

		<b>PROCES-VERBAL D'ESSAI</b> <b>TEST REPORT</b> <b>CRYOGENIC TURBO EXPANDER</b>			<b>N° : C4058-NT-25 (3)</b> Folio : 1 / 11		
<b>AFFAIRE : RHEA</b> <b>JOB :</b>				<b>N° : 301 0914</b> <b>N° :</b>		<b>Fiche Suiveuse n° :</b> <b>Inspection traveller n° :</b>	
Identification du matériel : <b>C6 596 HI<sub>1</sub></b> N° : 324-XT004 <i>Material identification :</i>				<b>Quantité / Quantity : 1</b> <b>Lot / Batch :</b>			
Fournisseur/Fabricant : <i>Supplier / Manufacturer :</i> <b>AIR LIQUIDE</b>		Organisme de Contrôle : <i>Inspected by :</i> <b>DTEC</b>		Lieu : <i>Location :</i> <b>Sassenage</b>		Phase : <i>Phase :</i>	
Documents de référence : <i>Reference documents :</i> <b>PROCEDURE : D4444-PO-2</b>				Instruments de contrôles utilisés : <i>Inspection instruments used :</i>			
				Type / Type		N° de Gestion/Control n°	
				<b>Test bed</b>		<b>504 9999 100</b>	
<b>MESURES</b>		<b>RESULTATS</b>		<b>OBSERVATIONS</b>			
PIVOTERIE / <i>BEARINGS</i>		Pass					
VITESSES CRITIQUES <i>Critical speeds</i>		Pass					
SURVITESSE / <i>Overspeeds</i>		Pass					
DESCENTE EN FROID <i>Cold down</i>		Pass		Limited by the test bench			
RENDEMENT / <i>Efficiency</i>		Pass		Limited by the test bench			
<b>DECISION :</b> <i>DECISION :</i> <b>CONFORME / PASS</b> <input checked="" type="checkbox"/> <b>NON CONFORME / FAIL</b> <input type="checkbox"/>				<b>OBSERVATIONS :</b> <i>COMMENTS :</i>			
	<b>ESSAI / TEST</b>	<b>Responsible / Manager</b>		<b>A.Q. / Q.A.</b>			
<b>NOM / NAME</b>	B. Renzetti	F. Delcayre					
<b>DATE / DATE</b>	11 09 2013	11 09 2013					
<b>SIGNATURE / VISA</b>							

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## 1. SCOPE

This report is a summary of the tests of a Cryogenic turbo-expander cartridge, performed on DTA test bed according to the procedure D4444-PO-2.

## 2. PROCESS CONDITION

The data sheet in appendix gives the turbine process conditions specified by the customer.

## 3. GAS USED FOR THE TEST

Helium

Nitrogen

## 4. BEARING CONDITIONS

The diagrams in appendix give the gas bearing conditions :

- to be applied on site,
- to be applied during the test.

## 5. ANNEXES

TESTS REPORTS

**TEST REPORT**
**5.1 THRUST BEARING TEST, LOW SPEED**

(Items 6.1 of procedure)

 Cartridge number: C6 596 HI<sub>1</sub>

Bearing conditions required: NORMAL

<b>CASE</b>	<b>EXTREME 1</b>	<b>EXTREME 2</b>	
<b>INPUTS</b>			
Load	0	826	N
On	Brake	Turbine	Bearing
Equivalent pressure difference on the shaft	0	26	10 <sup>5</sup> Pa
<b>OUTPUTS</b>			
Inlet bearing pressure	15.36	15.38	10 <sup>5</sup> Pa
Outlet bearing pressure	2.94	2.91	10 <sup>5</sup> Pa
Turbine outlet pressure (1)	3.08	3.07	10 <sup>5</sup> Pa
Brake pressure (2)	2.92	17.44	14.04
Pressure difference = (2) – (1)	-0.16	14.37	10 <sup>5</sup> Pa
Speed	12	8	Hz
Passed/failed	passed	passed	

**TEST REPORT**
**5.2 THRUST AND JOURNAL BEARINGS TEST, HIGH SPEED**

(Items 6.2 of procedure)

