

		PROCES-VERBAL D'ESSAI TEST REPORT CRYOGENIC TURBO EXPANDER			N° : C4058-NT-25 (4) Folio : 1 / 11		
AFFAIRE : RHEA JOB :				N° : 301 0914 N° :		Fiche Suiveuse n° : <i>Inspection traveller n° :</i>	
Identification du matériel : C6 596 HI₁ N° : 324-XT004 <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		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	R- Guimaraes	F. Delcayre					
DATE / DATE	08 12 2013	10 12 2013					
SIGNATURE / VISA							

CONTENTS

1. SCOPE.....	3
2. PROCESS CONDITION	3
3. GAS USED FOR THE TEST	3
4. BEARING CONDITIONS.....	3
5. ANNEXES.....	3
5.1 THRUST BEARING TEST, LOW SPEED	4
5.2 THRUST AND JOURNAL BEARINGS TEST, HIGHT SPEED	5
5.3 THRUST AND JOURNAL BEARING TEST,HIGH SPEED	6
5.4 CRITICAL SPEEDS AND SHAFT VIBRATIONS	7
5.5 OVERSPEED TEST	8
5.6 COOL DOWN, START-UP AND SHUT-DOWN	9
5.7 EFFICIENCY VERSUS U1/CO.....	11

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 596 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	15.44	15.46	10 ⁵ Pa
Outlet bearing pressure	2.87	2.88	10 ⁵ Pa
Turbine outlet pressure (1)	3.02	2.89	10 ⁵ Pa
Brake pressure (2)	3.02	17.24	14.04
Pressure difference = (2) – (1)	0	14.35	10 ⁵ Pa
Speed	10	3	Hz
Passed/failed	passed	passed	

TEST REPORT
5.2 THRUST AND JOURNAL BEARINGS TEST, HIGH SPEED

(Items 6.2 of procedure)

 Cartridge number: C6 596 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	15.42	15.44	15.44	10 ⁵ Pa
Outlet bearing pressure	2.81	2.86	2.9	10 ⁵ Pa
Turbine outlet test pressure (1)	3.2	3.25	3.33	10 ⁵ Pa
Brake test pressure (2)	6.22	9.38	14.11	10 ⁵ Pa
$\Delta = (2) - (1)$	3.02	6.13	10.78	10 ⁵ Pa
Speed	1175	948	806	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 596 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		14.25	10 ⁵ Pa
Outlet bearing pressure		2.81	10 ⁵ Pa
Turbine outlet test pressure		3.27	10 ⁵ Pa
Brake outlet pressure		6.46	10 ⁵ Pa
$\Delta = 2-1$		3.19	10 ⁵ Pa
Speed		1244	Hz
Passed/failed		passed	

TEST REPORT

5.4 CRITICAL SPEEDS AND SHAFT VIBRATIONS

(Items 6.3 of procedure)

Cartridge number: C6 596 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	
	580			730	H _z
Sound level estimation	A		A		
Time within the mode (> 3 ‘)					Min
Inlet bearing pressure	15.43		15.43		10 ⁵ Pa
Outlet bearing pressure	2.9		2.9		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 596 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	
15.41	2.85	15.7	24.7	

TURBINE TEST CONDITIONS

TURBINE PRESSURE (10 ⁵ Pa)		TURBINE TEMPERATURE (K)		TURBINE FLOW RATE (g/s)
SUPPLY	RETURN	SUPPLY	RETURN	
13.86	3.24	238.59	193.44	

BRAKE TEST CONDITIONS

INLET BRAKE PRESSURE 10 ⁵ Pa	OUTLET BRAKE TEMPERATURE °C
4.74	70.7

TEST RESULTS

ROTATION SPEED H _z	STEADY STATE	OVERSPEED STATE DURATION (mn)	COMMENTS	
			FAIL	PASS
1379	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 596 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	8.29	13.26	9.94			10 ⁵ Pa
Outlet pressure	3.1	3.24	3.58			10 ⁵ Pa
Inlet temperature	281.73	182.58	45.42			K
Outlet temperature	258.04	150.00	35.39			K
Flow	94.33	188.6	277.47			g/s
U1/C0	0.15	0.24	0.44			
μ	26.06	41.98	66.05			%
BRAKE :						
Inlet pressure	6.13	5.75	4.96			10 ⁵ Pa
Outlet temperature	21.1	60.5	43.7			°C
BEARING :						
Inlet pressure	15.43	15.32	16.02			10 ⁵ Pa
Outlet pressure	2.90	2.87	3.31			10 ⁵ Pa
Inlet temperature	15	16	17.1			°C
Outlet temperature	17.5	26.4	12.3			°C
Inlet flow	18.6	19.11	19.34			g/s
SPEED :	799	1205	959			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 596 HI₁

