

		<b>PROCES-VERBAL D'ESSAI</b> <b>TEST REPORT</b> <b>CRYOGENIC TURBO EXPANDER</b>			<b>N° : C4058-NT-21 (0)</b> Folio : 1 / 11		
<b>AFFAIRE : RHEA</b> <b>JOB :</b>				<b>N° : 301 0914</b> <b>N° :</b>		Fiche Suiveuse n° : <i>Inspection traveller n° :</i>	
Identification du matériel : <b>C7 510 HL<sub>1</sub></b> N° : 322XT001 <i>Material identification :</i>				Quantité / <i>Quantity</i> :      1 Lot / <i>Batch</i> :			
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 / <i>Type</i>		N° de Gestion/ <i>Control n°</i>	
				<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					
RENDEMENT / <i>Efficiency</i>		Pass					
<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>Responsable / Manager</b>		<b>A.Q. / Q.A.</b>			
<b>NOM / NAME</b>	L. Pelosi	F. Delcayre					
<b>DATE / DATE</b>	16 11 2011	17 11 2011					
<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: C7 510 HL<sub>1</sub>

Bearing conditions required: NORMAL

CASE	EXTREME 1	EXTREME 2	
INPUTS			
Load	0	900	N
On	Brake	Turbine	Bearing
Equivalent pressure difference on the shaft	0	14	10 <sup>5</sup> Pa
OUTPUTS			
Inlet bearing pressure	9.41	9.42	10 <sup>5</sup> Pa
Outlet bearing pressure	1.91	1.93	10 <sup>5</sup> Pa
Turbine outlet pressure (1)	1.94	1.97	10 <sup>5</sup> Pa
Brake pressure (2)	1.95	11.94	10 <sup>5</sup> Pa
Pressure difference = (2) – (1)	0.01	9.97	10 <sup>5</sup> Pa
Speed	6	14	Hz
Passed/failed	passed	passed	

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

(Items 6.2 of procedure)

 Cartridge number: C7 510 HL<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)	3.0	1.9	1.3	10 <sup>5</sup> Pa
Brake design pressure (2)	5.6	7.0	8.4	10 <sup>5</sup> Pa
$\Delta = 2-1$	2.6	5.1	7.1	10 <sup>5</sup> Pa
<b>OUTPUTS</b>				
Inlet bearing pressure	9.48	9.34	9.38	10 <sup>5</sup> Pa
Outlet bearing pressure	1.63	1.64	1.6	10 <sup>5</sup> Pa
Turbine outlet test pressure (1)	3.05	3.09	3.06	10 <sup>5</sup> Pa
Brake test pressure (2)	5.53	8.46	9.15	10 <sup>5</sup> Pa
$\Delta = (2) - (1)$	2.48	5.37	6.09	10 <sup>5</sup> Pa
Speed	558	462	445	Hz
Passed/failed	passed	passed	passed	

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

(Items 6.2 of procedure)

 Cartridge number: C7 510 HL<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)	1.9	1.9	10 <sup>5</sup> Pa
Brake design pressure (2)	7.0	7.0	10 <sup>5</sup> Pa
$\Delta = 2-1$	5.1	5.1	10 <sup>5</sup> Pa
<b>OUTPUTS</b>			
Inlet bearing pressure		8.2	10 <sup>5</sup> Pa
Outlet bearing pressure		1.6	10 <sup>5</sup> Pa
Turbine outlet test pressure		3.0	10 <sup>5</sup> Pa
Brake outlet pressure		4.53	10 <sup>5</sup> Pa
$\Delta = 2-1$		1.53	10 <sup>5</sup> Pa
Speed		609	Hz
Passed/failed		passed	

## TEST REPORT

### 5.4 CRITICAL SPEEDS AND SHAFT VIBRATIONS

(Items 6.3 of procedure)

Cartridge number: C7 510 HL<sub>1</sub>

Bearing conditions required: STOP

INPUTS					
	1 <sup>st</sup> RIGID MODE		2 <sup>nd</sup> RIGID MODE		
Calculated peak freq.	340		490		H <sub>z</sub>
OUTPUTS					
Measured critical speeds	BEGIN.	END	BEGIN.	END	
	300				H <sub>z</sub>
Sound level estimation	A		A		
Time within the mode (> 3 ')					Min
Inlet bearing pressure	9.38		9.38		10 <sup>5</sup> Pa
Outlet bearing pressure	1.89		1.89		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: C7 510 HL<sub>1</sub>

Bearing conditions required: NORMAL

INPUTS				
Nominal speed (Hz)		Maximum speed (Hz)		Over speed (Hz)
620		680		700
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	
9.44	1.6	17.7	18.9	

