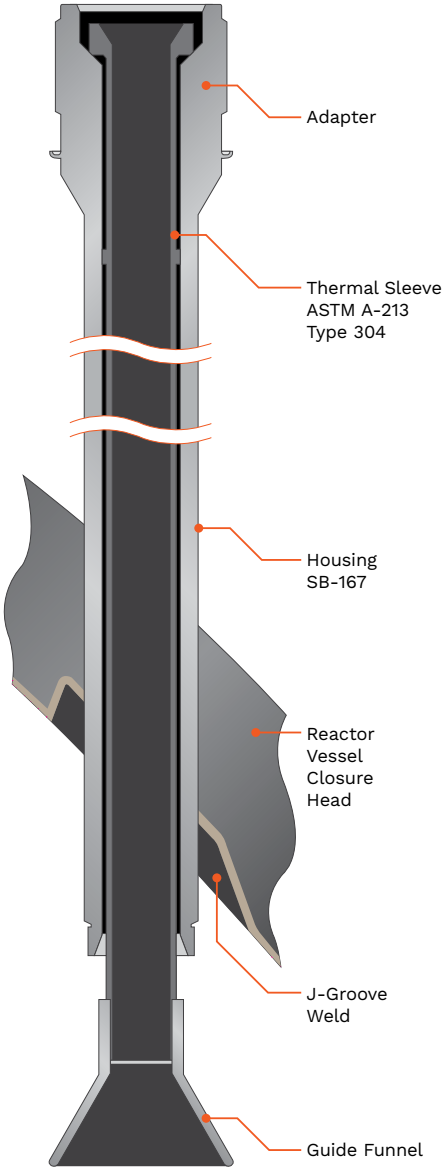


Framatome solutions address **wear both in the thermal sleeve flange and adapter**

In severe cases, wear on both the adapter and thermal sleeve stop causes loose parts, which could generate control rod blockage. The wear profile shown at right was determined by the detailed examination of worn adapters in French plants.



Original | Wear on thermal sleeve and adapter | Final situation with total wear



Thermal sleeve design functions

- Thermal sleeve is made of stainless steel.
- During plant operation with no control rod movement, the thermal sleeve limits hot water flow from vessel head to the CRDM.
- Guiding cone guides the drive shaft during reactor vessel head handling operation for closure. The thermal sleeve tube also guides control rod drives (CRD) through the adapter and inside the CRDM.
- In case of control rod drop, water flow from the bottom to the top of the CRDM lifts the thermal sleeve which increases the flow area to improve drop time.
- When the control rod is lifted, cold water at the top of the adapter moves down through the thermal sleeve tube, protecting the penetration weld.

Framatome's repair technology maintains all thermal sleeve design functions

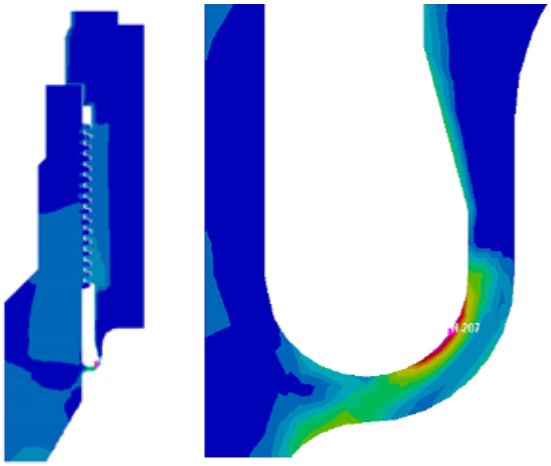
Engineering **and Safety**

Framatome and EDF apply their comprehensive experience to offer plant operators a predictive maintenance strategy that extends the lifetime of their component, vital to efficient long–term operation.

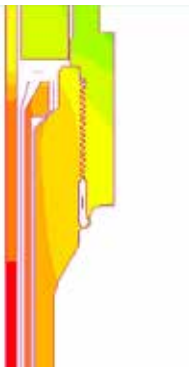
A thermal sleeve maintenance strategy can be managed with inspection(s) and characterization, and preventive maintenance according to the problem.

A preliminary assessment to detect damage can be performed by comparing data between outages. Wear criteria is defined based on inspections of damaged thermal sleeves and then adapted to the specific plant design. Wear criteria has already been defined for several types of plants in Belgium, China, France, Japan, South Africa, South Korea, Spain and the United Kingdom. The wear criteria includes a minimum acceptable wall thickness (using RCC-M or ASME codes if required) and determining the corresponding lowering of the thermal sleeve.

