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Note Technique

TITRE :

HTRE – Deliverable 38 of WP5
Review and identification of typical tribology conditions of components for the GTMHR

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RÉSUMÉ :

The aim of the WP5 of HTR-E is to update the inventory of tribological problems met in the formers HTRs, to review and identify the corresponding tribological environments and finally to check the possible materials or coatings able to provide a reliable answer to these situations through elementary tests in a representative and tribological Helium environment close to identified components such as the control rods, the stator seals or the hot gas duct.

This document is the contribution of the CEA to the D38 task named “Review and identification of typical tribology conditions of components”. Based on the available informations concerning the present design for the GT-MHR or the PBMR, this review puts the emphasis on the tribological operating conditions of the main components such as the control rods, the turbine, the rotating seals, the internal seals, the hot gas duct, …

Each component is depicted by means of a short technical description and a filling card where are summarized the available tribological informations.

L’objet du WP5 de HTR-E est de mettre àjour l’inventaire des problèmes tribologiques rencontrés dans les réacteurs HTR existants, d’identifier les situations tribologiques correspondantes, et de proposer des matériaux ou revêtements susceptibles d’être utilisés dans ces situations et de valider ces choix au travers d’un programme expérimental aussi représentatif que possible des conditions réelles correspondantes.

Ce document est la contribution du CEA au livrable 38 « Review and identification of typical tribology conditions of components ». Cette revue est basée sur les informations disponibles sur le design actuel du GT-MHR ou du PBMR, et permet de recenser les différentes conditions de fonctionnement du point de vue tribologique, des principaux composants comme le hot gaz duct, les internes, les joints du stator, …

Chaque composant est décrit au moyen d’une description technique ainsi qu’avec une (ou plusieurs) fiche(s) type(s) ou sont résumées les informations tribologiques disponibles.

MOTS CLÉS : HTR, GT-MHR, Tribology

(04/02 Modèle NT)

	Rédacteur	Vérificateur	Approbateur
Fonction			Le Chef du STR/LCET
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Date	01/10/02		

Cadre de réalisation du document.
DOB ..... DDIN
Domaine ..... Systèmes du futur
Projet..... RCG Technologie des circuits He
Contrat .....

Classification				
DR	CC	CD	SD	SANS
				X

Indice	OBJET DES RÉVISIONS	DATE	NUMÉRO DOC.
0	Émission initiale	01/10/02	02-037

REFERENCES

[1] Conceptual Design Report – Int. GT-MHR 100025 – Task PL-9, Product PL-9.4, Rev 0 March 1998

[2] Seals Performance Report – Task PCS-6, Product PCS-6.3, Rev 0 January 1997

[3] I. BOBIN VASTRA, “WP5 Work Plan Report for : Tribology in Helium Environment”, HTR-E contrat n° FIKI-CT-2001-00177

Contents

1. AIM OF THE TASK

The main purpose of the WP5 of the HTR-E is to draw up the list of the tribological problems encountered by the former HTR's while they were operating, to review and identify the related tribological environments and finally to check the possible materials or coatings able to overcome these situations through suitable elementary tests performed in realistic conditions, as close as possible to the corresponding identified components (control rods, stator seals, hot duct gas and so on).

The WP5 is divided in 6 parts, 6 deliverables identified from D37 to D42 [3]. This report is the contribution of CEA to the D38 task which is named "Review and identification of typical tribology conditions of components". Based on the available informations concerning the present design for GT-MHR or PBMR, this review puts the emphasis on the tribological operating conditions of the main components which are presenting some problems from the tribological point of view, such as the control rods, the turbine, the rotating seals, the internal seals, the hot gas duct, …

Each element is depicted in the following chapters by means of a short technical description [1] and a filling card where are summarized the available related tribological informations.

The filling cards contain a fully detailed list of parameters in order to give a sharp description of the experimental conditions, like the environmental or tribological conditions (temperatures, pressure, nature of gas, or the kind of contact, sliding, bearing, fretting…) and the typical contact data (pressure of contact, displacements, speed…).

