AIR LIQUIDE ADVANCED TECHNOLOGIES	**PROCES-VERBAL D'ESSAI** ***TEST REPORT*** **CRYOGENIC TURBO EXPANDER**	**N° : C4058-NT-23 (1)** Folio : 1 / 11

AFFAIRE : **RHEA** *JOB* :	N° : 301 0914 *N° :*	Fiche Suiveuse n° : *Inspection traveller n° :*
Identification du matériel : **C7 512 HG_1** N° : 324-XT002 *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***	30/11/2013	30/11/2013			
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: C7 512 HG_1
Bearing conditions required: NORMAL

CASE	EXTREME 1	EXTREME 2	
INPUTS			
Load	0	1233	N
On	Brake	Turbine	Bearing
Equivalent pressure difference on the shaft	0	19	10^5Pa
OUTPUTS			
Inlet bearing pressure	17.60	17.61	10^5Pa
Outlet bearing pressure	2.01	2.07	10^5Pa
Turbine outlet pressure (1)	2.12	2.09	10^5Pa
Brake pressure (2)	2.02	17.53	10^5Pa
Pressure difference = (2) – (1)	- 0.10	15.44	10^5Pa
Speed	18	6	H_Z
Passed/failed	passed	passed	

TEST REPORT

5.2 THRUST AND JOURNAL BEARINGS TEST, HIGH SPEED

(Items 6.2 of procedure)

Cartridge number: C7 512 HG_1
Bearing conditions required: NORMAL

MODE	MINIMAL	NOMINAL	MAXIMAL	
INPUTS				
Turbine outlet design pressure (1)	5.7	4.9	3.5	10^5Pa
Brake design pressure (2)	11.2	14	16.8	10^5Pa
Δ = 2-1	5.5	9.1	13.3	10^5Pa
OUTPUTS				
Inlet bearing pressure	17.63	17.69	17.58	10^5Pa
Outlet bearing pressure	2.34	3.31	3.36	10^5Pa
Turbine outlet test pressure (1)	2.68	3.84	3.87	10^5Pa
Brake test pressure (2)	8.01	12.94	17.04	10^5Pa
Δ = (2) – (1)	5.33	9.1	13.17	10^5Pa
Speed	676	649	574	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 512 HG_1
Bearing conditions required: ALARM AND STOP

BEARING CONDITIONS	**ALARM**	**STOP**	
Mode	Nominal	Nominal	
INPUTS			
Turbine design outlet pressure (1)	4.9	4.9	10^5Pa
Brake design pressure (2)	14	14	10^5Pa
Δ = 2-1	9.1	9.1	10^5Pa
OUTPUTS			
Inlet bearing pressure		17.54	10^5Pa
Outlet bearing pressure		2.83	10^5Pa
Turbine outlet test pressure		3.30	10^5Pa
Brake outlet pressure		8.89	10^5Pa
Δ = 2-1		5.59	10^5Pa
Speed		750	Hz
Passed/failed		passed	

TEST REPORT

5.4 CRITICAL SPEEDS AND SHAFT VIBRATIONS

(Items 6.3 of procedure)

Cartridge number: C7 512 HG_1
Bearing conditions required: STOP

INPUTS					
	1^{st} RIGID MODE		2^{nd} RIGID MODE		
Calculated peak freq.	650		750		H_z
OUTPUTS					
Measured critical speeds	BEGIN.	END	BEGIN.	END	
	600			700	H_z
Sound level estimation	B		B		
Time within the mode (> 3 ‘)	3		3		Min
Inlet bearing pressure	19.11		19.11		10^5Pa
Outlet bearing pressure	1.51		1.51		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: C7 512 HG_1
Bearing conditions required: NORMAL

INPUTS		
Nominal speed (Hz)	Maximum speed (Hz)	Over speed (Hz)
1060	1130	1140
OUPUTS		

BEARING TEST CONDITIONS

BEARING GAS PRESSURE (10^5Pa)		BEARING GAS TEMPERATURE (°C)		BEARING GAS FLOW RATE (g/s)
SUPPLY	RETURN	SUPPLY	RETURN	
18.92	1.82	16	18.3	0.23