Cartridge number: C6 596 HI<sub>1</sub>

Bearing conditions required: NORMAL

<b>MODE</b>	<b>MINIMAL</b>	<b>NOMINAL</b>	<b>MAXIMAL</b>	
<b>INPUTS</b>				
Turbine outlet design pressure (1)	5.7	4.9	3.5	10 <sup>5</sup> Pa
Brake design pressure (2)	8.8	11	14.3	10 <sup>5</sup> Pa
$\Delta = 2-1$	3.1	6.1	10.8	10 <sup>5</sup> Pa
<b>OUTPUTS</b>				
Inlet bearing pressure	15.33	15.33	15.35	10 <sup>5</sup> Pa
Outlet bearing pressure	2.99	3.05	2.98	10 <sup>5</sup> Pa
Turbine outlet test pressure (1)	3.36	3.42	3.46	10 <sup>5</sup> Pa
Brake test pressure (2)	6.26	9.44	14.27	10 <sup>5</sup> Pa
$\Delta = (2) - (1)$	2.9	6.02	10.81	10 <sup>5</sup> Pa
Speed	1159	949	826	Hz
Passed/failed	Passed	Passed	passed	

**TEST REPORT**
**5.3 THRUST AND JOURNAL BEARING TEST, HIGH SPEED**

(Items 6.2 of procedure)

 Cartridge number: C6 596 HI<sub>1</sub>

Bearing conditions required: ALARM AND STOP

<b>BEARING CONDITIONS</b>	<b>ALARM</b>	<b>STOP</b>	
Mode	Nominal	Nominal	
<b>INPUTS</b>			
Turbine design outlet pressure (1)	4.9	4.9	10 <sup>5</sup> Pa
Brake design pressure (2)	11	11	10 <sup>5</sup> Pa
$\Delta = 2-1$	6.1	6.1	10 <sup>5</sup> Pa
<b>OUTPUTS</b>			
Inlet bearing pressure		14.12	10 <sup>5</sup> Pa
Outlet bearing pressure		3.0	10 <sup>5</sup> Pa
Turbine outlet test pressure		3.39	10 <sup>5</sup> Pa
Brake outlet pressure		5.75	10 <sup>5</sup> Pa
$\Delta = 2-1$		2.36	10 <sup>5</sup> Pa
Speed		1243	Hz
Passed/failed		passed	

## TEST REPORT

### 5.4 CRITICAL SPEEDS AND SHAFT VIBRATIONS

(Items 6.3 of procedure)

Cartridge number: C6 596 HI<sub>1</sub>

Bearing conditions required: STOP

INPUTS					
	1 <sup>st</sup> RIGID MODE		2 <sup>nd</sup> RIGID MODE		
Calculated peak freq.	620		715		H <sub>z</sub>
OUTPUTS					
Measured critical speeds	BEGIN.	END	BEGIN.	END	H <sub>z</sub>
	650			750	
Sound level estimation	B		B		
Time within the mode (> 3 ')	3		3		Min
Inlet bearing pressure	15.33		15.33		10 <sup>5</sup> Pa
Outlet bearing pressure	2.99		2.99		10 <sup>5</sup> Pa
Passed/failed	passed		passed		

Sound level estimation:

A: Inaudible

B: Perceptible

C: Noisy

D: Excessive

## TEST REPORT

### 5.5 OVERSPEED TEST

(Items 6.4 of procedure)

Cartridge number: C6 596 HI<sub>1</sub>

Bearing conditions required: NORMAL

INPUTS				
Nominal speed (Hz)		Maximum speed (Hz)		Over speed (Hz)
1250		1350		1380
OUPUTS				
BEARING TEST CONDITIONS				
BEARING GAS PRESSURE (10 <sup>5</sup> Pa)		BEARING GAS TEMPERATURE (°C)		BEARING GAS FLOW RATE (g/s)
SUPPLY	RETURN	SUPPLY	RETURN	
15.32	2.99	16.3	24.3	19.61

