

		PROCES-VERBAL D'ESSAI TEST REPORT CRYOGENIC TURBO EXPANDER			N° : C4058-NT-20 (0) Folio : 1 / 11	
AFFAIRE : RHEA JOB :		N° : 301 0914 N° :		Fiche Suiveuse n° : Inspection traveller n° :		
Identification du matériel : C4 560 HK₁ N° : 324XT006 <i>Material identification :</i>		Quantité / <i>Quantity</i> : 1 Lot / <i>Batch</i> :				
Fournisseur/Fabricant : <i>Supplier / Manufacturer :</i> AIR LIQUIDE	Organisme de Contrôle : <i>Inspected by :</i> DTEC	Lieu : <i>Location :</i> Sassenage		Phase : <i>Phase :</i>		
Documents de référence : <i>Reference documents :</i> PROCEDURE : D4444-PO-2		Instruments de contrôles utilisés : <i>Inspection instruments used :</i>				
		Type / <i>Type</i>		N° de Gestion/ <i>Control n°</i>		
		Test bed		504 9999 100		
MESURES		RESULTATS		OBSERVATIONS		
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		Limited by the test bench.		
RENDEMENT / <i>Efficiency</i>		Pass				
DECISION : <i>DECISION :</i> CONFORME / PASS <input checked="" type="checkbox"/> NON CONFORME / FAIL <input type="checkbox"/>		OBSERVATIONS : <i>COMMENTS :</i>				
	ESSAI / TEST	Responsible / Manager		A.Q. / Q.A.		
NOM / NAME	L. Pelosi	F. Delcayre				
DATE / DATE	06 02 2012	07 02 2012				
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: C4 560 HK₁

Bearing conditions required: NORMAL

CASE	EXTREME 1	EXTREME 2	
INPUTS			
Load	0	394	N
On	Brake	Turbine	Bearing
Equivalent pressure difference on the shaft	0	30	10 ⁵ Pa
OUTPUTS			
Inlet bearing pressure	12.43	12.45	10 ⁵ Pa
Outlet bearing pressure	2.62	2.74	10 ⁵ Pa
Turbine outlet pressure (1)	2.9	2.53	10 ⁵ Pa
Brake pressure (2)	2.92	18.52	10 ⁵ Pa
Pressure difference = (2) – (1)	0.02	15.99	10 ⁵ Pa
Speed	40	20	Hz
Passed/failed	passed	passed	

TEST REPORT
5.2 THRUST AND JOURNAL BEARINGS TEST, HIGH SPEED

(Items 6.2 of procedure)

 Cartridge number: C4 560 HK₁

Bearing conditions required: NORMAL

MODE	MINIMAL	NOMINAL	MAXIMAL	
INPUTS				
Turbine outlet design pressure (1)	5.5	3.0	2.4	10 ⁵ Pa
Brake design pressure (2)	8.7	10.9	16.3	10 ⁵ Pa
$\Delta = 2-1$	3.2	7.9	13.9	10 ⁵ Pa
OUTPUTS				
Inlet bearing pressure	12.43	12.45	12.46	10 ⁵ Pa
Outlet bearing pressure	2.76	2.74	2.78	10 ⁵ Pa
Turbine outlet test pressure (1)	2.85	2.93	3.14	10 ⁵ Pa
Brake test pressure (2)	6.03	10.83	17.03	10 ⁵ Pa
$\Delta = (2) - (1)$	3.18	7.9	13.89	10 ⁵ Pa
Speed	1080	1092	1082	Hz
Passed/failed	Passed	Passed	passed	

TEST REPORT

5.3 THRUST AND JOURNAL BEARING TEST, HIGH SPEED

(Items 6.2 of procedure)

Cartridge number: C4 560 HK₁

Bearing conditions required: ALARM AND STOP

BEARING CONDITIONS	ALARM	STOP	
Mode	Nominal	Nominal	
INPUTS			
Turbine design outlet pressure (1)	3.0	3.0	10 ⁵ Pa
Brake design pressure (2)	10.9	10.9	10 ⁵ Pa
$\Delta = 2-1$	7.9	7.9	10 ⁵ Pa
OUTPUTS			
Inlet bearing pressure		11.86	10 ⁵ Pa
Outlet bearing pressure		2.74	10 ⁵ Pa
Turbine outlet test pressure		2.93	10 ⁵ Pa
Brake outlet pressure		10.86	10 ⁵ Pa
$\Delta = 2-1$		7.93	10 ⁵ Pa
Speed		1090	Hz
Passed/failed		passed	

TEST REPORT

5.4 CRITICAL SPEEDS AND SHAFT VIBRATIONS

(Items 6.3 of procedure)