It must be pointed out that the filling cards are not fully fulfilled because of the difficulties encountered to access to suitable and reliable data concerning topics like for example the typical contact conditions.

FRAMATOME ANP is in charge of the GT-MHR with the CEA, and the organization is described as following (appendix 1) :

- CEA : Hot gas duct, stator seals and internals,
- FRAMATOME ANP : control rod driver mechanisms, tubes or structures subject to vibrations.

This document is devoted to the CEA contribution of this work.

2. TECHNICAL DESCRIPTION OF EACH COMPONENT

2.1 Hot gas duct

The hot duct (fig 1) is designed to remove the primary coolant headed in the reactor system to PCS with minimum thermal losses due to hot-to-cold helium recuperation effect. The hot duct is located within the cross vessel and is made of a load bearing metallic tube, a thermal insulation, an expansion joint and supports. One end of the load bearing tube is welded tightly to the core metallic support. The other end of the hot duct is connected to the PCS inlet nozzle through an expansion joint.

The thermal insulation, made of an aluminia-silica fiber, is fixed on the inner surface of the load bearing tube and is lined with a metallic casing made of CrNi55MoWZr alloy.

The thermal expansion joint is a set of self-sealed metallic semi-rings that are pressed against a sealed surface due to the differential pressure between hot and cold helium flows [1].

Two filling cards have been established (appendix 2). One for the contact between the load bearing tube and the divided sealing strips, and the second for the contact between the divided sealing strips and the divided sealing strips or the housing ring. The working environment is He gas at 500°C with a differential pressure of 1 bar. For more details see the appendix 2.