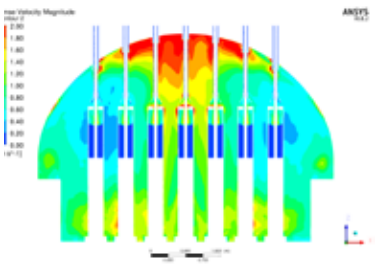
- Recommendations for future plant operation (continued operation as is, additional inspections and/or replacement) can be provided.
- Justifications to restart the plant as well as a rationale for preventive repair solutions can be produced.
- Licensing assistance according to local safety requirements can be provided.
- Engineering studies already performed and/or needed with various operators in the world (Belgium, China, France, Japan, RSA, South Korea, Spain and U.K.).



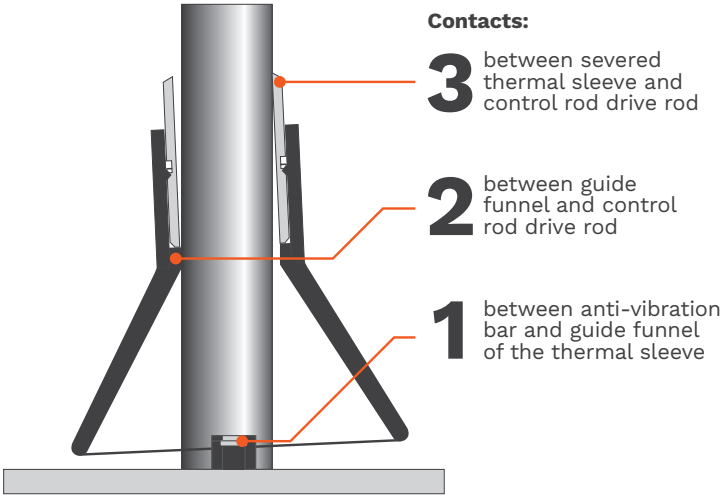
Mechanical analysis of worn out RPV nozzle adapter including canopy joint



Thermal analysis of RPV nozzle adapter and thermal sleeve



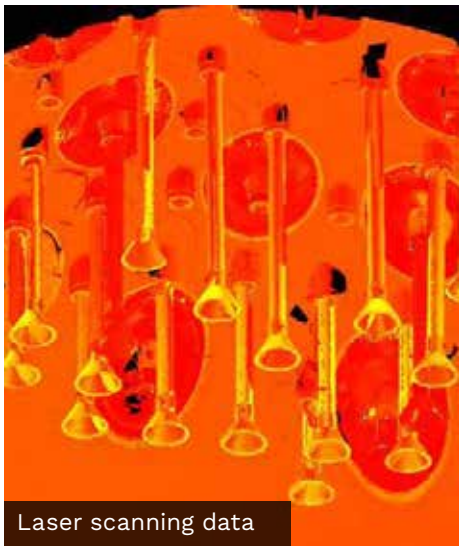
CFD calculations for FIV loading evaluation



Loose part analysis in case of thermal sleeve rupture at the bottom of the RPV adapter

Elevation Inspection **and Expertise**

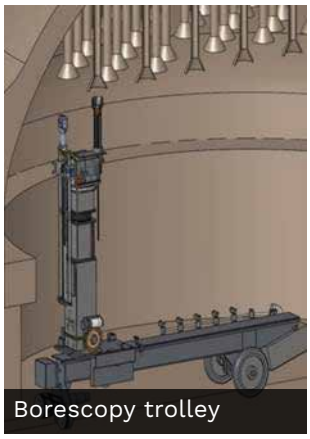
Three measurement methods accurate within +/- 0.3 to 2 mm



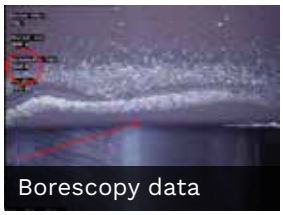
Laser scanning data

Laser scanning

- Take indirect measurements to identify possible wear locations using laser scan technology
- Measure height of the bottom of the thermal sleeve funnels relative to the mating surface of the reactor vessel head flange
- Compare measured data to design data to identify flange wear
- Can be delivered after the reactor vessel head (RVH) is positioned on the head stand



Borescopy trolley



Borescopy data

Borescopy data

Borescopy

- Use borescopy to measure thermal sleeve height compared to the original design height for each sleeve

UT probe

UT and NDE Expertise

- UT expertise can be performed to determine thickness measurement
- Borescopy can be performed when needed to check the surface condition (adapter and/or thermal sleeve)

A permanent solution to your CRDM thermal sleeve wear

Framatome is leading the industry in providing solutions for innovative measurement, inspection, and repair technologies to resolve wear issues to both the thermal sleeve flange and adapter.

