

		PROCES-VERBAL D'ESSAI TEST REPORT CRYOGENIC TURBO EXPANDER			N° : C4058-NT-18 (0) Folio : 1 / 11	
AFFAIRE : RHEA JOB :		N° : 301 0914 N° :		Fiche Suiveuse n° : Inspection traveller n° :		
Identification du matériel : C6 593 HI₁ <i>Material identification :</i>		N° : 324XT004		Quantité / Quantity : 1 Lot / Batch :		
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 / Type		N° de Gestion/Control n°
				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		Limited by the test bench		
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	B. Renzetti	F. Delcayre				
DATE / DATE	21 11 2011	21 11 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 593 HI₁

Bearing conditions required: NORMAL

CASE	EXTREME 1	EXTREME 2	
INPUTS			
Load	0	826	N
On	Brake	Turbine	Bearing
Equivalent pressure difference on the shaft	0	26	10 ⁵ Pa
OUTPUTS			
Inlet bearing pressure	13.98	14.04	10 ⁵ Pa
Outlet bearing pressure	2.99	2.99	10 ⁵ Pa
Turbine outlet pressure (1)	3.05	3.05	10 ⁵ Pa
Brake pressure (2)	3.13	17.5	10 ⁵ Pa
Pressure difference = (2) – (1)	0.08	14.45	10 ⁵ Pa
Speed	16	12	Hz
Passed/failed	passed	passed	

TEST REPORT
5.2 THRUST AND JOURNAL BEARINGS TEST, HIGH SPEED

(Items 6.2 of procedure)

 Cartridge number: C6 593 HI₁

Bearing conditions required: NORMAL

MODE	MINIMAL	NOMINAL	MAXIMAL	
INPUTS				
Turbine outlet design pressure (1)	5.7	4.9	3.5	10 ⁵ Pa
Brake design pressure (2)	8.8	11	14.3	10 ⁵ Pa
$\Delta = 2-1$	3.1	6.1	10.8	10 ⁵ Pa
OUTPUTS				
Inlet bearing pressure	14.05	14.05	14.04	10 ⁵ Pa
Outlet bearing pressure	3.01	3.01	3.01	10 ⁵ Pa
Turbine outlet test pressure (1)	3.28	3.36	3.43	10 ⁵ Pa
Brake test pressure (2)	6.4	9.51	14.23	10 ⁵ Pa
$\Delta = (2) - (1)$	3.12	6.15	10.8	10 ⁵ Pa
Speed	1036	932	813	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 593 HI₁

Bearing conditions required: ALARM AND STOP

BEARING CONDITIONS	ALARM	STOP	
Mode	Nominal	Nominal	
INPUTS			
Turbine design outlet pressure (1)	4.9	4.9	10 ⁵ Pa
Brake design pressure (2)	11	11	10 ⁵ Pa
$\Delta = 2-1$	6.1	6.1	10 ⁵ Pa
OUTPUTS			
Inlet bearing pressure		13.31	10 ⁵ Pa
Outlet bearing pressure		3.02	10 ⁵ Pa
Turbine outlet test pressure		3.42	10 ⁵ Pa
Brake outlet pressure		5.83	10 ⁵ Pa
$\Delta = 2-1$		2.41	10 ⁵ Pa
Speed		1250	Hz
Passed/failed		passed	

TEST REPORT

5.4 CRITICAL SPEEDS AND SHAFT VIBRATIONS

(Items 6.3 of procedure)

Cartridge number: C6 593 HI₁

Bearing conditions required: STOP

INPUTS					
	1 st RIGID MODE		2 nd RIGID MODE		
Calculated peak freq.	620		715		H _z
OUTPUTS					
Measured critical speeds	BEGIN.	END	BEGIN.	END	
	600			700	H _z
Sound level estimation	A		A		
Time within the mode (> 3 ‘)					Min
Inlet bearing pressure	14.03		14.03		10 ⁵ Pa
Outlet bearing pressure	2.94		2.94		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: C6 593 HI₁