TURBINE TEST CONDITIONS

TURBINE PRESSURE (10^5Pa)		TURBINE TEMPERATURE (K)		TURBINE FLOW RATE (g/s)
SUPPLY	RETURN	SUPPLY	RETURN	
8.25	2.47	236.95	190.61	168.4

BRAKE TEST CONDITIONS

INLET BRAKE PRESSURE 10^5 Pa	OUTLET BRAKE TEMPERATURE °C
2.94	53.9

TEST RESULTS

ROTATION SPEED H_z	STEADY STATE	OVERSPEED STATE DURATION (mn)	COMMENTS	
			FAIL	PASS
1144	A	3		X

Steady state evaluation:

A: Stable B: Noisy C: Unstable

TEST REPORT

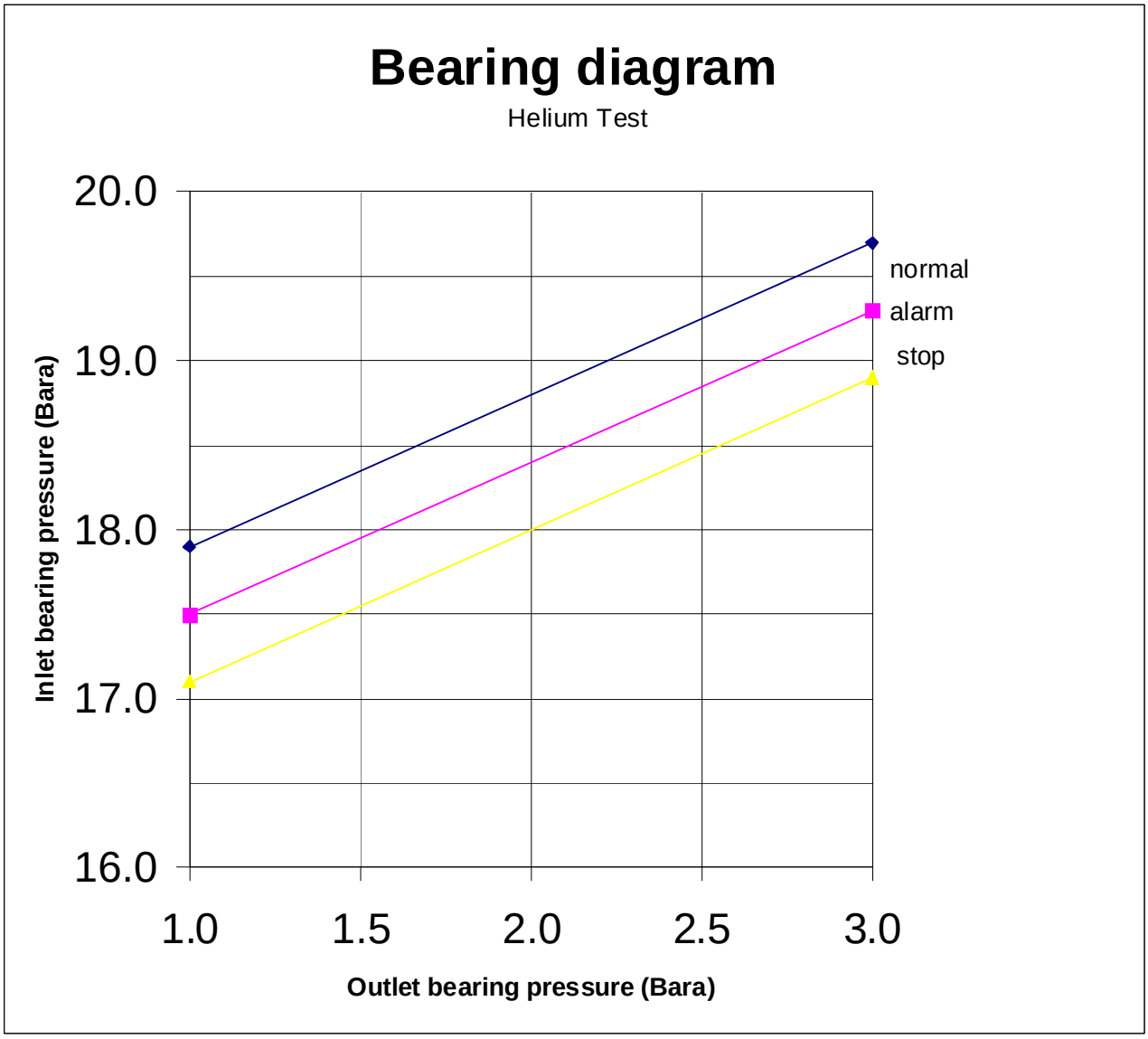
5.6 COOL DOWN, START-UP AND SHUT-DOWN

(Items 6.5 and 6.6 of procedure)

Cartridge number: C7 512 HG_1
Bearing conditions required: normal
Nominal speed:

	AMBIENT	MEDIUM	+10% K	NOMINAL	- 10%	
Target outlet temperature	250	150	108	99	90	K
TURBINE :						
Inlet pressure		6.17	6.18	6.23	6.22	10^5Pa
Outlet pressure		2.44	2.63	2.78	2.82	10^5Pa
Inlet temperature		172.92	130.06	116.01	105.71	K
Outlet temperature		147.99	109.92	98.83	89.66	K
Flow		144.28	164.38	177.74	184.36	g/s
U1/C0		0.34	0.41	0.41	0.43	
µ		46.72	53.93	53.69	55.99	%
BRAKE :						
Inlet pressure		2.62	3.45	3.49	3.49	10^5Pa
Outlet temperature		21.5	46.6	44.2	42.8	°C
BEARING :						
Inlet pressure		17.42	17.59	17.74	17.73	10^5Pa
Outlet pressure		2.22	2.42	2.56	2.59	10^5Pa
Inlet temperature		15.9	16.1	16.2	16.2	°C
Outlet temperature		17.2	15.4	14.6	13.6	°C
