AIR LIQUIDE ADVANCED TECHNOLOGIES	**PROCES-VERBAL D'ESSAI** ***TEST REPORT*** **CRYOGENIC TURBO EXPANDER**	**N° : C4058-NT-17 (0)** Folio : 1 / 11

AFFAIRE : **RHEA** *JOB* :	N° : 301 0914 *N° :*	Fiche Suiveuse n° : *Inspection traveller n° :*
Identification du matériel : **C6 592 HH$_1$** N° : 324-XT003 *Material identification* :	Quantité / *Quantity* : 1 Lot / *Batch* :	

Fournisseur/Fabricant : *Supplier / Manufacturer :* **AIR LIQUIDE**	Organisme de Contrôle : *Inspected by :* **DETEC**	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***	L. Pelosi	F. Delcayre			
DATE / ***DATE***	26 09 2012	26 09 2012			
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 592 HH_1
Bearing conditions required: NORMAL

CASE	EXTREME 1	EXTREME 2	
INPUTS			
Load	0	1092	N
On	Brake	Turbine	Bearing
Equivalent pressure difference on the shaft	0	35	10^5Pa
OUTPUTS			
Inlet bearing pressure	17.51	17.5	10^5Pa
Outlet bearing pressure	2.86	2.87	10^5Pa
Turbine outlet pressure (1)	2.77	2.76	10^5Pa
Brake pressure (2)	2.84	17.91	10^5Pa
Pressure difference = (2) – (1)	0.07	15.15	10^5Pa
Speed	13	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: C6 592 HH_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)	9.6	14	15.6	10^5Pa
Δ = 2-1	3.9	9.1	12.1	10^5Pa
OUTPUTS				
Inlet bearing pressure	17.74	17.76	17.8	10^5Pa
Outlet bearing pressure	3.16	2.91	2.95	10^5Pa
Turbine outlet test pressure (1)	3.57	3.30	3.37	10^5Pa
Brake test pressure (2)	7.44	12.31	15.47	10^5Pa
Δ = (2) – (1)	3.87	9.01	12.1	10^5Pa
Speed	1394	1048	934	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 592 HH_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		15.84	10^5Pa
Outlet bearing pressure		3.09	10^5Pa
Turbine outlet test pressure		3.46	10^5Pa
Brake outlet pressure		6.11	10^5Pa
Δ = 2-1		2.65	10^5Pa
Speed		1420	Hz
Passed/failed		passed	

TEST REPORT

5.4 CRITICAL SPEEDS AND SHAFT VIBRATIONS

(Items 6.3 of procedure)

Cartridge number: C6 592 HH_1
Bearing conditions required: STOP

INPUTS					
	1st RIGID MODE		2nd RIGID MODE		
Calculated peak freq.	630		690		H_z
OUTPUTS					
Measured critical speeds	BEGIN.	END	BEGIN.	END	
	550			850	H_z
Sound level estimation	B		B		
Time within the mode (> 3 ‘)					Min
Inlet bearing pressure	17.44		17.44		10^5Pa
Outlet bearing pressure	2.97		2.97		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 592 HH_1
Bearing conditions required: NORMAL

INPUTS		
Nominal speed (Hz)	Maximum speed (Hz)	Over speed (Hz)
1420	1480	1500
OUPUTS		

BEARING TEST CONDITIONS

BEARING GAS PRESSURE (10^5Pa)		BEARING GAS TEMPERATURE (°C)		BEARING GAS FLOW RATE (g/s)
SUPPLY	RETURN	SUPPLY	RETURN	
17.64	3.3	19.1	28.8	27.88

TURBINE TEST CONDITIONS

TURBINE PRESSURE (10^5Pa)		TURBINE TEMPERATURE (K)		TURBINE FLOW RATE (g/s)
SUPPLY	RETURN	SUPPLY	RETURN	
13.71	3.74	204.07	153.9	261.4