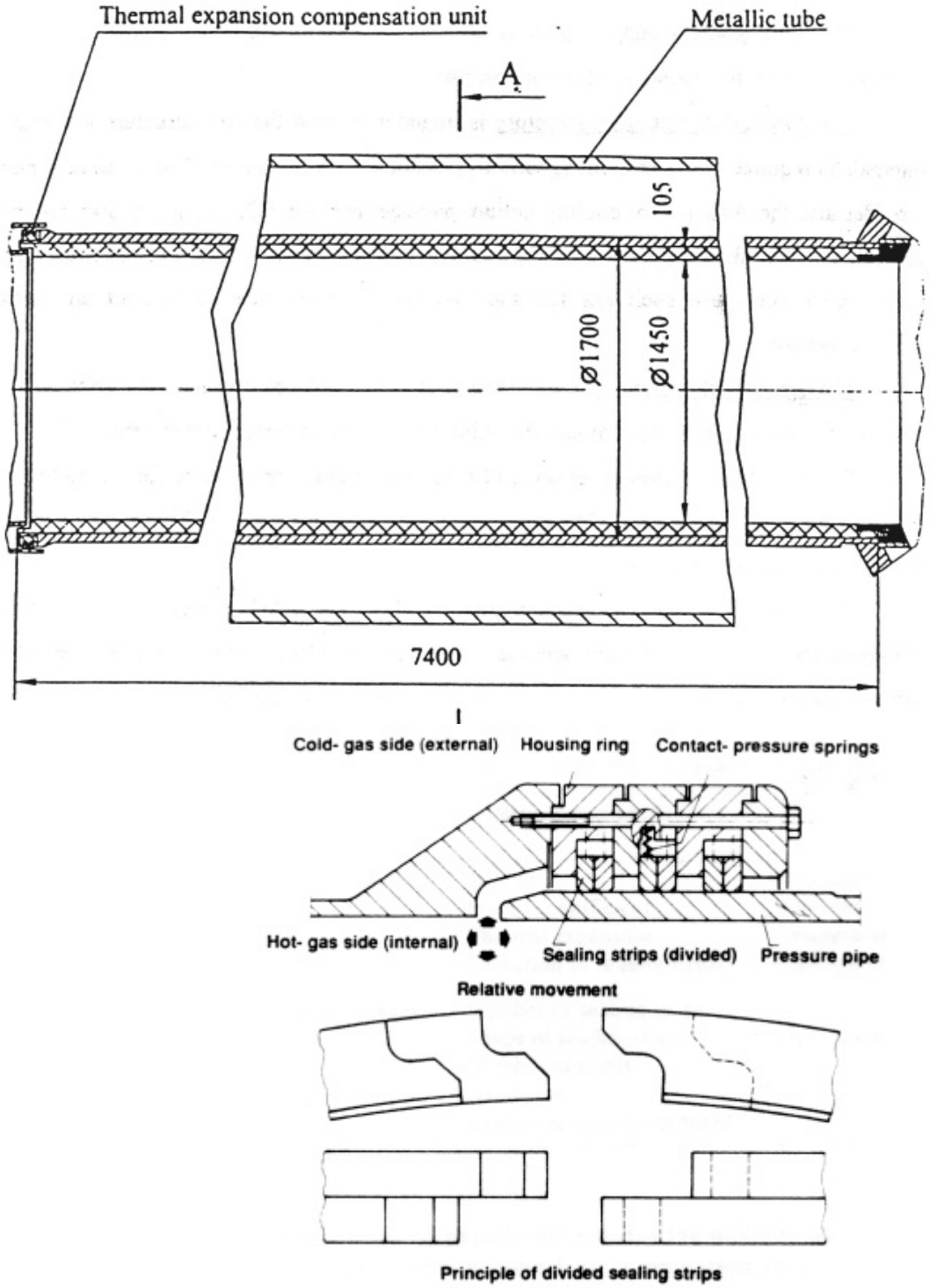

Figure 1 : Hot gas duct seals [1]

2.2 Stator seals

The turbocompressor design provides multistage seals for a stator (fig 2) in order to minimize coolant by-pass leaks. Each stage of the stator seal consists of two rings which are multisegment elements enclosed in casings (fig 1). The stator seals limit helium by-pass leaks between places of the turbocompressor interfacing and the other PCS components. Meanwhile, the stator seals act as radial friction supports for the turbocompressor [1][2].

