AIR LIQUIDE ADVANCED TECHNOLOGIES	**PROCES-VERBAL D'ESSAI** ***TEST REPORT*** **CRYOGENIC TURBO EXPANDER**	**N° : C4058-NT-19 (1)** Folio : 1 / 11

AFFAIRE : **RHEA** *JOB* :	N° : 301 0914 *N° :*	Fiche Suiveuse n° : *Inspection traveller n° :*
Identification du matériel : **C6 594 HJ$_1$** N° : 324XT005 *Material identification* :	Quantité / *Quantity* : 1 Lot / *Batch* :	

Fournisseur/Fabricant : *Supplier / Manufacturer :* **AIR LIQUIDE**	Organisme de Contrôle : *Inspected by :* **DTEC**	Lieu : *Location :* **Sassenage**	Phase : *Phase :*

Documents de référence : *Reference documents :* PROCEDURE : **D4444-PO-2**	Instruments de contrôles utilisés : *Inspection instruments used :*	
	Type / *Type*	N° de Gestion/*Control n°*
	Test bed	**504 9999 100**

MESURES	**RESULTATS**	**OBSERVATIONS**
PIVOTERIE / *BEARINGS*	Pass	
VITESSES CRITIQUES *Critical speeds*	Pass	
SURVITESSE / *Overspeeds*	Pass	
DESCENTE EN FROID *Cold down*	Pass	
RENDEMENT / *Efficiency*	Pass	Limited by our test bench

DECISION : *DECISION :* **CONFORME** / *PASS* ☑ **NON CONFORME** / *FAIL* ☐	**OBSERVATIONS :** *COMMENTS :*

	ESSAI / *TEST*	**Responsable / *Manager***	**A.Q. / *Q.A.***		
NOM / *NAME*	R-Guimaraes	F. Delcayre			
DATE / *DATE*	16 12 2013	18 12 2013			
SIGNATURE / *VISA*					

CONTENTS

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 594 HJ_1
Bearing conditions required: NORMAL

CASE	EXTREME 1	EXTREME 2	
INPUTS			
Load	0	774	N
On	Brake	Turbine	Bearing
Equivalent pressure difference on the shaft	0	25	10^5Pa
OUTPUTS			
Inlet bearing pressure	12.46	12.49	10^5Pa
Outlet bearing pressure	2.54	2.58	10^5Pa
Turbine outlet pressure (1)	2.66	2.65	10^5Pa
Brake pressure (2)	2.67	16.55	10^5Pa
Pressure difference = (2) – (1)	-0.01	13.9	10^5Pa
Speed	17	10	H_Z
Passed/failed	passed	passed	

TEST REPORT

5.2 THRUST AND JOURNAL BEARINGS TEST, HIGH SPEED

(Items 6.2 of procedure)

Cartridge number: C6 594 HJ_1
Bearing conditions required: NORMAL

MODE	MINIMAL	NOMINAL	MAXIMAL	
INPUTS				
Turbine outlet design pressure (1)	1.65	1.2	1.1	10^5Pa
Brake design pressure (2)	6.4	8.0	12.0	10^5Pa
Δ = 2-1	4.75	6.8	10.9	10^5Pa
OUTPUTS				
Inlet bearing pressure	10.46	10.47	10.48	10^5Pa
Outlet bearing pressure	1.65	1.50	1.52	10^5Pa
Turbine outlet test pressure (1)	1.65	1.62	1.63	10^5Pa
Brake test pressure (2)	6.33	8.40	12.50	10^5Pa
Δ = (2) – (1)	4.68	6.78	10.87	10^5Pa
Speed	1314	1216	1002	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 594 HJ_1
Bearing conditions required: ALARM AND STOP

BEARING CONDITIONS	**ALARM**	**STOP**	
Mode	Nominal	Nominal	
INPUTS			
Turbine design outlet pressure (1)	1.2	1.2	10^5Pa
Brake design pressure (2)	8.0	8.0	10^5Pa
Δ = 2-1	6.8	6.8	10^5Pa
OUTPUTS			
Inlet bearing pressure		9.75	10^5Pa
Outlet bearing pressure		1.51	10^5Pa
Turbine outlet test pressure		1.61	10^5Pa
Brake outlet pressure		6.2	10^5Pa
Δ = 2-1		4.59	10^5Pa
Speed		1333	Hz
Passed/failed		passed	

TEST REPORT

5.4 CRITICAL SPEEDS AND SHAFT VIBRATIONS

(Items 6.3 of procedure)

Cartridge number: C6 594 HJ_1
Bearing conditions required: STOP

INPUTS					
	1^{st} RIGID MODE		2^{nd} RIGID MODE		
Calculated peak freq.	570		660		H_z
OUTPUTS					
Measured critical speeds	BEGIN.	END	BEGIN.	END	
	600			750	H_z
Sound level estimation	A		A		
Time within the mode (> 3 ‘)					Min
Inlet bearing pressure	10.44		10.44		10^5Pa
Outlet bearing pressure	1.57		1.57		10^5Pa
Passed/failed	passed		passed		

