EUROPEAN COMMISSION
5th EURATOM FRAMEWORK PROGRAMME 1998-2002
KEY ACTION : NUCLEAR FISSION

HTR-E

High-Temperature Reactor Components and Systems

CONTRACT N°
FIKI-CT-2001-00177

D18 Recuperator: Adaptation of the test rig

F. PRA (CEA / FRANCE)

Dissemination level: RE
Document N°: HTR-E-05/03-D-2-3-2
Status: Final
Deliverable n°18

Direction de la recherche technologique
Laboratoire d'innovation pour les technologies
des énergies nouvelles et les nanomatériaux
Département des systèmes pour les énergies nouvelles
Service GREThE
LETH

Rapport technique DSEN/DR/2005/ 029

«HTR-E – D18 RECUPERATOR : Adaptation of the test rig»

Auteur (s): Franck PRA

Référence du contrat	
Référence PRODEM	05-00934-1
Nature du rapport	Avancement
Confidentialité	Les informations contenues dans le présent document sont la propriété des contractants. Il ne peut être reproduit ou transmis à des tiers sans l'autorisation expresse des contractants.

	Rédacteur	Vérificateur	Approbateur
Nom	F.PRA	P.TOCHON	P.MERCIER
Fonction	Chef de Projet	Responsable Technique	Chef du LETH
Signature			P.O.
Date	14-3-05	14-3-05	14-3-05

LISTE DE DIFFUSION

Rapport complet à :

CLIENT	D.BESSON (Framatome ANP Lyon)	1 ex.
DEN/CAD/DER/STR	A.BERJON	1 ex
DSEN/DIR	Chef de Département et son adjoint	1 ex.
	Correspondant Programme du thème de la note	1 ex.
DSEN/GREThE	C. MARVILLET	1 ex.
	P.MERCIER	1 ex.
	P.TOCHON	1 ex.
	F.PRA	
	Archivage	Original + 1 ex.

Page de garde + résumé + Liste de diffusion à :

Chefs des autres services du DSEN
Chefs des laboratoires du service

Page de garde + résumé + Liste de diffusion + Lettre d'envoi à :

Ingénieur Qualité
Bureau financier (Ventes)

Résumé

Résumé : Ce document présente le livrable 18 du WP 'Recuperator' du projet HTR-E. Les modifications de la boucle CLAIRE du GREThE, sur laquelle des récupérateurs de chaleur compacts doivent être testés, sont décrites.

Abstract:

This document presents the deliverable 18 of the WP 'Recuperator' of the HTR-E project. The upgrading of CLAIRE test loop of the GREThE, on which compact recuperators have to be tested, is described.

TABLE OF CONTENTS

1 INTRODUCTION

Within the HTR-E program, some recuperators have to be tested on a test rig of the GREThE. This loop, namely CLAIRE, is located at CEA research centre at GRENOBLE. To carry out thermal and hydraulic tests in steady and transient conditions, GREThE has to modify one of its test rig which was initially designed for glass industry components tests.
In its new configuration, the loop is designed to fit to HTR direct cycle working conditions of the recuperator.

2 DESIGN OF CLAIRE LOOP

The table 2.1 reminds the typical thermal and hydraulic steady state working conditions. The values are extracted from "HTR-E-Recuperator, specifications of typical operating conditions for HTR" written by Framatome ANP [1].

Name of parameter	Value
Thermal capacity	635 MWth
Thermal effectiveness	0.95
Helium parameters on low pressure side	
flow rate	316 kg/s
inlet temperature	510 °C
outlet temperature	125 °C
inlet pressure	2.63 MPa
pressure losses	no more than around 0.03 MPa
Helium parameters on high pressure side	
flow rate	313 kg/s
inlet temperature	105 °C
outlet temperature	490 °C
inlet pressure	7.07 MPa
pressure losses	not more than around 0.07 Mpa (instead of 0.03 Mpa in Framatome's report)
ΔP between the high and low pressure sides	4.5 MPa

Table 2.1: GT-MHR typical steady state working conditions

In accidental cases, some potential transients have been identified. For the recuperator, the most severe case generates high temperature variations. On low pressure side, the temperature at the inlet of the recuperator may decrease from 510 to 180°C within 5 seconds and it may reach again 510°C within 120 seconds.

