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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 595 HH₁

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 ⁵ Pa
OUTPUTS			
Inlet bearing pressure	17.5		10 ⁵ Pa
Outlet bearing pressure	2.88		10 ⁵ Pa
Turbine outlet pressure (1)	3.11		10 ⁵ Pa
Brake pressure (2)	3.10		10 ⁵ Pa
Pressure difference = (2) – (1)	0		10 ⁵ Pa
Speed	18		Hz
Passed/failed	passed	passed	

TEST REPORT

5.2 THRUST AND JOURNAL BEARINGS TEST, HIGH SPEED

(Items 6.2 of procedure)

Cartridge number: C6 595 HH₁

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)	9.6	14	15.6	10 ⁵ Pa
$\Delta = 2-1$	3.9	9.1	12.1	10 ⁵ Pa
OUTPUTS				
Inlet bearing pressure	17.53	17.51	17.56	10 ⁵ Pa
Outlet bearing pressure	2.78	2.99	2.83	10 ⁵ Pa
Turbine outlet test pressure (1)	3.11	3.47	3.40	10 ⁵ Pa
Brake test pressure (2)	7.03	12.55	15.44	10 ⁵ Pa
$\Delta = (2) - (1)$	3.92	9.08	12.04	10 ⁵ Pa
Speed	1162	1011	962	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 595 HH₁

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)	14	14	10 ⁵ Pa
$\Delta = 2-1$	9.1	9.1	10 ⁵ Pa
OUTPUTS			
Inlet bearing pressure		15.86	10 ⁵ Pa
Outlet bearing pressure		2.88	10 ⁵ Pa
Turbine outlet test pressure		3.31	10 ⁵ Pa
Brake outlet pressure		5.83	10 ⁵ Pa
$\Delta = 2-1$		2.52	10 ⁵ Pa
Speed		1416	Hz
Passed/failed		passed	

TEST REPORT

5.4 CRITICAL SPEEDS AND SHAFT VIBRATIONS

(Items 6.3 of procedure)

Cartridge number: C6 595 HH₁

Bearing conditions required: STOP

INPUTS					
	1 st RIGID MODE		2 nd RIGID MODE		
Calculated peak freq.	630		690		H _z
OUTPUTS					
Measured critical speeds	BEGIN.	END	BEGIN.	END	
	400			600	H _z
Sound level estimation	B		B		
Time within the mode (> 3 ‘)	3		3		Min
Inlet bearing pressure	17.47		17.47		10 ⁵ Pa
Outlet bearing pressure	3.02		3.02		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 595 HH₁

Bearing conditions required: NORMAL

INPUTS				
Nominal speed (Hz)		Maximum speed (Hz)		Over speed (Hz)
1420		1480		1520
OUPUTS				
BEARING TEST CONDITIONS				
BEARING GAS PRESSURE (10 ⁵ Pa)		BEARING GAS TEMPERATURE (°C)		BEARING GAS FLOW RATE (g/s)
SUPPLY	RETURN	SUPPLY	RETURN	
17.49	2.86	18.6	30.0	

TURBINE TEST CONDITIONS

TURBINE PRESSURE (10 ⁵ Pa)		TURBINE TEMPERATURE (K)		TURBINE FLOW RATE (g/s)
SUPPLY	RETURN	SUPPLY	RETURN	
12.98	3.42	254.06	196.43	

BRAKE TEST CONDITIONS

INLET BRAKE PRESSURE 10 ⁵ Pa	OUTLET BRAKE TEMPERATURE °C
5.91	55.3

TEST RESULTS

ROTATION SPEED H _z	STEADY STATE	OVERSPEED STATE DURATION (mn)	COMMENTS	
			FAIL	PASS
1534	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 595 HH₁

Bearing conditions required: normal

Nominal speed:

	AMBIENT	MEDIUM	+10% K	NOMINAL	- 10%	
Target outlet temperature	250	150	50	45	40	K
TURBINE :						
Inlet pressure	12.44	10.62	9.04	8.95	9.13	10 ⁵ Pa
Outlet pressure	3.40	3.25	3.77	3.69	3.91	10 ⁵ Pa
Inlet temperature	288.68	190.55	61.48	55.99	50.15	K
Outlet temperature	230.4	150.13	49.92	44.97	40.5	K
Flow	198.37	203.58	278.27	282.49	301.64	g/s
U1/C0	0.30	0.35	0.51	0.53	0.56	
μ	50.4	56.3	64	66.1	67	%
BRAKE :						
Inlet pressure	6.03	6.17	5.78	5.77	5.65	10 ⁵ Pa
Outlet temperature	30.2	58.5	40.7	39.3	37.5	°C
BEARING :						
Inlet pressure	17.45	17.54	17.55	17.45	17.50	10 ⁵ Pa
Outlet pressure	2.83	2.89	3.54	3.45	3.66	10 ⁵ Pa
Inlet temperature	19.0	18.1	18.6	18.6	18.7	°C
Outlet temperature	27.0	31.3	22.1	21.5	20.0	°C
Inlet flow	25.95	26.16	24.32	24.09	24.01	g/s
SPEED :	1435	1303	966	958	937	Hz
Number of start up/shut down	3	 	 	 	3	
Fail/pass	passed	passed	passed	passed		