Bearing conditions required: NORMAL

INPUTS				
Nominal speed (Hz)		Maximum speed (Hz)		Over speed (Hz)
1250		1350		1380
OUPUTS				
BEARING TEST CONDITIONS				
BEARING GAS PRESSURE (10 ⁵ Pa)		BEARING GAS TEMPERATURE (°C)		BEARING GAS FLOW RATE (g/s)
SUPPLY	RETURN	SUPPLY	RETURN	
14.03	3.01	17.5	26.3	

TURBINE TEST CONDITIONS

TURBINE PRESSURE (10 ⁵ Pa)		TURBINE TEMPERATURE (K)		TURBINE FLOW RATE (g/s)
SUPPLY	RETURN	SUPPLY	RETURN	
13.12	3.37	264.51	217.71	

BRAKE TEST CONDITIONS

INLET BRAKE PRESSURE 10 ⁵ Pa	OUTLET BRAKE TEMPERATURE °C
3.47	52.3

TEST RESULTS

ROTATION SPEED H _z	STEADY STATE	OVERSPEED STATE DURATION (mn)	COMMENTS	
			FAIL	PASS
1385	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 593 HI₁

Bearing conditions required: normal

Nominal speed:

	AMBIENT	MEDIUM	+10% K	NOMINAL	- 10%	
Target outlet temperature	250	150	21	19	17	K
TURBINE :						
Inlet pressure	11.4	13.92	8.6			10 ⁵ Pa
Outlet pressure	3.19	3.36	3.54			10 ⁵ Pa
Inlet temperature	289.21	186.83	31.94			K
Outlet temperature	245.57	150.47	24.57			K
Flow	132.6	199.9	294.1			g/s
U1/C0	0.21	0.25	0.56			
μ	38.19	45.36	76.64			%
BRAKE :						
Inlet pressure	4.31	5.91	3.51			10 ⁵ Pa
Outlet temperature	31.9	55.8	34.8			°C
BEARING :						
Inlet pressure	14.04	13.97	14.44			10 ⁵ Pa
Outlet pressure	2.88	3.0	3.39			10 ⁵ Pa
Inlet temperature	17.9	18.2	19.1			°C
Outlet temperature	23.5	30.5	12.9			°C
Inlet flow	16.19	15.58	14.43			g/s
SPEED :	1255	1244	971			Hz
Number of start up/shut down	3	X	3			
Fail/pass	passed	passed	passed			