### TURBINE TEST CONDITIONS

TURBINE PRESSURE (10 <sup>5</sup> Pa)		TURBINE TEMPERATURE (K)		TURBINE FLOW RATE (g/s)
SUPPLY	RETURN	SUPPLY	RETURN	
13.97	3.4	262.31	214.84	170.6

### BRAKE TEST CONDITIONS

INLET BRAKE PRESSURE 10 <sup>5</sup> Pa	OUTLET BRAKE TEMPERATURE °C
4.70	47.9

### TEST RESULTS

ROTATION SPEED Hz	STEADY STATE	OVERSPEED STATE DURATION (mn)	COMMENTS	
			FAIL	PASS
1380	A	3		X

Steady state evaluation:

A: Stable

B: Noisy

C: Unstable

## TEST REPORT

### 5.6 COOL DOWN, START-UP AND SHUT-DOWN

(Items 6.5 and 6.6 of procedure)

Cartridge number: C6 596 HI<sub>1</sub>

Bearing conditions required: normal

Nominal speed:

	AMBIENT	MEDIUM	+10% K	NOMINAL	- 10%	
Target outlet temperature	250	150	21	19	17	K
<b>TURBINE :</b>						
Inlet pressure	12.73	13.34	9.86			10 <sup>5</sup> Pa
Outlet pressure	3.34	3.20	3.67			10 <sup>5</sup> Pa
Inlet temperature	294.77	184.93	44.21			K
Outlet temperature	249.67	149.90	34.74			K
Flow	147.2	191.53	287.74			g/s
U1/C0	0.20	0.24	0.45			
μ	37.2	43.9	65.47			%
<b>BRAKE :</b>						
Inlet pressure	4.75	5.78	4.78			10 <sup>5</sup> Pa
Outlet temperature	25.4	54.9	35.3			°C
<b>BEARING :</b>						
Inlet pressure	15.32	15.40	16.02			10 <sup>5</sup> Pa
Outlet pressure	2.96	2.84	3.42			10 <sup>5</sup> Pa
Inlet temperature	16.1	18.93	18.77			°C
Outlet temperature	20.3	21.57	12.7			°C
Inlet flow	19.17	18.93	18.77			g/s
<b>SPEED :</b>	1258	1213	964			Hz
Number of start up/shut down	3	<del>X</del>	3			
Fail/pass	passed	passed	passed			

AFFAIRE / JOB : RHEA

N° : 301 0914

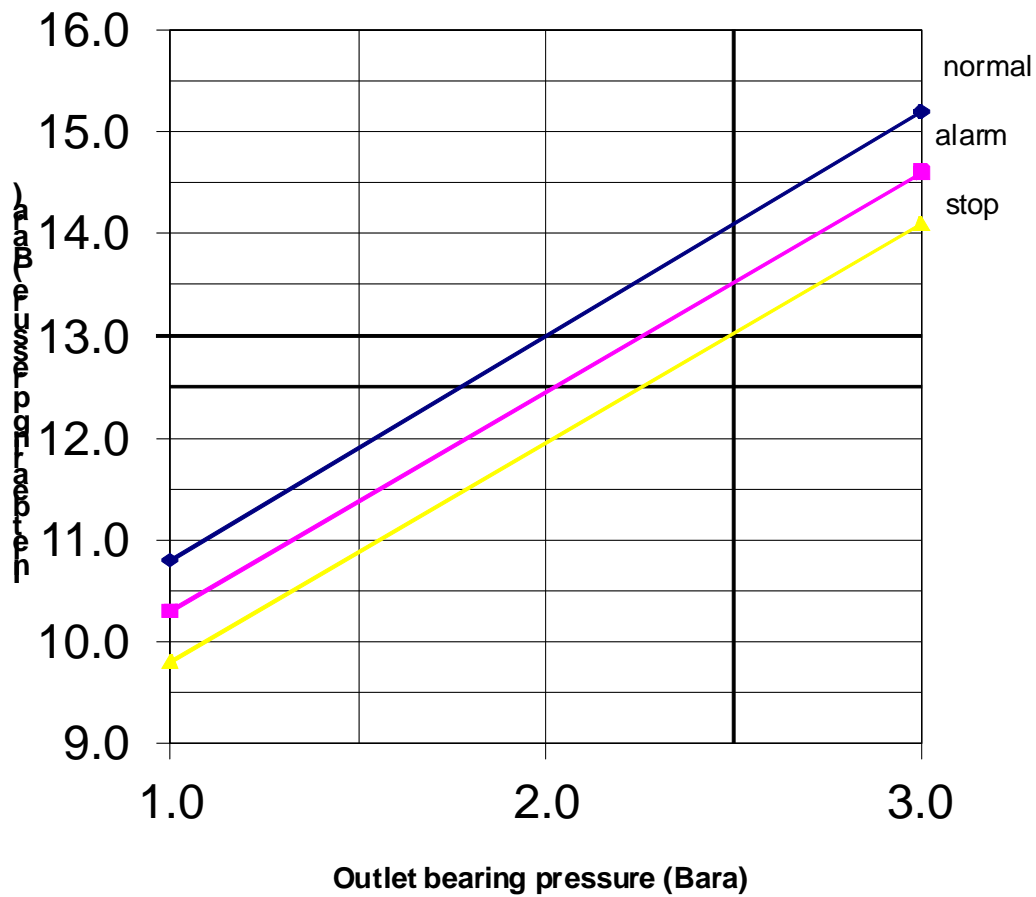
 Identification du matériel / Material identification : C6 596 HI<sub>1</sub>