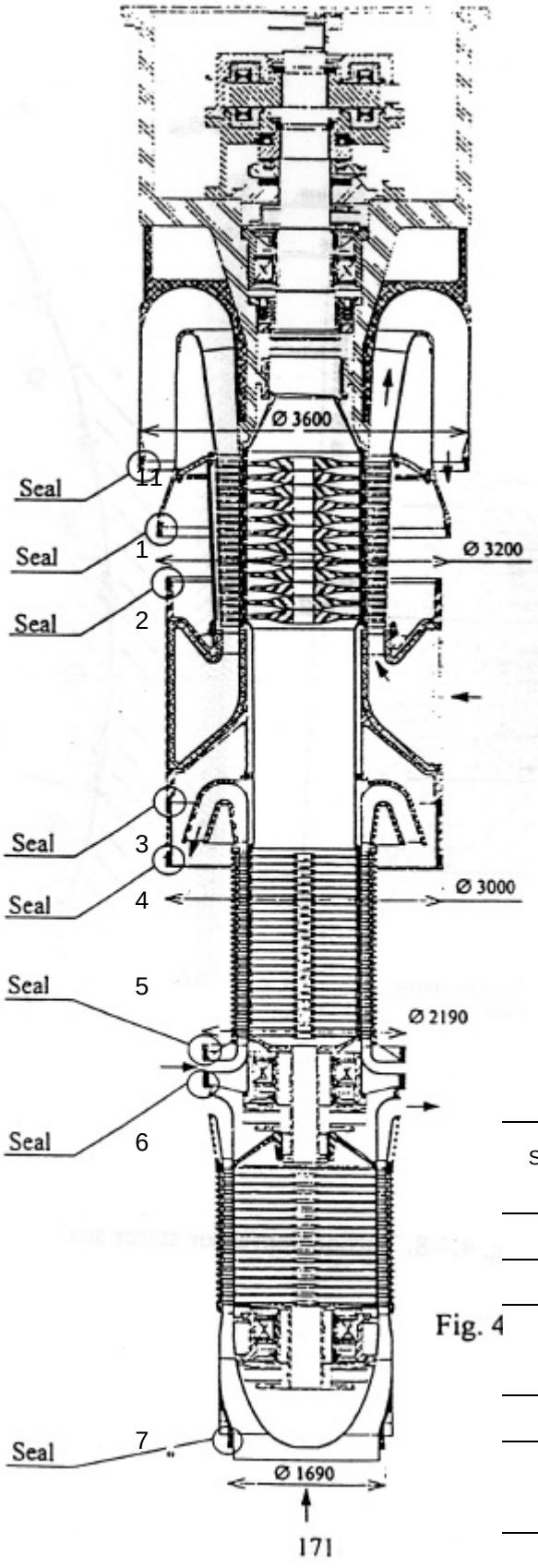

Fig. 4

The stator seals have the same design as the hot gas duct seal. The environment working and dimensions are differents and summarized in the table of the figure 2.

For more details see the appendix 2 to consult the filling card of the stator seals.

Seal number	Pressure (MPa)		Helium temperature (°C)	Sealed diame (mm)
	Before seal P1	After seal P2		
1	7.14	2.62	490	3200
2	7.14	7.01	490	3000
3	7.14	7.01	490	3000
4	7.24	7.14	108	3000
5	7.24	4.28	108	2190
6	4.34	4.28	106	2190
7	4.33	2.57	106	1690
11	2.623	2.59	510	3600

Figure 2 : Turbocompressor stator seals arrangement [1][2].

2.3 Internals

The reactor internals are intended to dispose and put the core into the required configuration, as well as to organize the coolant circulation path from both the PCS and SCS to the core and in the opposite direction.

The reactor internal components are arranged in such a manner to maintain a stable core position within the reactor vessel, thus ensuring its cooling and control in both normal and emergency operating modes, as well as the reliable cooling of the reactor vessel.

The reactor internals (fig. 3) consist of a permanent site reflector, a core graphite support structure, a metallic support structure, a top collector plenum, a upper core restraint and the hot duct. The reactor internals are located within the reactor vessel [1].

