Water Tightness of Heat Exchanger's Non Axisymmetrical Bolted Flanges Under Thermal Shocks

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- ABSTRACT

In order to eliminate leakages that appear on bolted junctions submitted to pressure, temperature and thermal transients, and particularly in case of TEMA BEU heat exchangers, the following programme was realised :

- Expérimental analysis of unsymmetrical bolted joints' behaviour, in several configurations
- Modelling of these configurations (Ø pressure temperature).
- Design of an elastic washer to be installed between the flange and the nut, around the bolt. The elastic washer has to filter thermal strains and to ensure an elastic behaviour to the junction. That helical shaped elastic washer is compact enough to be set up on an existing bolted joint, and designed so that stresses that are developped in it, in operating conditions, meet ASME requirements for boltings.
- That device was experimented on several existing nuclear plants' heat exchangers.

1. INTRODUCTION

Very frequently, bolted joints that are placed on pressure vessels, heat exchangers, pipes etc..., when submitted to pressure, temperature, and thermal shocks, don't remain watertight. That phenomenon is essentially due to the thermal strains developping in the bolted junctions, and causing non reversing local deformations. Thus, the load applied on the gasket progressively decreseases, and the junction's tightness cannot be ensured anymore.

In following paragraphs, are exposed :

- two examples of experimental investigations concerning the behaviour of heat exchangers bolted junctions, submitted to thermal shocks - a model by means of finite elements method - the design, realisation and experiment of a device, to restore an elastic behaviour to the bolted junction.

2. RESIDUAL HEAT EXCHANGERS

Residual heat exchangers in case of a FRAMATOME 900 MW nuclear power plant, are vertical BEU TEMA type heat exchangers. General dimensions are shown in figure (1). The main design characteristics are :

tube side
- pressure = 45 bar
- temperature = 204°C
- two passes
- flange material = 304 L austenitic stainless steel
- bolts material = A 193 B7 ferritic steel.

The main thermal transient is shown in fig. (5).

2.1. Modelling by means of elastic axisymetric finite elements method, as shown in fig. (3). It was supposed that the tube side is entirely submitted to pressure, temperature and thermal transient caused by the entering fluid.

The strain developped in the bolts, during the thermal transient (the fluid temperature shown in fig. (5) was measured) was calculated as a function of time, and is shown in figure (5).

During the first part of the transient, the hight strains applied on the bolts are registred. On the contrary, during the second part of the transient, strains on bolts become very low, and the load applied on the gasket becomes lower than the minimum value required by the gasket manufacturer. Very often, then, a leakage appears.

That kind of modelling is not entirely satisfiying : the junction's mechanical behaviour is not really elastic, and plastic local deformations occur during the first part of the transient, because of the hight strains. More over, because of the pass partition, the thermal field is not axisymetrical. An evaluation of the influence of this last point was performed by means of three dimensional modelling.

2.2. Three dimensional modelling

The model is shown in fig. (2). Geometrical, thermal and mechanical characteristics are the same as for axisymetric model. Thermal and mechanical loadings are also identical, for the hot side of the channel. In the cold part of the channel, fluid temperature is lower, as shown in fig. (5).
Results are shown in fig. (5).

2.3. In order to avoid either bolts overloadings that induce local plastic deformations, and underloadings that induce leakages, when bolted junctions are submitted to hot and cold thermal shocks, helical shaped elastic washers were designed - fig. (10).
The elastic washers are placed between flange and nuts, as shown in fig. (11) and (12).

The mechanical response (strain - deflection) was determined by means of a three dimensional model fig. (9) and experimentally measured fig. (8). A linear approximation of the response was used fig. (8), for analysing junction's mechanical behaviour under thermal shocks, when fitted with these elastic washers.

The gasket is an helicoflex gasket, silver coated with deflection limiter.

The elastic washers are designed in order to reduce loadings'range, restore an elastic behaviour to the bolted junction, and maintain an adequate gasket load during thermal transients. More over an elastic washer is considered as a bolting element and must meet ASME stress limits requirements for boltings.

Main characteristics of an example of elastic washer are given in fig. (13).