 APPLICATION :  Site Client/Customer

 ALAT Test

## Bearing diagram

Helium Test



## TEST REPORT

### 5.7 EFFICIENCY VERSUS U1/CO

(Items 6.7 of procedure)

Cartridge number: C6 596 HI<sub>1</sub>

#### INPUTS

#### TURBINE PROCESS CONDITIONS

GAS	PRESSURES 10 <sup>5</sup> Pa		TEMPERATURES K		FLOW kg/s 10 <sup>-3</sup>	ENTHALP. DROP kJ/kg		$\eta$ $\Delta H_r / \Delta H_s$	ROTATION SPEED Hz	REFRIG. POWER Watt	INLET WHEEL PRESS. 10 <sup>5</sup> Pa
	INLET	OUTLET	INLET	OUTLET		$\Delta H_s$	$\Delta H_r$				
He	19.1	4.9	28.6	19.1	987	63.3	49.3	0.78	1250	48600	10.5

#### OUTPUTS

#### TURBINE TEST CONDITIONS

GAS	PRESSURES 10 <sup>5</sup> Pa		TEMPERATURES K		FLOW kg/s 10 <sup>-3</sup>	ENTHALP. DROP KJ/kg		$\eta$ $\Delta H_r / \Delta H_s$	ROTATION SPEED Hz	REFRIG. POWER Watt	INLET WHEEL PRESS. 10 <sup>5</sup> Pa
	INLET	OUTLET	INLET	OUTLET		$\Delta H_s$	$\Delta H_r$				
He	9.86	3.67	44.21	34.74	287.7	76.43	50.03	0.65	964	14938	5.14

#### BEARING TEST CONDITIONS

GAS	PRESSURES 10 <sup>5</sup> Pa		TEMPERATURES °C	
	INLET	OUTLET	INLET	OUTLET
He	16.02	3.42	17.9	12.7

#### BRAKE TEST CONDITIONS

GAS	PRESSURES 10 <sup>5</sup> Pa		TEMPERATURES °C	
	INLET	OUTLET	INLET	OUTLET
He	4.78			35.3

#### TEST RESULTS

WHEEL DIAM. mm	TIP VELOCITY U <sub>1</sub> m/s	SPOUTING VELOCITY C <sub>0</sub> m/s	U <sub>1</sub> / C <sub>0</sub>	$\eta$ %	COMMENTS	
					FAIL	PASS
58.0	175.65	390.97	0.45	65.4		X

#### UTILITY FLOW RATE

GAS BEARING SUPPLY g / s	BRAKE SUPPLY g / s	SEAL GAS g / s	RETURN g / s
18.77	0	0.2	20.62