BRAKE TEST CONDITIONS

INLET BRAKE PRESSURE 10^5 Pa	OUTLET BRAKE TEMPERATURE °C
6.71	71.3

TEST RESULTS

ROTATION SPEED H_z	STEADY STATE	OVERSPEED STATE DURATION (mn)	COMMENTS	
			FAIL	PASS
1502	A	3		X

Steady state evaluation:

A: Stable B: Noisy C: Unstable

TEST REPORT

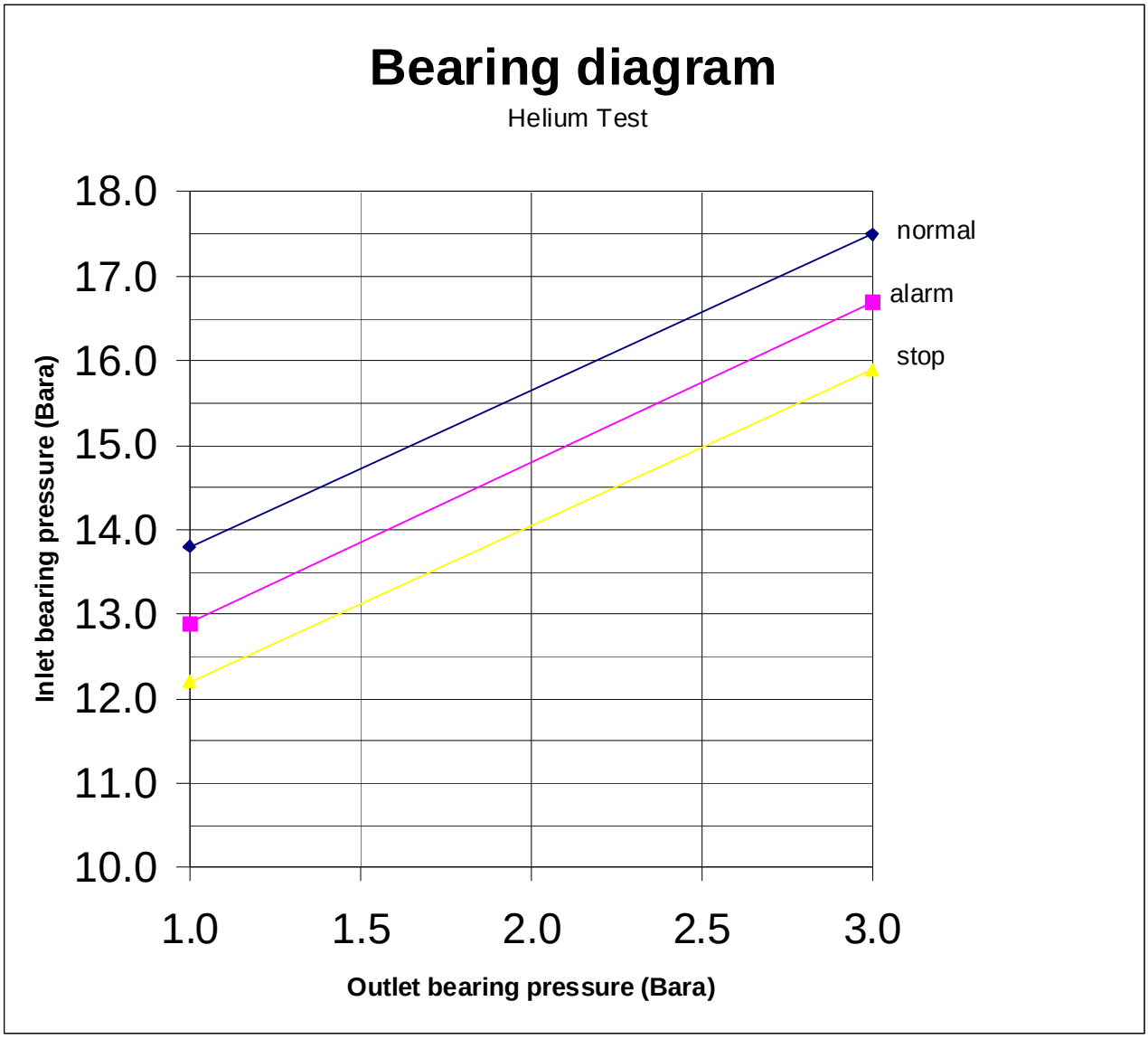
5.6 COOL DOWN, START-UP AND SHUT-DOWN

(Items 6.5 and 6.6 of procedure)

Cartridge number: C6 592 HH_1
Bearing conditions required: normal
Nominal speed:

	AMBIENT	MEDIUM	+10% K	NOMINAL	- 10%	
Target outlet temperature	250	150	50	45	40	K
TURBINE :						
Inlet pressure	5.9	12.01	8.47	8.34	8.13	10^5Pa
Outlet pressure	3.03	3.48	3.67	3.7	3.72	10^5Pa
Inlet temperature	203.95	179.53	62.73	57.46	51.36	K
Outlet temperature	195.71	136.4	50.31	46.21	41.4	K
Flow	99.2	243.0	273.8	279.4	280.6	g/s
U1/C0	0.24	0.38	0.55	0.57	0.61	
µ	17.5	61.94	70.15	71.02	72.38	%
BRAKE :						
Inlet pressure	6.91	6.16	5.21	5.22	4.72	10^5Pa
Outlet temperature	22.9	45.9	44.7	41.9	38.0	°C
BEARING :						
Inlet pressure	17.44	17.81	17.75	17.93	17.87	10^5Pa
Outlet pressure	2.97	3.14	3.48	3.51	3.54	10^5Pa
Inlet temperature	19.5	19.4	19.6	19.8	19.8	°C
Outlet temperature	23.5	27.9	24.9	23.4	19.7	°C
Inlet flow	24.71	27.84	26.18	26.48	26.28	g/s