Sound level estimation:

A: Inaudible B: Perceptible C: Noisy D: Excessive

TEST REPORT

TEST REPORT

5.5 OVERSPEED TEST

(Items 6.4 of procedure)

Cartridge number: C6 594 HJ_1
Bearing conditions required: NORMAL

INPUTS		
Nominal speed (Hz)	Maximum speed (Hz)	Over speed (Hz)
1320	1420	1460
OUPUTS		

BEARING TEST CONDITIONS

BEARING GAS PRESSURE (10^5Pa)		BEARING GAS TEMPERATURE (°C)		BEARING GAS FLOW RATE (g/s)
SUPPLY	RETURN	SUPPLY	RETURN	
10.31	1.56	17.0	23.6	12.27

TURBINE TEST CONDITIONS

TURBINE PRESSURE (10^5Pa)		TURBINE TEMPERATURE (K)		TURBINE FLOW RATE (g/s)
SUPPLY	RETURN	SUPPLY	RETURN	
18.26	1.67	243.49	192.79	57.97

BRAKE TEST CONDITIONS

INLET BRAKE PRESSURE 10^5 Pa	OUTLET BRAKE TEMPERATURE °C
6.13	36.8

TEST RESULTS

ROTATION SPEED H_z	STEADY STATE	OVERSPEED STATE DURATION (mn)	COMMENTS	
			FAIL	PASS
1422	A	3		X

Steady state evaluation:

A: Stable B: Noisy C: Unstable

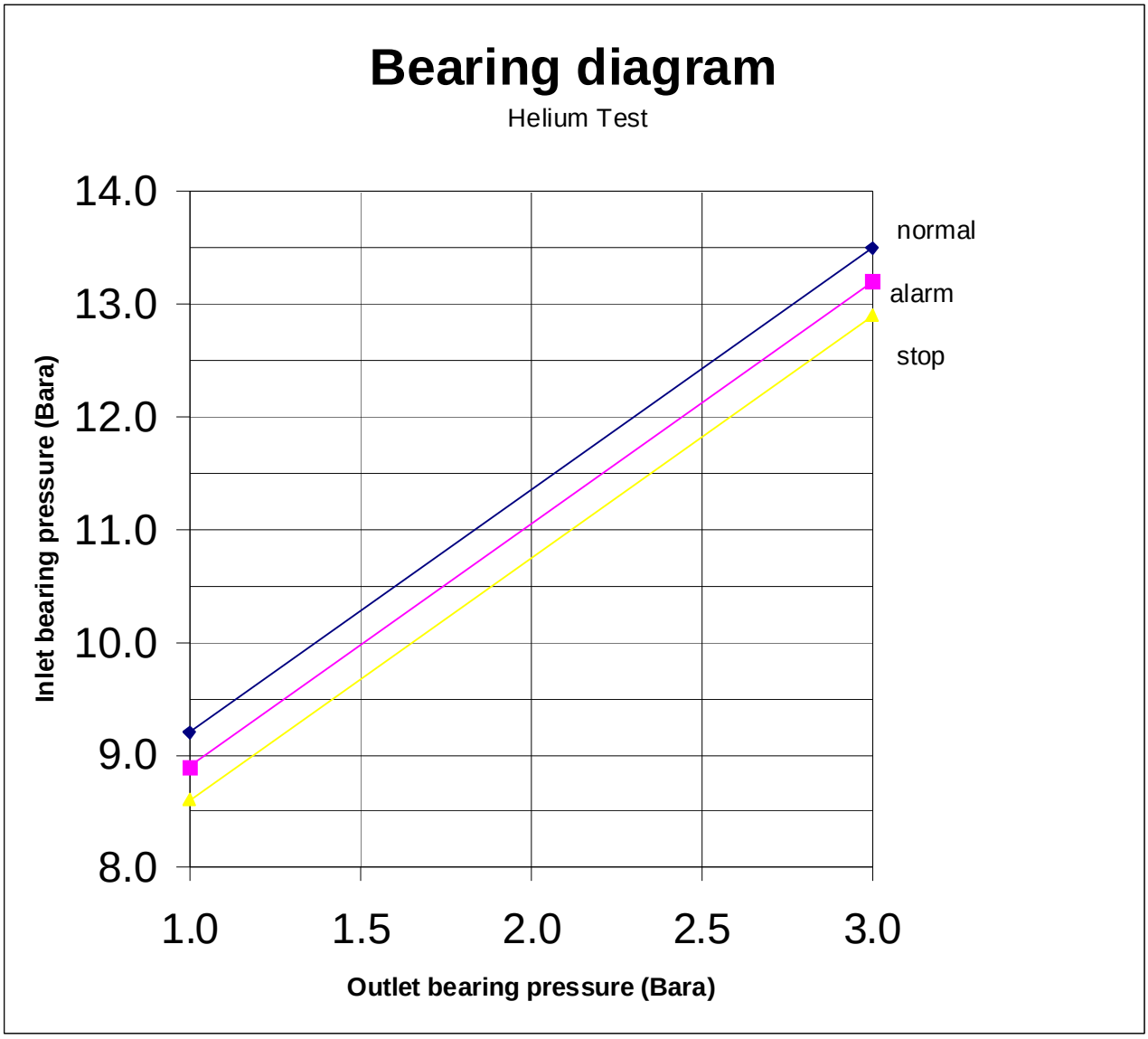
5.6 COOL DOWN, START-UP AND SHUT-DOWN

(Items 6.5 and 6.6 of procedure)

Cartridge number: C6 594 HJ_1
Bearing conditions required: normal
Nominal speed:

	AMBIENT	MEDIUM	+10% K	NOMINAL	- 10%	
Target outlet temperature	250	150	10.0	8.9	8.0	K
TURBINE :						
Inlet pressure	7.17	17.04	17.84			10^5Pa
Outlet pressure	1.59	1.64	2.37			10^5Pa
Inlet temperature	234.48	190.31	29.65			K
Outlet temperature	228.72	150.33	18.31			K
Flow (Ø distrib. 50 % nominal)		60.51	161.74			g/s
U1/C0	0.13	0.21	0.51			
µ	5.66	35.10	67.66			%
BRAKE :						
Inlet pressure	5.98	6.62	5.96			10^5Pa
Outlet temperature	18.1	37.4	33.9			°C
BEARING :						
Inlet pressure	10.44	10.33	11.22			10^5Pa
Outlet pressure	1.57	1.55	2.33			10^5Pa
Inlet temperature	15.5	17.1	17.1			°C
Outlet temperature	17.9	25.7	10.4			°C
Inlet flow	11.49	11.93	12.63			g/s
SPEED :	788	1311	1233			Hz
Number of start up/shut down	3		3			
Fail/pass	passed	passed	passed			

AIR LIQUIDE ADVANCED TECHNOLOGIES	**DIAGRAMME PIVOTERIE** ***GAS BEARING DIAGRAM***	**N° : C4058-NT-19 (1)** Folio : 10 / 11
AFFAIRE / *JOB* : RHEA	N° : 301 0914	
Identification du matériel / *Material identification* : C6 594 HJ_1		
APPLICATION : ☑ Site Client/*Customer* ☑ ALAT Test		



TEST REPORT

5.7 EFFICIENCY VERSUS U1/CO

(Items 6.7 of procedure)
Cartridge number: C6 594 HJ_1

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

GAS	PRESSURES 10^5Pa		TEMPERATURES K		FLOW kg/s 10^{-3}	ENTHALP. DROP kJ/kg		η	ROTATION SPEED Hz	REFRIG. POWER Watt	INLET WHEEL PRESS. 10^5Pa
	INLET	OUTLET	INLET	OUTLET		Δ Hs	Δ Hr	Δ Hr/ Δ Hs			
He	18.87	1.22	19.7	8.9	423	63.7	49.7	0.78	1320	21000	7.01

OUTPUTS **TURBINE TEST CONDITIONS**

GAS	PRESSURES 10^5Pa		TEMPERATURES K		FLOW kg/s.10^{-3} (Ø 50 % nominal)	ENTHALP. DROP KJ/kg		η	ROTATION SPEED Hz	REFRIG. POWER Watt	INLET WHEEL PRESS. 10^5Pa
	INLET	OUTLET	INLET	OUTLET		Δ Hs	Δ Hr	Δ Hr/ Δ Hs			
He	17.84	2.37	29.65	18.31	161.74	86.02	54.2	0.63	1233	9414	4.70

BEARING TEST CONDITIONS

GAS	PRESSURES 10^5Pa		TEMPERATURES °C	
	INLET	OUTLET	INLET	OUTLET
He	11.22	2.23	17.1	10.4

BRAKE TEST CONDITIONS

GAS	PRESSURES 10^5Pa		TEMPERATURES °C	
	INLET	OUTLET	INLET	OUTLET
He	5.96	6.09	25.2	33.9

TEST RESULTS

WHEEL DIAM. mm	TIP VELOCITY U_1 m/s	SPOUTING VELOCITY C_O m/s	U_1/ Co	η %	COMMENTS	
					FAIL	PASS
55.0	212.9	414.7	0.51	67.66		X

UTILITY FLOW RATE

GAS BEARING SUPPLY g / s	BRAKE SUPPLY g / s	SEAL GAS g / s	RETURN g / s
12.63	0.49	0.27	14.36