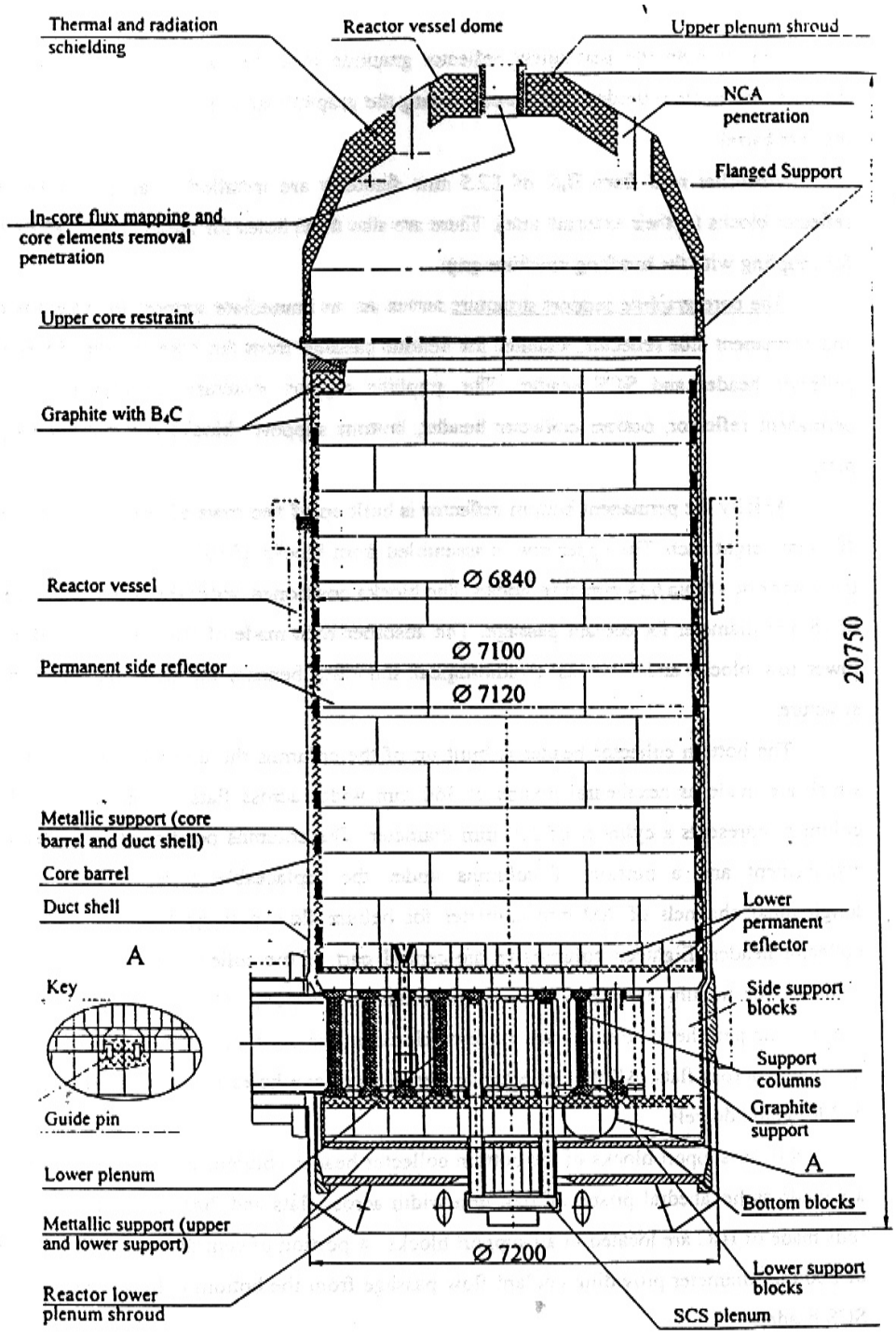

Figure 3 : Reactor internals [1].

2.3.1 Permanent side reflector .

The permanent side reflector is designed (except the neutron reflector function) to arrange the core, to limit the neutron exposure to the core barrel shell and the reactor vessel, and to transfer radial loads between the core barrel and the core itself.

The permanent side reflector is made of a compound annular graphite structure consisting of twelve rings of 800 mm height, one upper ring of 500 mm height and one lower ring of 400 mm height, which are assembled from five different-size blocks. Each ring is displaced relatively to the other one for a half of the block sector length and is fastened together along the height by guide dowels of 60 mm diameter.

2.3.2 Core graphite support structure.

The core graphite support structure serves as an immediate support for both the core and the permanent side reflector, channel for the helium passage from the core to both the bottom collector header and SCS header. The graphite support structure includes the bottom permanent reflector, the bottom collector header, the bottom support blocks and the bottom support plate.

The different parts of the core graphite the support structure are built up of hexahedral blocks or prisms with dimensions about 360 mm up to 624 mm. The blocks located under the core have channels of 16 mm diameter for the coolant passage. The absorber rods made of B4C are arranged in the lower row blocks and act as a radiological shielding beneath the core metallic support structure.

2.3.3 The core metallic structure.

It is intended to hold the core structure and the reactor internals within the reactor vessel in the required configurations. The metallic support provides also some channels for the cooling helium passage from the PCS to the top core collector plenum. The metallic support structure is installed into the reactor vessel and includes : the upper support plate, the core barrel shell, the gas duct shell, the bottom collector header shroud, the hot duct nozzle and the SCS header.

2.3.4 The top collector plenum.

It is designed to organize an ordered coolant flow into the core, and to provide thermal and radiological shielding for the reactor vessel upper head. The top collector plenum ensures also an opportunity for the core fuel reloading by means of the handling machine. The collector is located above the core and is installed on the core metallic support structure.

The structure is made of a hemispherical dome on which both the thermal and radiological shielding are placed. There are necessary penetrations in the dome for the guide tubes of the control rods and the absorber elements of RSS and also for the core fuel reloading.