2.1 Main specifications of the loop

Figure 2.2 shows the schema of the loop.

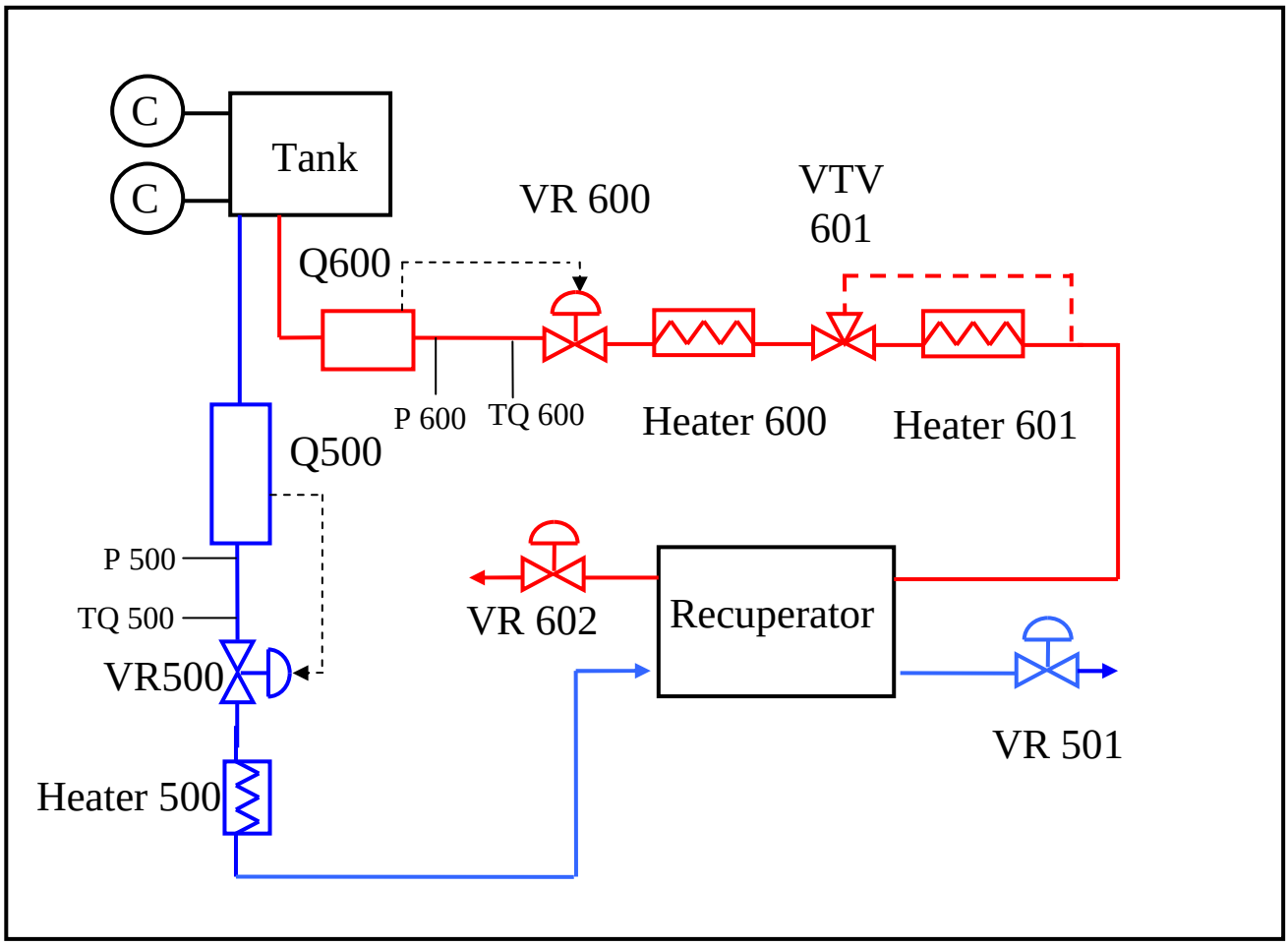


Figure 2.2: Schema of the loop

CLAIRE is an air open loop and the heat exchanger is fed by a compressor on both sides. It includes 2 different circuits:

- A hot one (red line)
- A cold one (blue line)

Depending on the heat duty one or two compressors are used. A tank is fed by compressor(s) and is equipped with regulation valves so that the flow rate remains steady.