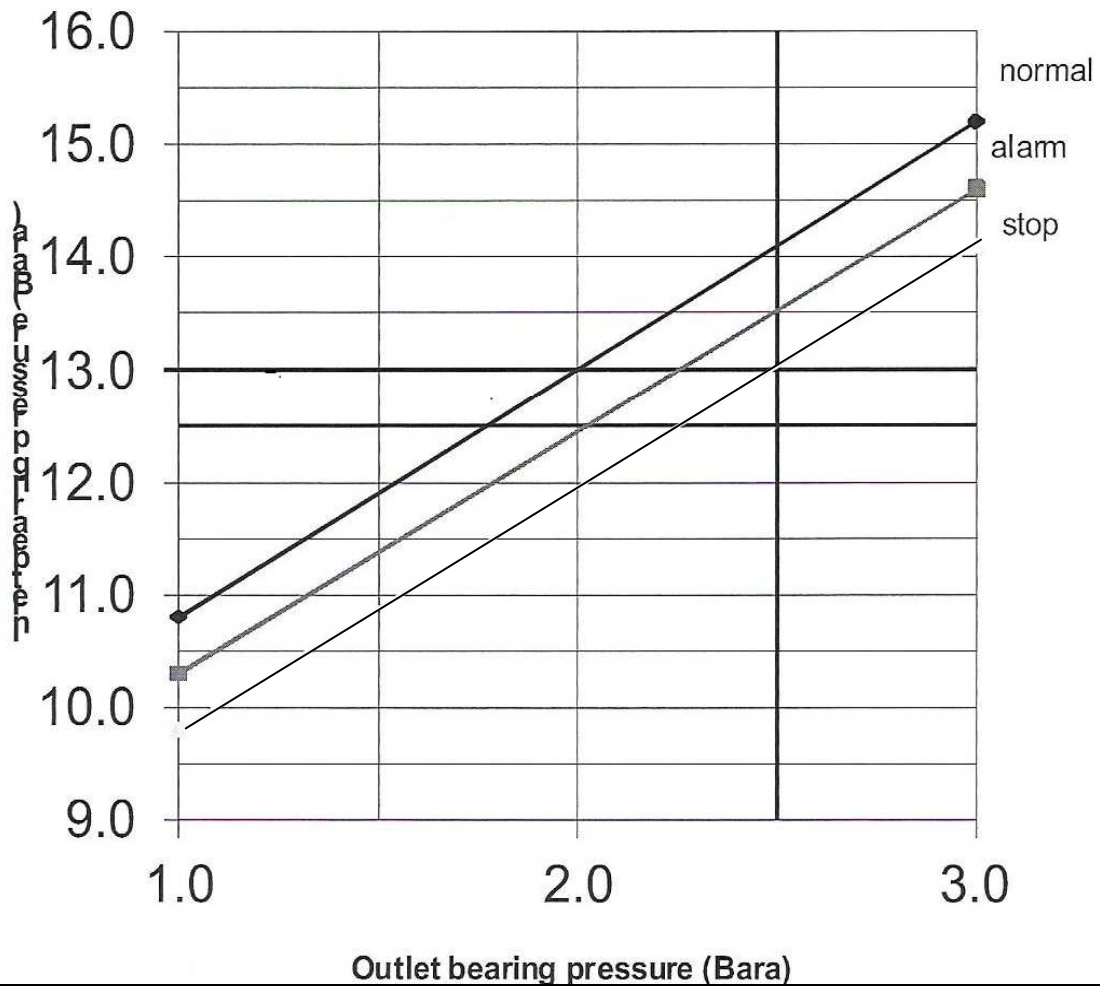
APPLICATION :

Site Client/*Customer*

ALAT Test

Bearing diagram

Helium Test



TEST REPORT

5.7 EFFICIENCY VERSUS U1/CO

(Items 6.7 of procedure)

Cartridge number: C6 596 HI₁

INPUTS

TURBINE PROCESS CONDITIONS

GAS	PRESSURES 10 ⁵ Pa		TEMPERATURES K		FLOW kg/s 10 ⁻³	ENTHALP. DROP kJ/kg		η $\Delta H_r / \Delta H_s$	ROTATION SPEED Hz	REFRIG. POWER Watt	INLET WHEEL PRESS. 10 ⁵ Pa
	INLET	OUTLET	INLET	OUTLET		ΔH_s	ΔH_r				
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 $\Delta H_r / \Delta H_s$	ROTATION SPEED Hz	REFRIG. POWER Watt	INLET WHEEL PRESS. 10 ⁵ Pa
	INLET	OUTLET	INLET	OUTLET		ΔH_s	ΔH_r				
He	9.94	3.58	45.42	35.39	277.47	80.363	53.079	0.66	959	14728	5.03

BEARING TEST CONDITIONS

GAS	PRESSURES 10 ⁵ Pa		TEMPERATURES °C	
	INLET	OUTLET	INLET	OUTLET
He	16.02	3.31	17.1	12.3

BRAKE TEST CONDITIONS

GAS	PRESSURES 10 ⁵ Pa		TEMPERATURES °C	
	INLET	OUTLET	INLET	OUTLET
He	4.96	5.06	28.5	43.7

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	174.65	400.9	0.44	66.05		X

UTILITY FLOW RATE

GAS BEARING SUPPLY	BRAKE SUPPLY	SEAL GAS	RETURN
g / s	g / s	g / s	g / s
19.34	-0.09	0.21	21.20