2.3.5 Upper core restraint.

It provides spacing for the core and the reflectors graphite columns, and organizes the channels for coolant passage from the upper collector plenum to the core, distributes the coolant flow through the channels in the core columns, and also holds the control rods and absorber element guide channels in a proper position to ensure their normal motion.

The upper core restraint consists of 317 metallic hexahedral elements of 200 mm height installed above the central and the side permanent reflectors. All those structural elements are subdivided into 6 basic types according to the reactor system items above which they are located. All the elements are supplied with their fixation and replacement items.

2.3.6 Discussions

For internals, two kinds of contact have been identified :

- Graphite / graphite contact for a temperature range between 500 and 850°C,
- Graphite / metallic structure or guides with a temperature up to 450°C for structure and up to 800°C for guides.

For these two types of contact, the working environment is He gas under a pressure of 70 bar. Filling cards summarizing the principal tribological conditions are reported in appendix 2.

3. FILLING CARDS

The filling cards are presented in appendix 2. For each component, the filling cards gather the following elements :

- General informations,
- Parts in contact dimensions
- Tribological conditions
- Environmental conditions
- Observations

4. CONCLUSION

This review, which is the contribution of the CEA to the deliverable 38 of WP5, gathers some informations concerning the environmental and tribological conditions met in the former HTR's during operations.

The informations concerning both the geometrical and environmental conditions (size of components, temperature, pressure, …) are well known and commonly described.

However, some informations are missing. For example, the typical contact parameters (contact pressure, displacement, speed, …) cannot be clearly specified because of the lack of reliable and accessible data concerning this topic.

APPENDICES

5.1 Appendix 1 : Deliverable 38

Deliverable 38

DELIVERABLE D38
Title "Review and identification of typical HTR tribology conditions of components"
Schedule January 2002 –November 2002
Responsible Framatome ANP S.A.S (1)
Partners CEA (2), NNC (7)
DOCUMENT ORGANISATION

INDEX	**RESPONSIBLE**	**INPUT NEEDED**	**DATE**
General principles			
Document listing the information required in the text, will concern the following types of reactors: • GTMHR • PBMR			
PBMR	**NNC**		Document available in June 2002
GTMHR • Internals • Hot gas duct • Stator seals	**CEA**		Document available in June 2002
GTMHR • Control rods • …	**FRA-ANP**		Document available in June 2002
Conclusion: synthesis of documents	**Framatome**		Draft : Sep 2002 for partner comments Final : Nov 2002

5.2 Appendix 2 : Filling cards

5.2.1 Hot gas duct

NAME OF THE EQUIPMENT:

GENERAL INFORMATION

- Short description of the equipment :
- Usual characterisation :
- Surface of studied friction zone : cm² (cm^2 / mm^2 / μm^2 / Other):
- Lifetime :

PARTS IN CONTACT DIMENSIONS

- Part 1 Shape: Dim: - ☐fixed / ☒moving
  Material:
- Part 2 Shape: Dim: - ☒fixed / ☐moving
  Material:
  cylinder into a cylinder
- Representative of a particular setting?

TRIBOLOGICAL CONDITIONS

- Load or torque :
- Sliding speed :
- Shift range :
- Frequency :
- Nature of the studied contact : ☒pure sliding / ☐pure bearing / ☐sliding + bearing / ☒impact + sliding (fretting) / ☐Other:
- Displacement kinetics
  - Constant speed ☒YES / ☐NO, value
  - Constant acceleration ☐YES / ☐NO, value
  - Sinusoidal speed ☒YES / ☐NO, value
  - Tangential acceleration ☐YES / ☐NO, value
  - Other :

ENVIRONMENT CONDITIONS

- Working environment :
- Temperature range :
- Pressure range :
- Particular conditions (magnetism, ...) :

OBSERVATIONS

NAME OF THE EQUIPMENT:

GENERAL INFORMATION

- Short description of the equipment :
- Usual characterisation :
- Surface of studied friction zone : cm² (cm^2 / mm^2 / μm^2 / Other):
- Lifetime :

PARTS IN CONTACT DIMENSIONS

- Part 1 Shape: Dim: - ☒fixed / ☐moving
  Material:
- Part 2 Shape: Dim: - ☐fixed / ☒moving
  Material:
  plane / plane
-
- Representative of a particular setting?