2.4. Calculations' and experment's results

A residual heat exchanger which had leakage problems was fitted with elastic washers and an helicoflex gasket on BLAYAIS II nuclear plant, and submitted to five thermal cycles as shown in fig. (5). Beforehand, it had been impossible to keep that heat exchanger tight. Fluid temperature, flow rate, flange and bolts temperatures, and bolts loadings were measured. The same figure (5) shows bolts' loadings measured and calculated.

Figure (7) shows the most sollicited bolt's residual loading after each cycle. At the end of the first and second cycle, bolts were tighten again. At the end of the following cycles, residual loadings remained constant.
No leakage was observed.

3. EXCESS LETDOWN HEAT EXCHANGER

3.1. Excess letdown exchangers, in case of a FRAMATOME 900 MW nuclear power plant, are horizontal BEU type six passes tube side, heat exchangers. General dimensions are shown in fig. (14) and (11). The main design characteristics are :

Tube side
design pressure = 171 bar
design temperature = 343°C
six passes
flange material = 304 L austenitic stainless steel
bolts material A193 B7 ferritic steel

The main thermal transient is very severe and is represented in fig. (17).

In it's original configuration, it appeared impossible to keep that heat exchanger tight, after one or two thermal cycles.

The same calculations (axisymetric method - fig. (15) and experiments, as for the excess let down heat exchanger, were performed - fig. 17-18 and 19.

3.2. Experiment's and calculation's results

Results are given in figure (17), fig. (18) and fig. (19).

Fig. (17) shows fluid pressure, flow rate, and temperature, most sollicitated bolt's load measured and calculated, versus time and most sollicitated bolt's load calculated assuming the heat exchanger without elastic washers.

Fig. (18) shows maximum bolt's load versus angular position in the flange.

4. GENERAL CONCLUSION

It is possible to design, in several configurations of non axisymetrical heat exhangers bolted joints, submitted to thermal shocks, compact elastic washers which are associeted to helicoflex silver coated gaskets, and which restore to the bolted junction an elastic behaviour, so that :

- thermal over loadings are substantially decreased, and then no local plastic deformations appear during thermal shocks.
- gasket loading remains sufficient to keep the bolted junction tight.

It is possible to determine the bolted junction mechanical behaviour by means elastic axisymetric finite elements method. Elastic washers are considered as bolking elements and meet ASME stress limits requirements for boltings.
However, it must be noticed that :

- It is necessary to preload bolts at a higher value than required by ASME appendix XI, and therefore, to oversize bolted junctions.
- Bolts' loading's value must be checked.
- Gasket seats must be perfectly cleaned, and machined without radial flaws.

REFERENCES :

- B. CHIAVASSA : Etude d'échangeur boulonné par la méthode des super éléments en modelisation 3D. Etude FRAMATOME N° ETC-DM-0025 du 20.09.84

- J.C. YAZIDJIAN : Modification de l'échangeur de soutirage excédentaire de BLAYAIS 2.
Résultats des essais de qualification.
Rapport FRAMATOME N° ETCTC-DC-0055 du 18.05.1984.

- G. MIRANDA : Modification des échangeurs de refroidissement à l'arrêt de BLAYAIS 2 -
Résultats des essais de qualification.
Rapport FRAMATOME N° ETCTC-DC-0056 du 1.07.1984.

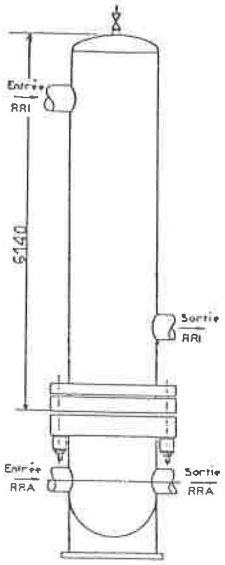
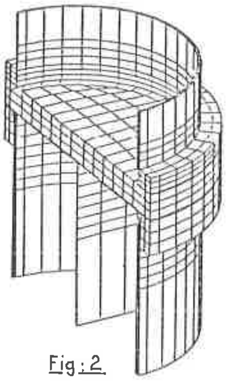