SPEED :	726	1395	1033	1004	994	Hz
Number of start up/shut down	3				3	
Fail/pass	passed	passed	passed	passed		

AIR LIQUIDE ADVANCED TECHNOLOGIES	**DIAGRAMME PIVOTERIE** ***GAS BEARING DIAGRAM***	**N° : C4058-NT-17 (0)** Folio : 10 / 11
AFFAIRE / *JOB* : RHEA	N° : 301 0914	
Identification du matériel / *Material identification* : C6 592 HH_1		
APPLICATION : ☑ Site Client/*Customer* ☑ ALAT Test		



TEST REPORT

5.7 EFFICIENCY VERSUS U1/CO

(Items 6.7 of procedure)
Cartridge number: C6 592 HH_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	19.2	4.9	65.85	44.35	865.5	147.8	115.3	0.78	1420	99792	10.5

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	8.28	3.71	54.95	44.24	281.7	79.5	56.7	0.71	988	15981	5.05

BEARING TEST CONDITIONS

GAS	PRESSURES 10^5Pa		TEMPERATURES °C	
	INLET	OUTLET	INLET	OUTLET
He	17.95	3.53	19.7	22.3

BRAKE TEST CONDITIONS

GAS	PRESSURES 10^5Pa		TEMPERATURES °C	
	INLET	OUTLET	INLET	OUTLET
He	5.23			40.2

TEST RESULTS

WHEEL DIAM. mm	TIP VELOCITY U_1 m/s	SPOUTING VELOCITY C_O m/s	U_1/ Co	η %	COMMENTS	
					FAIL	PASS
74.0	229.6	398.9	0.58	71.38		X

UTILITY FLOW RATE

GAS BEARING SUPPLY g / s	BRAKE SUPPLY g / s	SEAL GAS g / s	RETURN g / s
26.35	0.16	0.19	28.17