TRIBOLOGICAL CONDITIONS

- Load or torque :
- Sliding speed :
- Shift range :
- Frequency :
- Nature of the studied contact : ☐pure sliding / ☐pure bearing / ☐sliding + bearing / ☒impact + sliding (fretting) / ☐Other:
- Displacement kinetics
  - Constant speed ☒YES / ☐NO, value
  - Constant acceleration ☐YES / ☐NO, value
  - Sinusoidal speed ☒YES / ☐NO, value
  - Tangential acceleration ☐YES / ☐NO, value
  - Other :

ENVIRONMENT CONDITIONS

- Working environment :
- Temperature range :
- Pressure range :
- Particular conditions (magnetism, ...) :

OBSERVATIONS

5.2.2 Stator seals

NAME OF THE EQUIPMENT:

GENERAL INFORMATION

- Short description of the equipment :
- Usual characterisation :
- Surface of studied friction zone : cm² (cm^2 / mm^2 / μm^2 / Other):
- Lifetime :

PARTS IN CONTACT DIMENSIONS

- Part 1 Shape: Dim: - ☒fixed / ☐moving
  Material:
- Part 2 Shape: Dim: - ☐fixed / ☒moving
  Material: unknow
- Representative of a particular setting? cylinder into a cylinder

TRIBOLOGICAL CONDITIONS

- Load or torque :
- Sliding speed :
- Shift range :
- Frequency :
- Nature of the studied contact : ☐pure sliding / ☐pure bearing / ☐sliding + bearing / ☒impact + sliding (fretting) / ☐Other:
- Displacement kinetics
  - Constant speed ☒YES / ☐NO, value
  - Constant acceleration ☐YES / ☐NO, value
  - Sinusoidal speed ☒YES / ☐NO, value
  - Tangential acceleration ☐YES / ☐NO, value
  - Other :

ENVIRONMENT CONDITIONS

- Working environment :
- Temperature range : 100 °C to 500 °C
- Pressure range : DP 1 to 45 bar
- Particular conditions (magnetism, ...) :

OBSERVATIONS

5.2.3 Internals

NAME OF THE EQUIPMENT:

GENERAL INFORMATION

- Short description of the equipment :
- Usual characterisation :
- Surface of studied friction zone : cm² (cm^2 / mm^2 / μm^2 / Other):
- Lifetime :

PARTS IN CONTACT DIMENSIONS

- Part 1 — Shape: — Material: — Dim: — ☒fixed / ☐moving
- Part 2 — Shape: plane — Material: — Dim: — ☐fixed / ☒moving
- Representative of a particular setting?

TRIBOLOGICAL CONDITIONS

- Load or torque :
- Sliding speed :
- Shift range :
- Frequency :
- Nature of the studied contact : ☐pure sliding / ☐pure bearing / ☐sliding + bearing / ☒impact + sliding (fretting) / ☐Other:
- Displacement kinetics
  - Constant speed ☒YES / ☐NO, value
  - Constant acceleration ☐YES / ☐NO, value
  - Sinusoidal speed ☒YES / ☐NO, value
  - Tangential acceleration ☐YES / ☐NO, value
  - Other :

ENVIRONMENT CONDITIONS

- Working environment :
- Temperature range :
- Pressure range :
- Particular conditions (magnetism, ...) :

OBSERVATIONS

NAME OF THE EQUIPMENT:

GENERAL INFORMATION

- Short description of the equipment :
- Usual characterisation :
- Surface of studied friction zone : cm² (cm^2 / mm^2 / μm^2 / Other):
- Lifetime :

PARTS IN CONTACT DIMENSIONS

- Part 1 Shape: Dim: - ☐fixed / ☒moving
  Material:
- Part 2 Shape: Dim: - ☒fixed / ☐moving
  Material:
  Ex: plane / plane and cylinder into a cylinder
- Representative of a particular setting?