**TURBINE TEST CONDITIONS**

TURBINE PRESSURE (10 <sup>5</sup> Pa)		TURBINE TEMPERATURE (K)		TURBINE FLOW RATE (g/s)
SUPPLY	RETURN	SUPPLY	RETURN	
8.67	3.03	218.17	174.34	

**BRAKE TEST CONDITIONS**

INLET BRAKE PRESSURE 10 <sup>5</sup> Pa	OUTLET BRAKE TEMPERATURE °C
3.13	75.1

**TEST RESULTS**

ROTATION SPEED H <sub>z</sub>	STEADY STATE	OVERSPEED STATE DURATION (mn)	COMMENTS	
			FAIL	PASS
707	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: C7 510 HL<sub>1</sub>

Bearing conditions required: normal

Nominal speed:

	AMBIENT	MEDIUM	+10% K	NOMINAL	- 10%	
Target outlet temperature	250	150	110	100	90	K
<b>TURBINE :</b>						
Inlet pressure	7.14	8.59	8.1	8.02	7.92	10 <sup>5</sup> Pa
Outlet pressure	2.91	2.99	3.04	3.1	3.08	10 <sup>5</sup> Pa
Inlet temperature	266.3	194.11	134.02	125.1	120.76	K
Outlet temperature	228.02	156.6	107.79	100.39	96.91	K
Flow	689.2	969.2	1129.8	1164.2	1173.8	g/s
U1/C0	0.4	0.5	0.58	0.59	0.6	
μ	62.81	71.41	74.27	73.33	76.04	%
<b>BRAKE :</b>						
Inlet pressure	4.81	4.62	4.62	4.58	4.63	10 <sup>5</sup> Pa
Outlet temperature	33.2	66.0	60.4	57.8	56.8	°C
<b>BEARING :</b>						
Inlet pressure	9.4	8.88	8.77	9.27	9.28	10 <sup>5</sup> Pa
Outlet pressure	1.85	1.6	1.68	1.8	1.73	10 <sup>5</sup> Pa
Inlet temperature	15.7	18.9	19.5	19.6	19.7	°C
Outlet temperature	17.7	18.5	15.7	14.7	14.1	°C
Inlet flow	38.6	34.99	33.95	35.84	35.85	g/s
<b>SPEED :</b>	522	596	542	530	523	Hz
Number of start up/shut down	3	<del>          </del>	<del>          </del>	<del>          </del>	3	
Fail/pass	passed	passed	passed	passed	passed	