Current status in France

- Belleville plant has a replacement head operating at full power for less than 18 years
- EDF decided to conduct examinations on all reactors to identify the possible reactors that may be affected during their next scheduled outage
- All 58 initial examinations have been completed and in-service inspection has started
  - Wear magnitude is determined through thermal sleeve measurement

Framatome has successfully replaced more than 30 thermal sleeves since 2018

Repair and replacement from above the head in 12 French plants:

- Replacement of 20 thermal sleeves in order to understand the global wear and define the right maintenance strategy in one unit
- Replacement of one or two thermal sleeves with advanced wear in seven of them
- Replacement of one thermal sleeve after an unexpected event

Removal of thermal sleeve from under the head for position without Rod Cluster Control Assembly (RCCA) — operation completed in two French plants.

Framatome has replaced 8 thermal sleeves from the botttom at the Hanul plants in South Korea

NEI recognized Hanul Unit 1 with a TIP Award for the plant's implementation of Framatome's bottom-up thermal sleeve replacement technology.

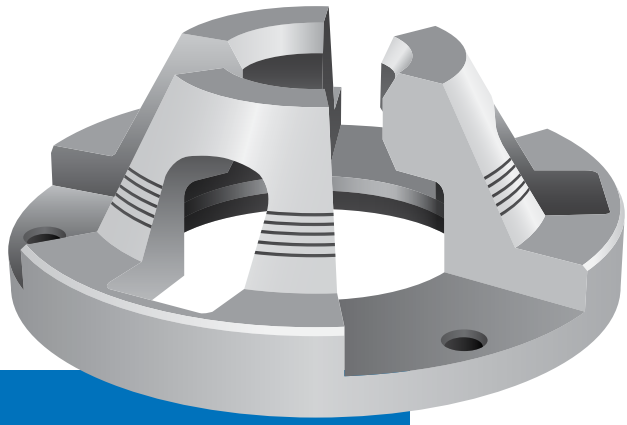
Option 1: **Install thermal sleeve spacer to stop wear**

Spacer by Framatome Features

To avoid and prevent extensive damage to thermal sleeve

- Easy to install
- More than 30 spacers have been installed in France on EDF reactors and a large campaign of spacer installation is planned for the future
- Qualified for RCC-M code and ASME code
- Preventive and predictive solution

The **preeminent** thermal sleeve mitigation

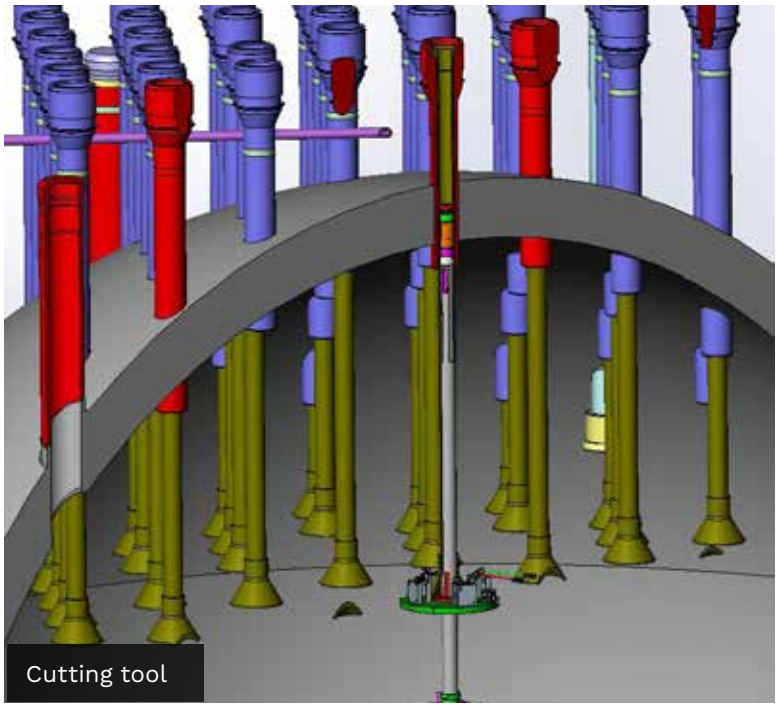


The most efficient solution

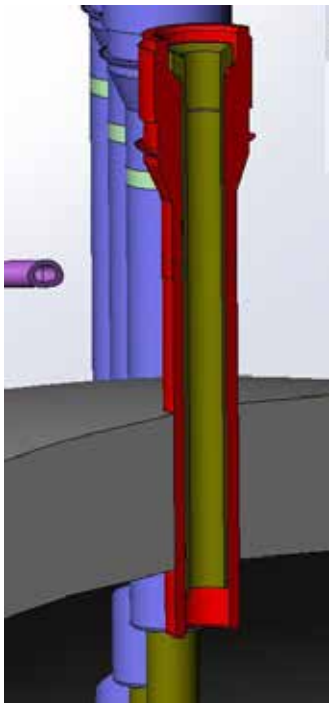
- **Maintain functions of initial design**
- **Avoid unnecessary replacement**
- **Low impact to outage schedule: few hours per spacer (critical path)**
- **Non-destructive operation and no impact in the pressure vessel area**
- **Minimize personnel dose rate**