2.1.1 Cold circuit (500)

The cold circuit is equipped with following elements:

- Flow meter (Q500) (a thermocouple and a pressure sensor are located near the flow meter to get the mass flow rate);
- An electro pneumatic regulation valve (VR500) to regulate the air flow to desired value;
- A pneumatic valve (VR501) to adjust the heat exchanger inlet pressure;

- A 24 kW electrical heater (Heater 500) which allows to heat cold air to the expected temperature. The temperature is regulated by the inlet heat exchanger temperature.

2.1.2 Hot circuit (600)

The hot circuit is quite similar to the cold one since it always has the following elements:

- Flow meter (600) (a thermocouple and a pressure sensor are located near the flow meter to get the mass flow rate);
- An electro pneumatic regulation valve (VR600) to regulate the air flow to desired value;
- A pneumatic valve (VR602) to adjust the heat exchanger inlet pressure.

This circuit is equipped with 2 heaters (heater 600 and heater 601). Heater 600 is a 42 kW electrical heater which used to preheat air from ambient temperature to 180°C. Heater 601 is a 80 kW electrical heater which allows to heat air from 180°C to 510°C.
A 3 ways valve (VTV 601) is inserted between the 2 heaters to generate the desired temperature transient at the inlet of the heat exchanger. In nominal working conditions, air circulates simultaneously through both heaters.

To generate a sudden temperature variation, the valve is commutated so that heater 601 is bypassed and the inlet temperature of the heat exchanger becomes equal to the outlet temperature of heater 600. So cold shocks can be generated.

In the other way, it is also possible to realize hot shocks by commutating VTV 601 in its preliminary position.

3 RANGE OF WORKING CONDITIONS

3.1 Steady state

The loop is designed to test significant size of heat exchangers without generating too expensive costs. So the maximum mass flow rate is limited to 0.2 kg/s on both side and the maximum operating pressure at the inlet of the heat exchanger is 6 bars.

Table 3.1 gives the nominal operating conditions of CLAIRE loop.

	Hot side (600)	**Cold side (500)**
Mass flow rate (kg/s)	0.04 <M<0.2	
Inlet HX temperature (°C)	510 (up to 550)	105
Inlet HX pressure (Bar)	~6	~6
Allowed HX pressure drop (bar)	~2	

Table 3.1: nominal working conditions

3.2 Transient conditions

The loop is designed to generate transient temperature on hot side (600). Cold and hot shocks can be realized on CLAIRE loop. By passing the second heater (heater 601) it is possible to change the inlet heat exchanger temperature from 510°C to 180°C within 5 seconds.
In the same way it is possible to generate hot shock by flowing once again in heater 601. This shock is less severe (in term of temperature variation by unit of time) since it is directly linked to the thermal inertia of the heater. Typically, it requires about 120 seconds for increasing the temperature at the inlet of the heat exchanger from 180°C to 510°C (with nominal mass flow rate equals to 0.1 kg/s).