Cartridge number: C4 560 HK₁

Bearing conditions required: STOP

INPUTS					
	1 st RIGID MODE		2 nd RIGID MODE		
Calculated peak freq.	710				H _z
OUTPUTS					
Measured critical speeds	BEGIN.	END	BEGIN.	END	H _z
	750			950	
Sound level estimation	B		B		
Time within the mode (> 3 ‘)					Min
Inlet bearing pressure	12.43		12.43		10 ⁵ Pa
Outlet bearing pressure	2.81		2.81		10 ⁵ 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: C4 560 HK₁

Bearing conditions required: NORMAL

INPUTS				
Nominal speed (Hz)		Maximum speed (Hz)		Over speed (Hz)
1080		1160		1190
OUPUTS				
BEARING TEST CONDITIONS				
BEARING GAS PRESSURE (10 ⁵ Pa)		BEARING GAS TEMPERATURE (°C)		BEARING GAS FLOW RATE (g/s)
SUPPLY	RETURN	SUPPLY	RETURN	
12.44	2.77	16.5	21.8	

TURBINE TEST CONDITIONS

TURBINE PRESSURE (10 ⁵ Pa)		TURBINE TEMPERATURE (K)		TURBINE FLOW RATE (g/s)
SUPPLY	RETURN	SUPPLY	RETURN	
8.2	2.87	281.74	264.53	

BRAKE TEST CONDITIONS

INLET BRAKE PRESSURE 10 ⁵ Pa	OUTLET BRAKE TEMPERATURE °C
6.01	43.4

TEST RESULTS

ROTATION SPEED H _z	STEADY STATE	OVERSPEED STATE DURATION (mn)	COMMENTS	
			FAIL	PASS
1192	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: C4 560 HK₁

Bearing conditions required: normal

Nominal speed:

	AMBIENT	MEDIUM	+10% K	NOMINAL	- 10%	
Target outlet temperature	250	150	6.0	5.5	5.0	K
TURBINE :						
Inlet pressure	8.65	14.58	16.26			10 ⁵ Pa
Outlet pressure	2.7	2.96	3.22			10 ⁵ Pa
Inlet temperature	256.0	165.0	17.97			K
Outlet temperature	241.47	148.77	11.23			K
Flow	33.3	70.4	267.7			g/s
U1/C0	0.1	0.12	0.55			
μ	15.59	21.57	72.97			%
BRAKE :						
Inlet pressure	10.66	15.88	7.15			10 ⁵ Pa
Outlet temperature	32.0	57.7	73.0			°C
BEARING :						
Inlet pressure	12.8	13.25	13.26			10 ⁵ Pa
Outlet pressure	2.8	3.03	3.3			10 ⁵ Pa
Inlet temperature	12.5	14.5	17.3			°C
Outlet temperature	17.2	19.2	14.9			°C
Inlet flow	7.17	7.62	8.39			g/s
SPEED :	1082	1198	1711			Hz
Number of start up/shut down	3	 	3			
Fail/pass	passed	passed	passed			