Spacers installed on Cattenom NPP

Option 2: **Cut thermal sleeve without replacement for non-rodded location**



Cutting tool



Process

- Remove the existing sleeve by machining (EDM) the flange
- Remove the thermal sleeve and remnant
- Proven tooling used for numerous thermal sleeve removals

The simplest solution for locations without control rods

- **Quick intervention and justifications already available**
- **Low impact to outage schedule: less than one day per location (critical path)**

Remnant tool

Removal operation

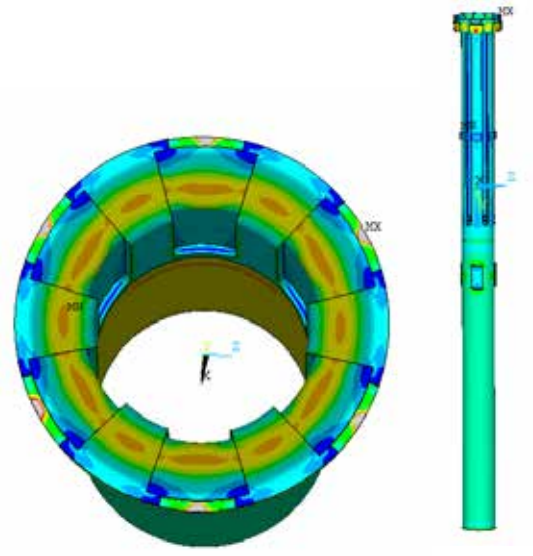
Bent remnant after extraction

Option 3: **Replace thermal sleeve from under the head**

Electrical discharge machining

Process

- Remove the existing sleeve by machining (EDM) the flange
- Machine (EDM) a new seating surface in the CRDM nozzle
- Perform visual inspection of the new seating surface
- Install the new two-piece thermal sleeve from under the head and secure with ID weld



Features

- Like-for-like design with all thermal protections preserved
- Address all categories of thermal sleeve wear

The most cost-effective solution to repair and replace

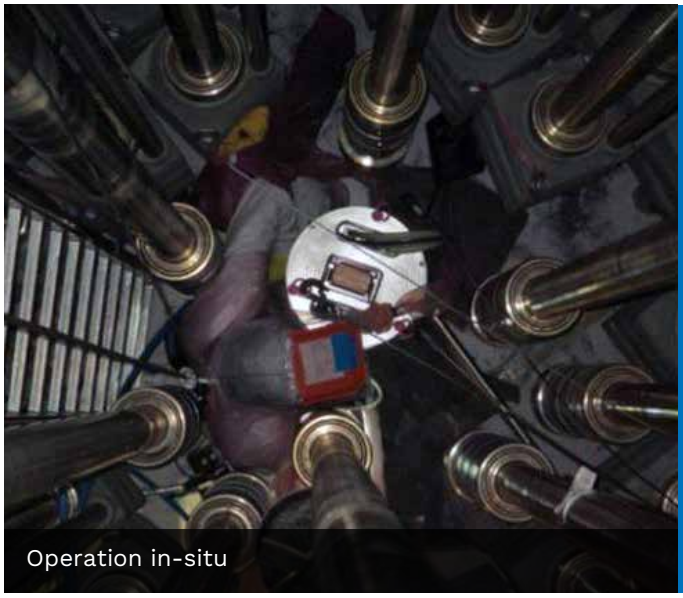
- **Replace the thermal sleeve without disassembly above the head**
- **Moderate impact to outage schedule: 2 days estimated time per location (critical path)**

Successful replacement of thermal sleeves

Option 4: **Replace thermal sleeve from above the head**

Process

- Remove CRDM
- Lift and cut the old thermal sleeve
- Machine adapter to restore original configuration at a lower position
- Install a new thermal sleeve from above equipped with a shim to compensate for wear and machining



Operation in-situ

Qualified and reliable solution

- **Remote tooling**
- **Moderate impact to outage schedule: two days per location (critical path) after CRDM removal is performed**
- **The back-up solution to answer for any unexpected event**
- **References: more than 30 adapters and thermal sleeves repaired and replaced in French and Korean nuclear reactors**

Framatome is an international leader in nuclear energy recognized for its innovative solutions and value added technologies for the global nuclear fleet. With worldwide expertise and a proven track record for reliability and performance, the company designs, services and installs components, fuel, and instrumentation and control systems for nuclear power plants. Its more than 14,000 employees work every day to help Framatome's customers supply ever cleaner, safer and more economical low-carbon energy. Visit us at www.framatome.com, and follow us on Twitter: @Framatome_ and LinkedIn: Framatome.

Framatome is owned by the EDF Group (75.5%), Mitsubishi Heavy Industries (MHI – 19.5%) and Assystem (5%).

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