Fig: 1



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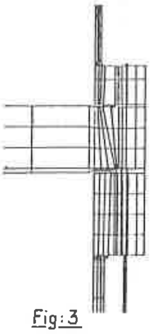

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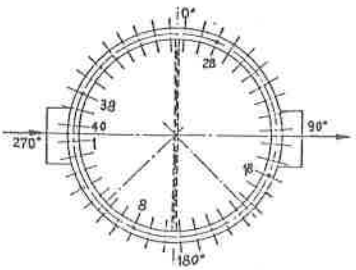

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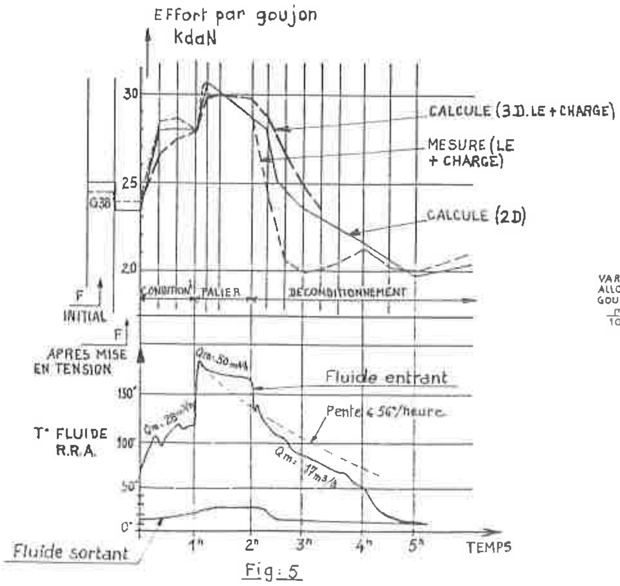

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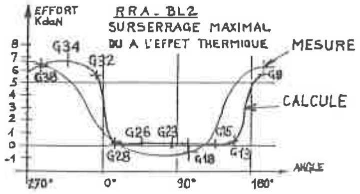

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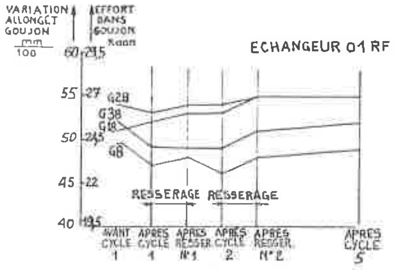

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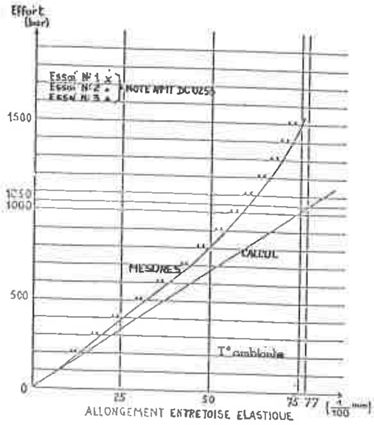

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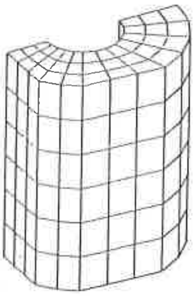

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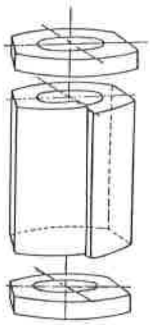

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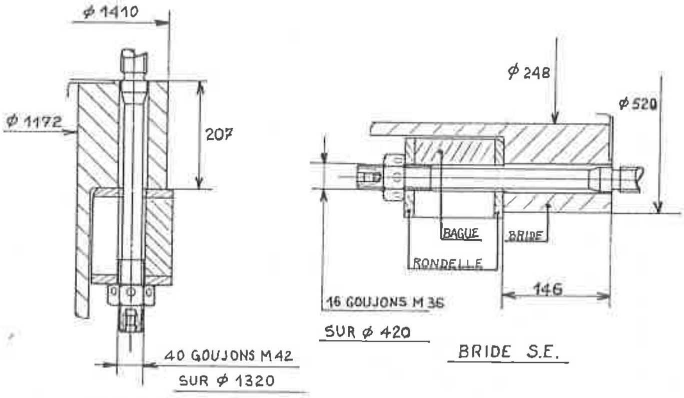


BRIDE R.R.A.