TRIBOLOGICAL CONDITIONS

- Load or torque :
- Sliding speed :
- Shift range :
- Frequency :
- Nature of the studied contact : ☐pure sliding / ☐pure bearing / ☐sliding + bearing / ☒impact + sliding (fretting) / ☐Other:
- Displacement kinetics
  - Constant speed ☒YES / ☐NO, value
  - Constant acceleration ☐YES / ☐NO, value
  - Sinusoidal speed ☒YES / ☐NO, value
  - Tangential acceleration ☐YES / ☐NO, value
  - Other :

ENVIRONMENT CONDITIONS

- Working environment :
- Temperature range :
- Pressure range :
- Particular conditions (magnetism, ...) :

OBSERVATIONS

FICHE DE VÉRIFICATION DU DOCUMENT

TITRE DU DOCUMENT :

Rédacteur :

Domaines* de la Vérification	**Résultats **		
1) Vérification de la forme : respect de la PR1 G1 du MQ DER	Conformité		
Modèle de NT	C	NC	
Contenu des « cartouches » : page 1, page 2 et page courante	C	NC	
Plan du document et Pagination	C	NC	
Clarté de la mise en forme (traitement de texte)	C	NC	
Respect de l'orthographe et de la grammaire françaises	C	NC	
Formules, Figures, Tableaux, … (titres, unités, échelles, légendes, …)	C	NC	SO
2) Vérification scientifique			
Les documents de références et les documents applicables sont-ils mentionnés ?	Oui	Non	SO
L'étude s'appuie-t-elle sur une analyse de l'état de l'art ?	Oui	Non	SO
Le problème est-il clairement posé ?	Oui	Non	SO
Les hypothèses sont-elles clairement définies ?	Oui	Non	SO
Les données sont-elles appropriées et validées ?	Oui	Non	SO
Les méthodes employées sont-elles justifiées et validées ?	Oui	Non	SO
Les ordres de grandeur sont-ils cohérents ?	Oui	Non	SO
Les conclusions sont-elles justifiées ?	Oui	Non	SO
3) Vérification de la clarté et de la cohérence d'ensemble			
Le Titre est-il explicite et pertinent ?	Oui	Non	
Le Résumé est-il autoporteur, clair et conclusif ?	Oui	Non	
Le Résumé est-il cohérent avec l'Introduction et la Conclusion ?	Oui	Non	
Les Mots Clés sont-ils pertinents et exhaustifs ?	Oui	Non	
L'Introduction indique-t-elle suffisamment : les objectifs contractuels, le contexte technique, les objectifs précis, les enjeux, …	Oui	Non	
L'Introduction présente-t-elle l'articulation de la présentation ?	Oui	Non	
L'enchaînement des étapes de la présentation est-il compréhensible ?	Oui	Non	
La Conclusion précise-t-elle clairement le degré d'atteinte des objectifs contractuels ?	Oui	Non	
La Conclusion ouvre-t-elle des perspectives ?	Oui	Non	SO

Bilan de la Vérification			
Les modifications demandées ont toutes été prises en compte par le Rédacteur	Oui	Non	SO
Les modifications listées en PJ n'ont pas été suffisamment prises en compte par le Rédacteur et nécessitent l'arbitrage de l'Approbateur	Oui	Non	SO

** C et Oui Jugé Satisfaisant par le Vérificateur
** NC et Non Jugé Non Satisfaisant par le Vérificateur : modifications demandées au Rédacteur
** S.O. Jugé Sans Objet par le Vérificateur (la rubrique ne s'applique pas)

Vérificateur* :	**Domaines* : 1, 2 et 3**	**Date :**	**Visa :**

* S'il y a plusieurs vérificateurs, chacun remplit une Fiche en précisant les domaines qu'il a vérifiés