AIR LIQUIDE ADVANCED TECHNOLOGIES	**PROCES-VERBAL D'ESSAI** ***TEST REPORT*** **CRYOGENIC TURBO EXPANDER**	**N° : C4058-NT-19 (0)** 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***	B. Renzetti L. Pelosi	F. Delcayre			
DATE / ***DATE***	01 12 2011	01 12 2011			
SIGNATURE / *VISA*					

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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 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	10.29	10.34	10^5Pa
Outlet bearing pressure	1.5	1.5	10^5Pa
Turbine outlet pressure (1)	1.59	1.52	10^5Pa
Brake pressure (2)	1.57	18.03	10^5Pa
Pressure difference = (2) – (1)	-0.2	16.51	10^5Pa
Speed	>0	>0	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	10.17	10.06	10.08	10^5Pa
Outlet bearing pressure	1.49	1.4	1.4	10^5Pa
Turbine outlet test pressure (1)	1.61	1.57	1.62	10^5Pa
Brake test pressure (2)	6.16	8.29	12.48	10^5Pa
Δ = (2) – (1)	4.55	6.72	10.86	10^5Pa
Speed	1319	1315	1162	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		9.45	10^5Pa
Outlet bearing pressure		1.4	10^5Pa
Turbine outlet test pressure		1.55	10^5Pa
Brake outlet pressure		7.47	10^5Pa
Δ = 2-1		5.92	10^5Pa
Speed		1337	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					
	1st RIGID MODE		2nd RIGID MODE		
Calculated peak freq.	570		660		H_z
OUTPUTS					
Measured critical speeds	BEGIN.	END	BEGIN.	END	
	600			800	H_z
Sound level estimation	A		A		
Time within the mode (> 3 ‘)					Min
Inlet bearing pressure	10.16		10.16		10^5Pa
Outlet bearing pressure	1.38		1.38		10^5Pa
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 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	
10.19	1.4	17.0	24.1	13.1

TURBINE TEST CONDITIONS

TURBINE PRESSURE (10^5Pa)		TURBINE TEMPERATURE (K)		TURBINE FLOW RATE (g/s)
SUPPLY	RETURN	SUPPLY	RETURN	
13.26	1.55	2.67.34	213.2	58.4

BRAKE TEST CONDITIONS

INLET BRAKE PRESSURE 10^5 Pa	OUTLET BRAKE TEMPERATURE °C
6.18	34.7

TEST RESULTS

ROTATION SPEED H_z	STEADY STATE	OVERSPEED STATE DURATION (mn)	COMMENTS	
			FAIL	PASS
1468	A	3		X

Steady state evaluation:

A: Stable B: Noisy C: Unstable

TEST REPORT

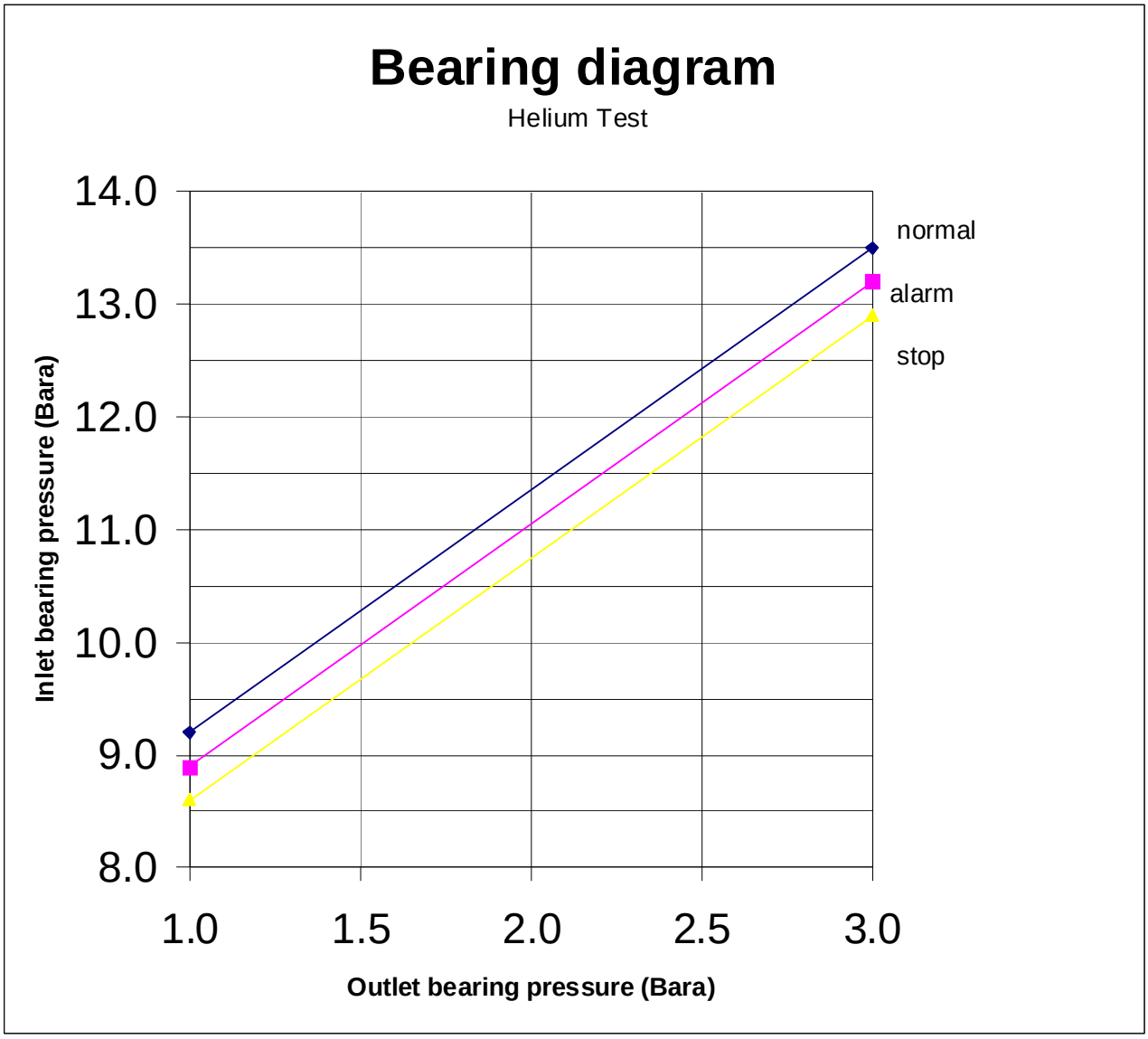
5.6 COOL DOWN, START-UP AND SHUT-DOWN

(Items 6.5 and 6.6 of procedure)

Cartridge number: C6 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	7.64	13.57	14.96			10^5Pa
Outlet pressure	1.45	1.53	2.95			10^5Pa
Inlet temperature	270.87	191.43	20.16			K
Outlet temperature	244.2	150.03	12.95			K
Flow (Ø distrib. 70% nominal)	32.3	70.8	238.2			g/s
U1/C0	0.15	0.21	0.64			
µ	20.37	37.59	70.22			%
BRAKE :						
Inlet pressure	6.22	7.58	6.66			10^5Pa
Outlet temperature	22.4	41.0	30.3			°C
BEARING :						
Inlet pressure	10.16	10.16	13.49			10^5Pa
Outlet pressure	1.38	1.41	2.85			10^5Pa
Inlet temperature	16.8	17.6	17.8			°C
Outlet temperature	20.7	28.5	10.8			°C
Inlet flow	12.06	12.44	15.56			g/s
SPEED :	992	1341	1148			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 (0)** 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 70% 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	15.81	3.06	20.71	13.22	249.7	50.1	35.58	0.71	1196	8884	6.21

BEARING TEST CONDITIONS

GAS	PRESSURES 10^5Pa		TEMPERATURES °C	
	INLET	OUTLET	INLET	OUTLET
He	13.51	2.95	18.4	10.3

BRAKE TEST CONDITIONS

GAS	PRESSURES 10^5Pa		TEMPERATURES °C	
	INLET	OUTLET	INLET	OUTLET
He	6.46			32.9

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	206.55	316.57	0.65	71.0		X

UTILITY FLOW RATE

GAS BEARING SUPPLY g / s	BRAKE SUPPLY g / s	SEAL GAS g / s	RETURN g / s
15.62	0.32	0.4	17.34