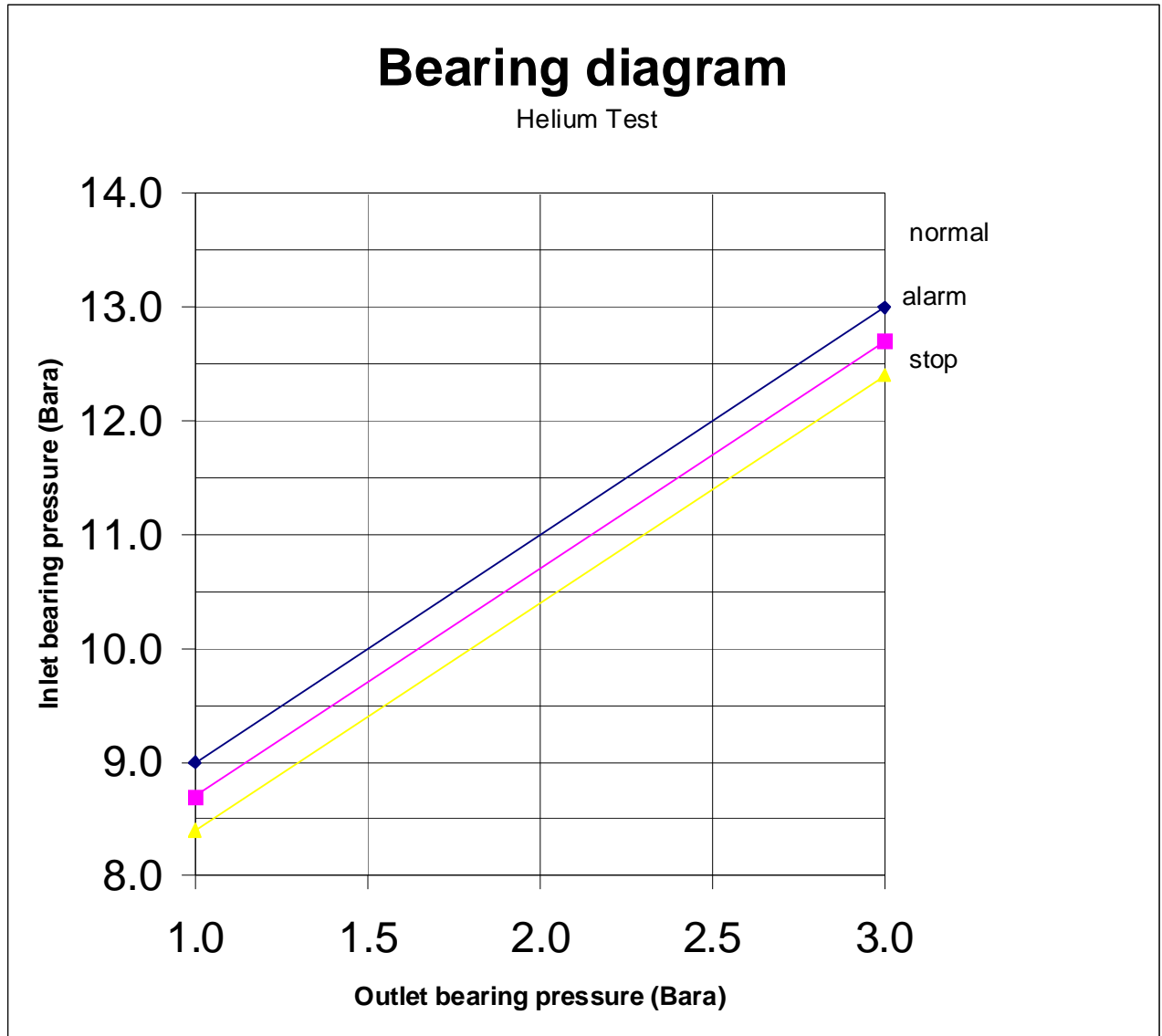
AFFAIRE / JOB : RHEA

N° : 301 0914

Identification du matériel / Material identification : C4 560 HK₁

APPLICATION : Site Client/Customer

ALAT Test



TEST REPORT

5.7 EFFICIENCY VERSUS U1/CO

(Items 6.7 of procedure)

Cartridge number: C4 560 HK₁

INPUTS

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

GAS	PRESSURES 10 ⁵ Pa		TEMPERATURES K		FLOW kg/s 10 ⁻³	ENTHALP. DROP kJ/kg		η $\Delta_{Hr} / \Delta_{Hs}$	ROTATION SPEED Hz	REFRIG. POWER Watt	INLET WHEEL PRESS. 10 ⁵ Pa
	INLET	OUTLET	INLET	OUTLET		Δ_{Hs}	Δ_{Hr}				
He	18.85	3.0	7.5	5.5	530	13.0	9.5	0.73	1079	5029	10.8

OUTPUTS

TURBINE TEST CONDITIONS

GAS	PRESSURES 10 ⁵ Pa		TEMPERATURES K		FLOW kg/s 10 ⁻³	ENTHALP. DROP KJ/kg		η $\Delta_{Hr} / \Delta_{Hs}$	ROTATION SPEED Hz	REFRIG. POWER Watt	INLET WHEEL PRESS. 10 ⁵ Pa
	INLET	OUTLET	INLET	OUTLET		Δ_{Hs}	Δ_{Hr}				
He	16.26	3.22	17.97	11.23	267.7	41.68	30.42	0.73	1711	8144	8.63

BEARING TEST CONDITIONS

GAS	PRESSURES 10 ⁵ Pa		TEMPERATURES °C	
	INLET	OUTLET	INLET	OUTLET
He	13.26	3.3	17.3	14.9

BRAKE TEST CONDITIONS

GAS	PRESSURES 10 ⁵ Pa		TEMPERATURES °C	
	INLET	OUTLET	INLET	OUTLET
He	7.15			73.0

TEST RESULTS

WHEEL DIAM. mm	TIP VELOCITY U ₁ m/s	SPOUTING VELOCITY C ₀ m/s	U ₁ / C ₀	η %	COMMENTS	
					FAIL	PASS
29.5	158.5	288.7	0.55	72.97		X

UTILITY FLOW RATE

GAS BEARING SUPPLY	BRAKE SUPPLY	SEAL GAS	RETURN
g / s	g / s	g / s	g / s
8.39	0.1	0.37	9.15