BRIDE S.E.

Fig: 11

SE-BAGUES ELASTIQUES

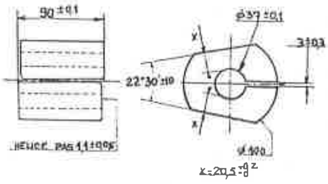


Fig: 12

BAGUE TYPE "CP2"

MATIERE 40 NCDV 07.03

F max : 34 T .

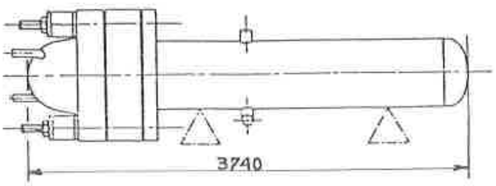
σ MENBRANE : 31 hbar

σ MENBRANE - FLEXION : 66, 4 hbar

FLECHE SOUS CHARGEMENT MAX : 0, 96 mm

FLECHE MAX : 0,99 mm

Fig: 13



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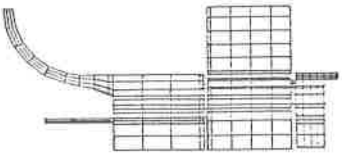

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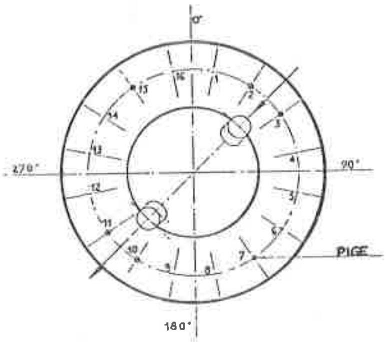

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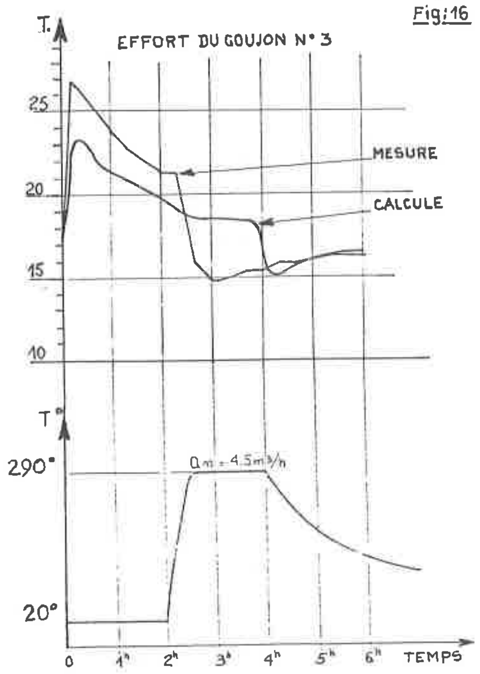
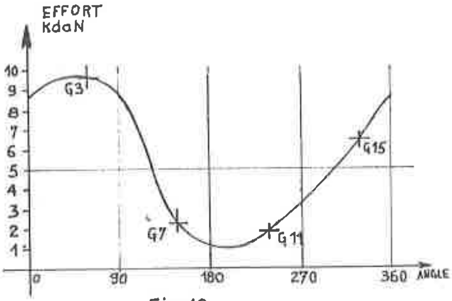


Fig:17



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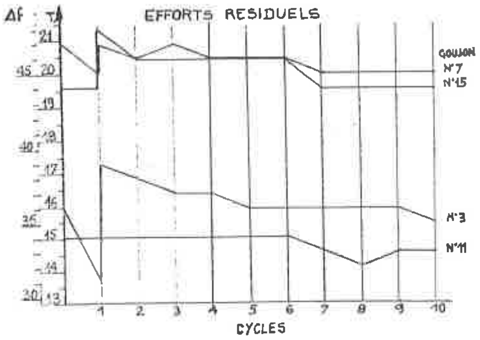

Fig: 19