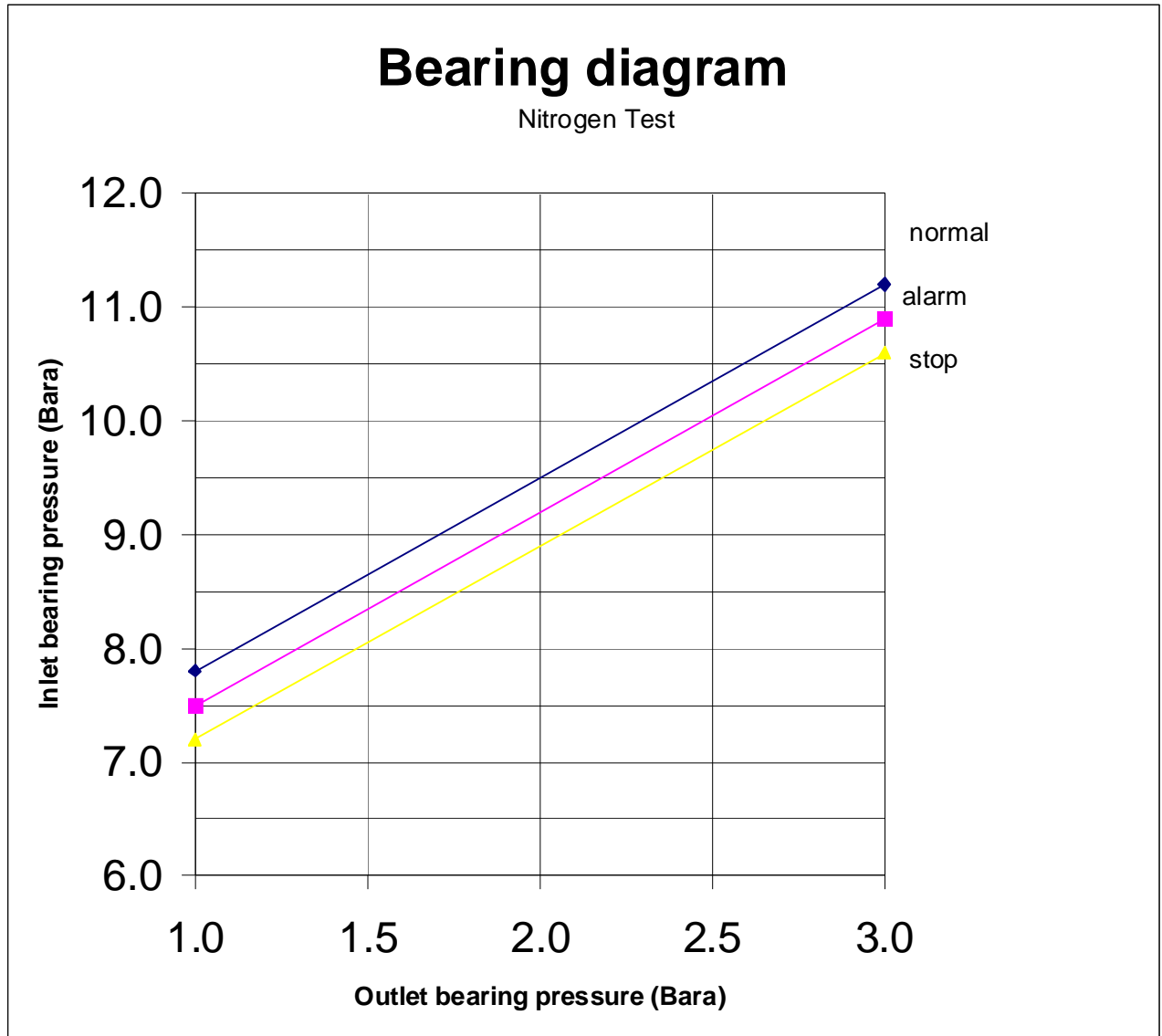
AFFAIRE / JOB : RHEA

N° : 301 0914

Identification du matériel / Material identification : C7 510 HL<sub>1</sub>

APPLICATION :  Site Client/Customer

ALAT Test



## TEST REPORT

### 5.7 EFFICIENCY VERSUS U1/CO

(Items 6.7 of procedure)

Cartridge number: C7 510 HL<sub>1</sub>

#### INPUTS

#### TURBINE PROCESS CONDITIONS (12.5Bar 735W/37Lh w LN2)

GAS	PRESSURES 10 <sup>5</sup> Pa		TEMPERATURES K		FLOW kg/s 10 <sup>-3</sup>	ENTHALP. DROP kJ/kg		$\eta$ $\Delta_{Hr} / \Delta_{Hs}$	ROTATION SPEED Hz	REFRIG. POWER Watt	INLET WHEEL PRESS. 10 <sup>5</sup> Pa
	INLET	OUTLET	INLET	OUTLET		$\Delta_{Hs}$	$\Delta_{Hr}$				
N <sub>2</sub>	5.53	1.86	127	99.8	743	34.4	26.2	0.76	620	19451	3.23

#### OUTPUTS

#### TURBINE TEST CONDITIONS

GAS	PRESSURES 10 <sup>5</sup> Pa		TEMPERATURES K		FLOW kg/s 10 <sup>-3</sup>	ENTHALP. DROP KJ/kg		$\eta$ $\Delta_{Hr} / \Delta_{Hs}$	ROTATION SPEED Hz	REFRIG. POWER Watt	INLET WHEEL PRESS. 10 <sup>5</sup> Pa
	INLET	OUTLET	INLET	OUTLET		$\Delta_{Hs}$	$\Delta_{Hr}$				
N <sub>2</sub>	8.14	3.17	124.53	99.83	1187.1	27.85	21.51	0.77	532	25532	5.04

#### BEARING TEST CONDITIONS

GAS	PRESSURES 10 <sup>5</sup> Pa		TEMPERATURES °C	
	INLET	OUTLET	INLET	OUTLET
N <sub>2</sub>	9.27	1.84	19.6	14.6

#### BRAKE TEST CONDITIONS

GAS	PRESSURES 10 <sup>5</sup> Pa		TEMPERATURES °C	
	INLET	OUTLET	INLET	OUTLET
N <sub>2</sub>	4.58			57.5

#### 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
85.0	142.0	236.0	0.6	77.21		X

#### UTILITY FLOW RATE

GAS BEARING SUPPLY	BRAKE SUPPLY	SEAL GAS	RETURN
g / s	g / s	g / s	g / s
35.8	1.23	1.63	42.26