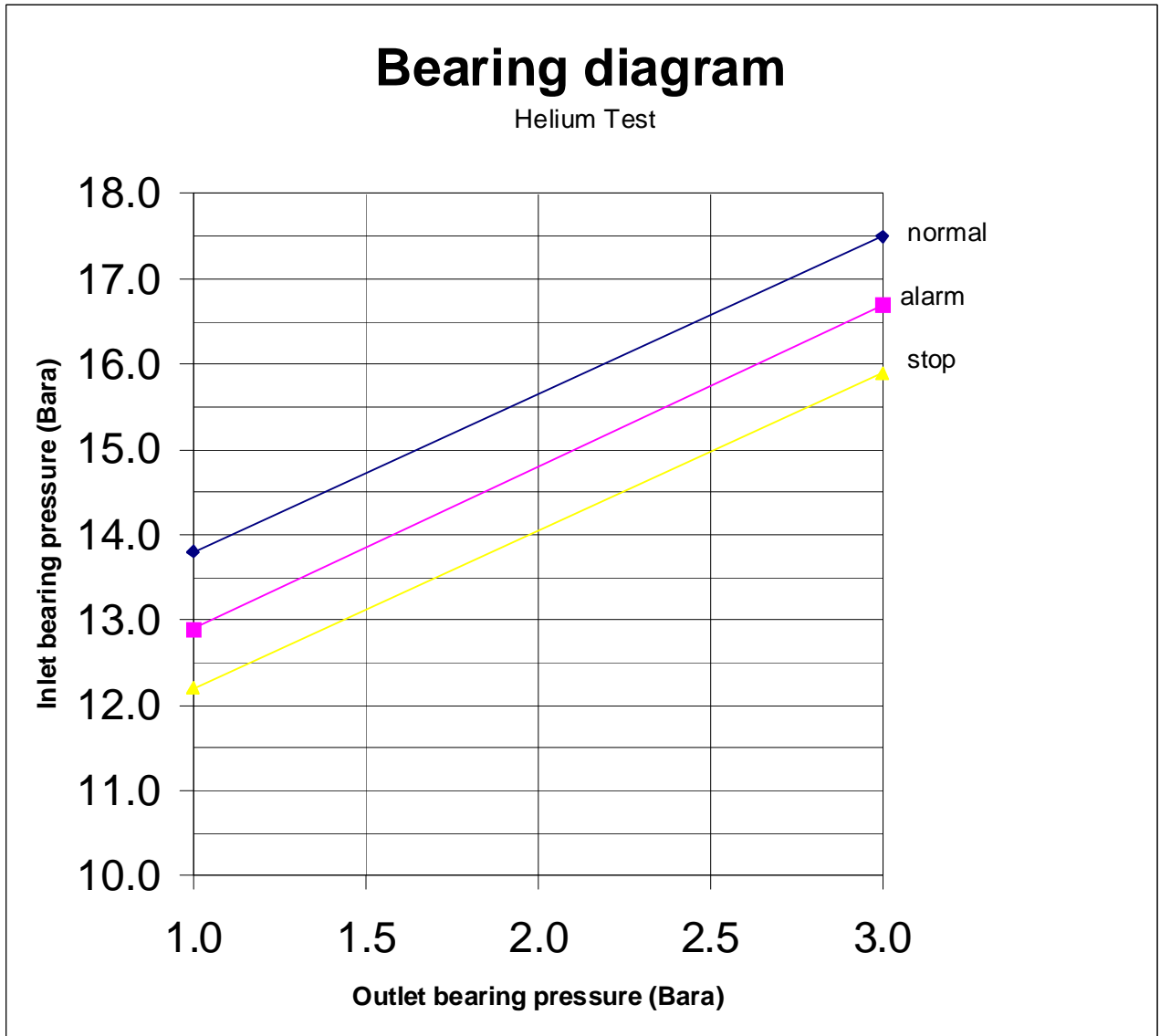
AFFAIRE / JOB : RHEA

N° : 301 0914

Identification du matériel / Material identification : C6 595 HH₁

APPLICATION : Site Client/Customer

ALAT Test



TEST REPORT

5.7 EFFICIENCY VERSUS U1/CO

(Items 6.7 of procedure)

Cartridge number: C6 595 HH₁

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	19.2	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 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	8.95	3.69	55.99	44.97	282.49	88.285	58.277	0.66	958	16463	4.99

BEARING TEST CONDITIONS

GAS	PRESSURES 10 ⁵ Pa		TEMPERATURES °C	
	INLET	OUTLET	INLET	OUTLET
He	17.45	3.45	18.6	21.5

BRAKE TEST CONDITIONS

GAS	PRESSURES 10 ⁵ Pa		TEMPERATURES °C	
	INLET	OUTLET	INLET	OUTLET
He	5.77			39.3

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
74.0	222.71	420.20	0.53	66		X

UTILITY FLOW RATE

GAS BEARING SUPPLY g / s	BRAKE SUPPLY g / s	SEAL GAS g / s	RETURN g / s
24.09	0.24	0.18	26.39