

		<b>PROCES-VERBAL D'ESSAI</b> <b>TEST REPORT</b> <b>CRYOGENIC TURBO EXPANDER</b>			<b>N° : C4058-NT-25 (0)</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> <i>Material identification :</i>		<b>N° : 324-XT004</b>		<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>	09 07 2012	10 07 2012				
<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	14.05	14.07	10 <sup>5</sup> Pa
Outlet bearing pressure	3.13	3.0	10 <sup>5</sup> Pa
Turbine outlet pressure (1)	3.16	2.98	10 <sup>5</sup> Pa
Brake pressure (2)	3.17	17.64	14.04
Pressure difference = (2) – (1)	0.01	14.66	10 <sup>5</sup> Pa
Speed	>0	3	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

MODE	MINIMAL	NOMINAL	MAXIMAL	
INPUTS				
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
OUTPUTS				
Inlet bearing pressure	14.08	14.07	14.1	10 <sup>5</sup> Pa
Outlet bearing pressure	2.84	3.0	3.01	10 <sup>5</sup> Pa
Turbine outlet test pressure (1)	3.37	3.46	3.48	10 <sup>5</sup> Pa
Brake test pressure (2)	6.33	9.57	14.17	10 <sup>5</sup> Pa
$\Delta = (2) - (1)$	2.96	6.11	10.69	10 <sup>5</sup> Pa
Speed	1253	1037	853	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		13.2	10 <sup>5</sup> Pa
Outlet bearing pressure		2.97	10 <sup>5</sup> Pa
Turbine outlet test pressure		3.36	10 <sup>5</sup> Pa
Brake outlet pressure		5.25	10 <sup>5</sup> Pa
$\Delta = 2-1$		1.89	10 <sup>5</sup> Pa
Speed		1260	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	
	650			750	H <sub>z</sub>
Sound level estimation	A		A		
Time within the mode (> 3 ')					Min
Inlet bearing pressure	14.06		14.06		10 <sup>5</sup> Pa
Outlet bearing pressure	3.0		3.0		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	
14.06	3.02	18.8	31.6	14.64

**TURBINE TEST CONDITIONS**

TURBINE PRESSURE (10 <sup>5</sup> Pa)		TURBINE TEMPERATURE (K)		TURBINE FLOW RATE (g/s)
SUPPLY	RETURN	SUPPLY	RETURN	
14.28	3.42	251.14	203.99	175.5

**BRAKE TEST CONDITIONS**

INLET BRAKE PRESSURE 10 <sup>5</sup> Pa	OUTLET BRAKE TEMPERATURE °C
4.92	55.8

**TEST RESULTS**

ROTATION SPEED H <sub>z</sub>	STEADY STATE	OVERSPEED STATE DURATION (mn)	COMMENTS	
			FAIL	PASS
1392	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	12.41	12.77	8.96			10 <sup>5</sup> Pa
Outlet pressure	3.35	3.34	3.9			10 <sup>5</sup> Pa
Inlet temperature	278.94	183.88	30.85			K
Outlet temperature	235.39	150.02	24.26			K
Flow	144.3	183.7	310.5			g/s
U1/C0	0.21	0.25	0.56			
μ	38.61	44.77	74.99			%
<b>BRAKE :</b>						
Inlet pressure	4.84	5.32	3.96			10 <sup>5</sup> Pa
Outlet temperature	34.2	54.0	35.9			°C
<b>BEARING :</b>						
Inlet pressure	14.07	13.99	14.02			10 <sup>5</sup> Pa
Outlet pressure	3.02	3.02	3.76			10 <sup>5</sup> Pa
Inlet temperature	19.4	18.8	19.3			°C
Outlet temperature	28.3	33.0	15.0			°C
Inlet flow	14.5	14.19	13.4			g/s
<b>SPEED :</b>	1256	1237	923			Hz
Number of start up/shut down	3	<del>          </del>	3			
Fail/pass	passed	passed	passed			