Inlet flow		31.59	31.66	31.26	31.07	g/s
SPEED :		863	861	802	790	Hz
Number of start up/shut down					3	
Fail/pass		passed	passed	passed	passed	

AIR LIQUIDE ADVANCED TECHNOLOGIES	**DIAGRAMME PIVOTERIE** ***GAS BEARING DIAGRAM***	**N° : C4058-NT-23 (0)** Folio : 10 / 11
AFFAIRE / *JOB* : RHEA	N° : 301 0914	
Identification du matériel / *Material identification* : C7 512 HG_1		
APPLICATION : ☑ Site Client/*Customer* ☑ ALAT Test		



TEST REPORT

5.7 EFFICIENCY VERSUS U1/CO

(Items 6.7 of procedure)
Cartridge number: C7 512 HG_1

INPUTS **TURBINE PROCESS CONDITIONS**

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	12.16	4.87	128.2	99.3	1166	206.3	152.7	0.74	1060	178026	7.35

OUTPUTS **TURBINE TEST CONDITIONS**

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	6.23	2.78	116.01	98.83	177.74	166.54	89.42	0.53	802	15894	3.35

BEARING TEST CONDITIONS

GAS	PRESSURES 10^5Pa		TEMPERATURES °C	
	INLET	OUTLET	INLET	OUTLET
He	17.74	2.56	16.2	14.6

BRAKE TEST CONDITIONS

GAS	PRESSURES 10^5Pa		TEMPERATURES °C	
	INLET	OUTLET	INLET	OUTLET
He	3.49	3.76	30.2	44.2

TEST RESULTS

WHEEL DIAM. mm	TIP VELOCITY U_1 m/s	SPOUTING VELOCITY C_O m/s	U_1/ Co	η %	COMMENTS	
					FAIL	PASS
94.00	236.83	577.1	0.41	53.69		X

UTILITY FLOW RATE

GAS BEARING SUPPLY g / s	BRAKE SUPPLY g / s	SEAL GAS g / s	RETURN g / s
31.26	-0.01	0.16	34.30