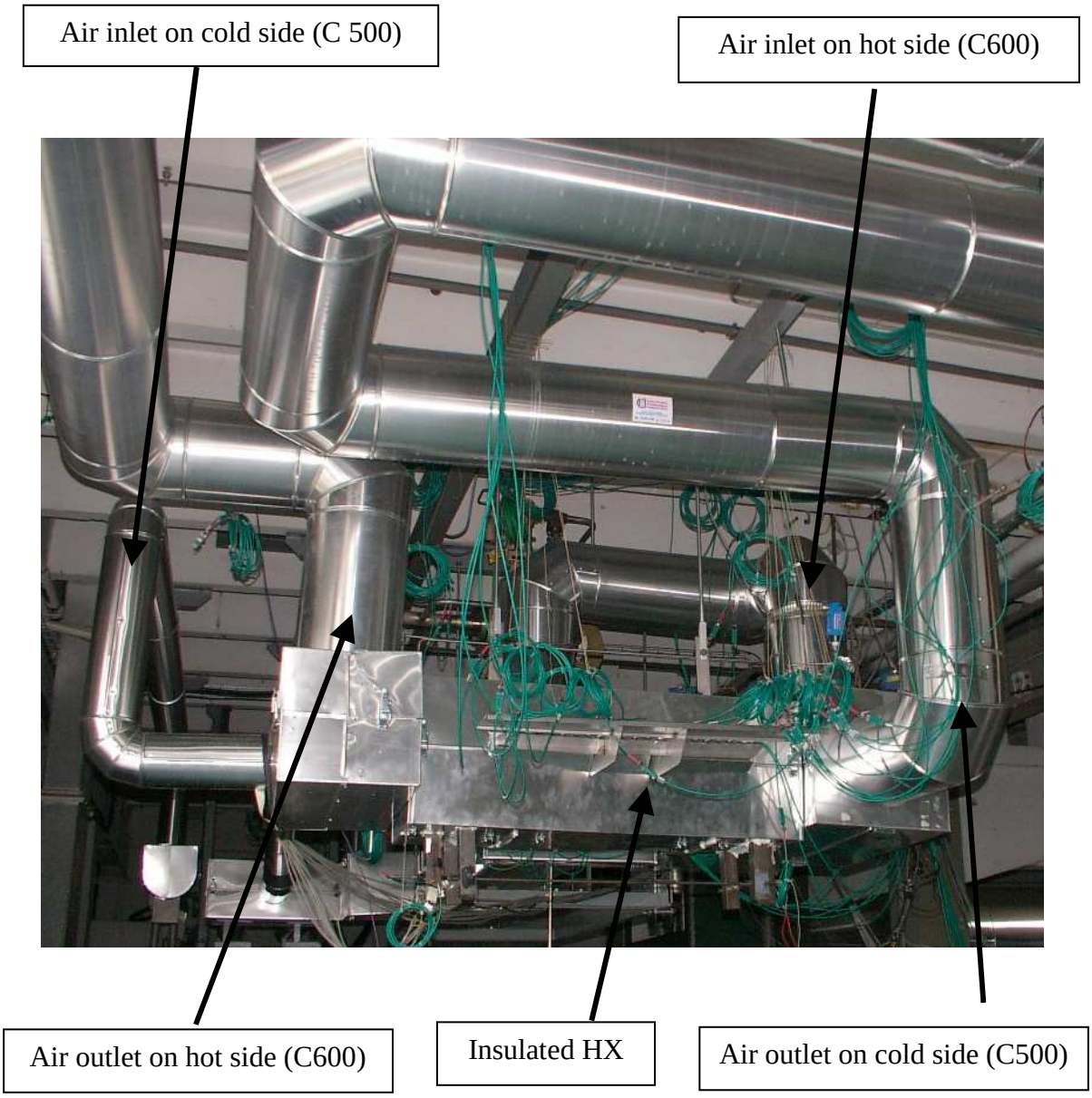
4 CONCLUSIONS

CLAIRE loop was designed to suit to HTR direct cycle specifications in order to test heat exchangers. With this loop, it is possible to test components in steady state working conditions but also in temperature transient conditions. In steady state conditions, it is possible to determine friction and thermal law of heat exchangers. In transient conditions, by repeating cold and hot shocks, CLAIRE loop allows having tendencies for thermo mechanical behaviour on a given technology of recuperator.
CLAIRE loop may be also used to test other components under hot gas temperature. At the moment, the loop is designed to work up to 550°C but adding other heaters and modifying some pipes, it will be possible to increase its nominal working temperature.

Annexe 1: Photos of the test rig

Electrical heaters of circuit 600 : Heater 600 et Heater 601

3 ways valve of circuit 600



Heat exchanger during tests

Bibliography

1. HTR-E-Recuperator, specifications of typical operating conditions for HTR" by Framatome ANP, First issue, 31/05/2002.