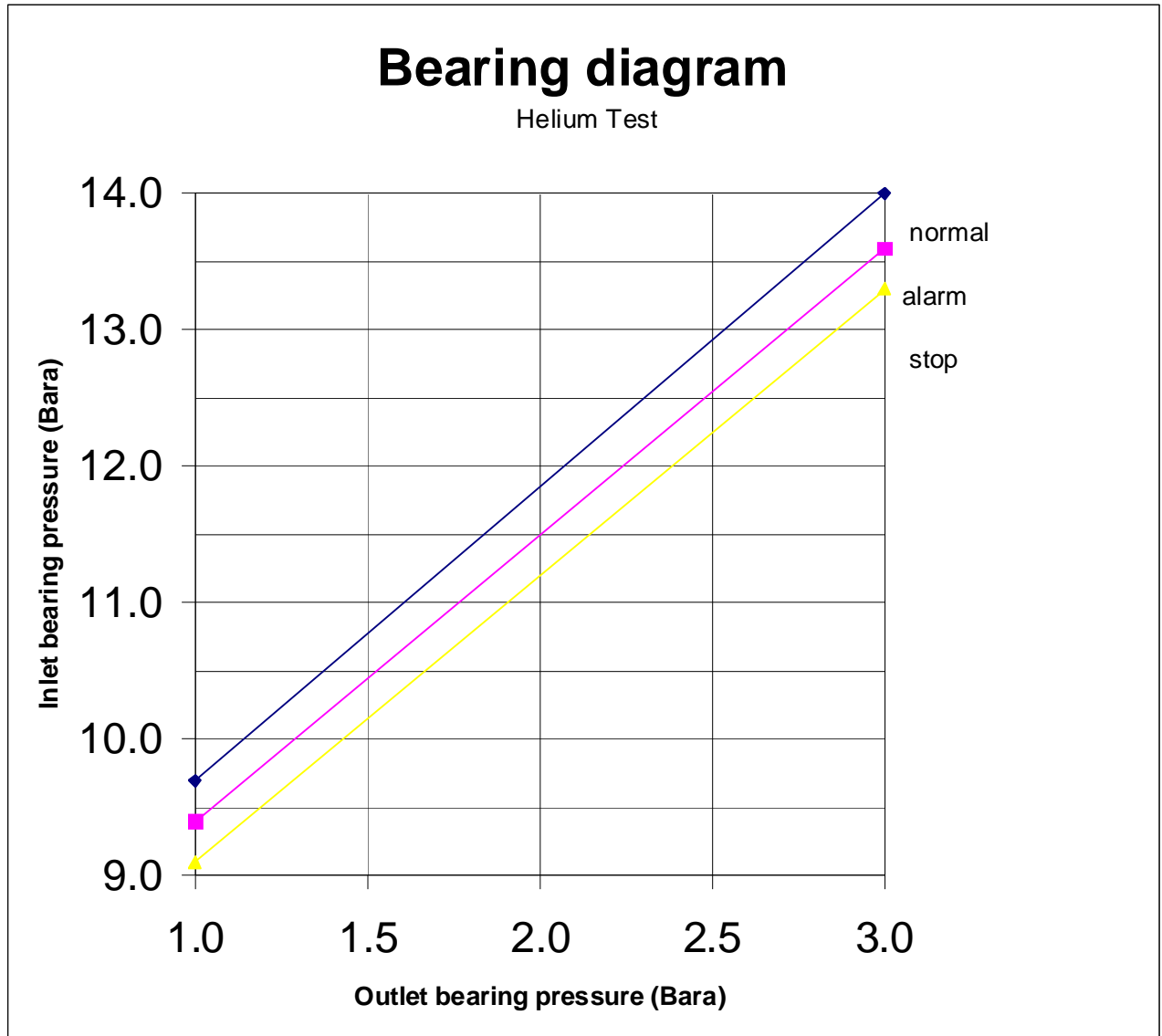
AFFAIRE / JOB : RHEA

N° : 301 0914

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

APPLICATION :     Site Client/Customer

ALAT Test



## 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	9.55	3.93	33.91	26.11	318.4	53.37	40.9	0.76	959	13026	5.47

#### BEARING TEST CONDITIONS

GAS	PRESSURES 10 <sup>5</sup> Pa		TEMPERATURES °C	
	INLET	OUTLET	INLET	OUTLET
He	14.03	3.77	19.4	15.5

#### BRAKE TEST CONDITIONS

GAS	PRESSURES 10 <sup>5</sup> Pa		TEMPERATURES °C	
	INLET	OUTLET	INLET	OUTLET
He	4.2			37.5

#### 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	174.65	326.7	0.54	76.65		X

#### UTILITY FLOW RATE

GAS BEARING SUPPLY g / s	BRAKE SUPPLY g / s	SEAL GAS g / s	RETURN g / s
13.47	0.12	0.23	14.49