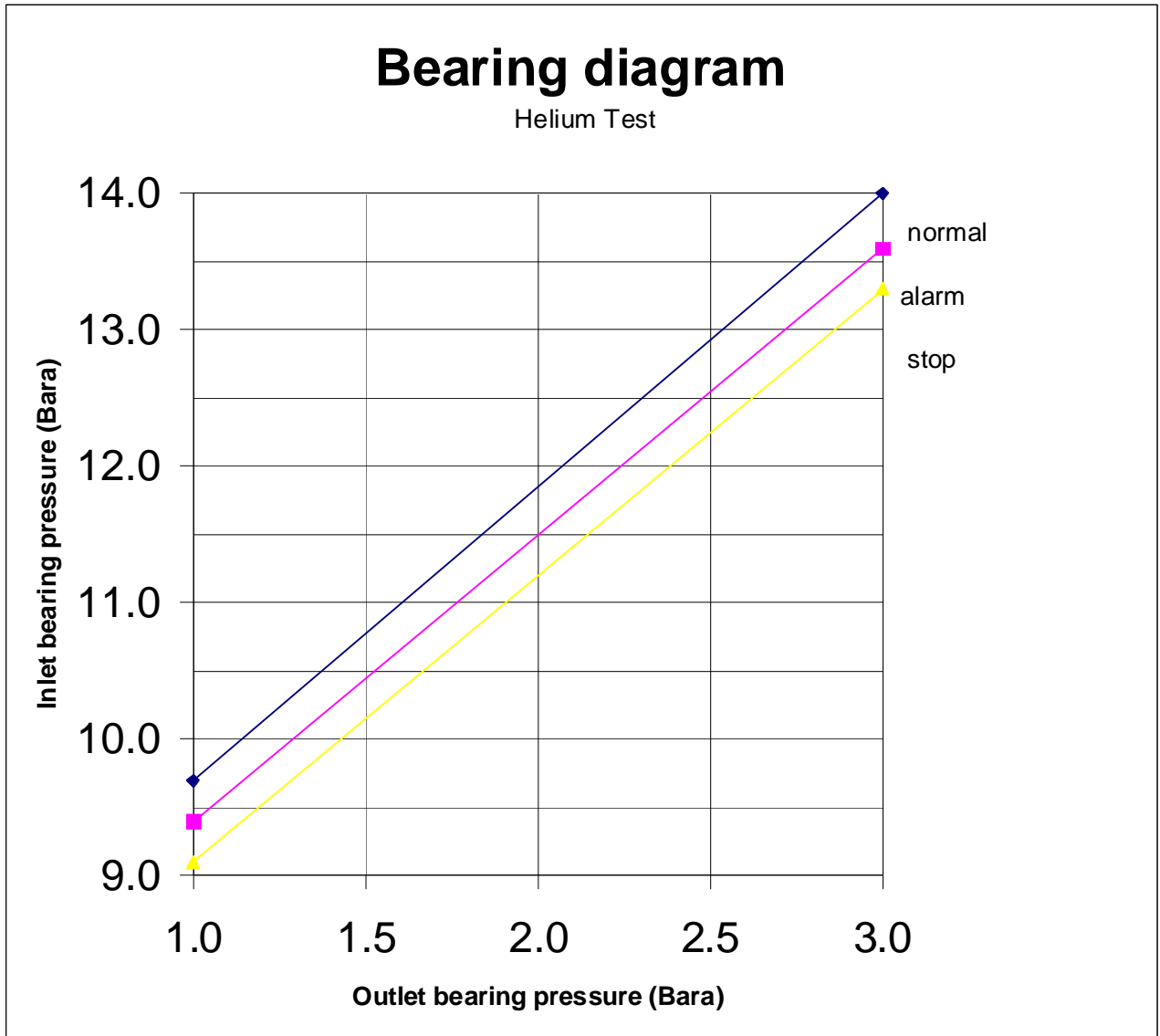
AFFAIRE / JOB : RHEA

N° : 301 0914

Identification du matériel / Material identification : C6 593 HI₁

APPLICATION : Site Client/Customer

ALAT Test



TEST REPORT

5.7 EFFICIENCY VERSUS U1/CO

(Items 6.7 of procedure)

Cartridge number: C6 593 HI₁

INPUTS

TURBINE PROCESS 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	19.1	4.9	28.6	19.1	987	63.3	49.3	0.78	1250	48600	10.5

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	8.6	3.54	31.94	24.57	294.1	50.15	38.44	0.77	971	11306	5.01

BEARING TEST CONDITIONS

GAS	PRESSURES 10 ⁵ Pa		TEMPERATURES °C	
	INLET	OUTLET	INLET	OUTLET
He	14.44	3.39	19.1	12.9

BRAKE TEST CONDITIONS

GAS	PRESSURES 10 ⁵ Pa		TEMPERATURES °C	
	INLET	OUTLET	INLET	OUTLET
He	3.51			34.8

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
58.0	176.84	1.41	0.56	76.64		X

UTILITY FLOW RATE

GAS BEARING SUPPLY g / s	BRAKE SUPPLY g / s	SEAL GAS g / s	RETURN g / s
15.43	0.0	0.2	16.07