CGEN12

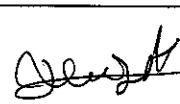
AIR LIQUIDE DIVISION TECHNIQUES AVANCEES	**PROCES-VERBAL D' ESSAI** ***TEST REPORT*** **CRYOGENIC TURBO EXPANDER**	**N° : C 4023 NT 11 (0)** Folio : 1 / 11 *Folio :*

AFFAIRE : KSTAR *JOB :*		N° : T04 *N° :*	Fiche Suiveuse n° : *Inspection traveller n° :*
Identification du matériel : C4 *Material identification :*	N° : 554 FV1	Quantité / *Quantity* : 1 Lot / *Batch* :	
Fournisseur/Fabricant : *Supplier / Manufacturer :* **AIR LIQUIDE**	Organisme de Contrôle : *Inspected by :* D2TI	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*	Passed	
VITESSES CRITIQUES *Critical speeds*	Passed	
SURVITESSE / *Overspeeds*	Passed	
START/STOP	Passed	
DESCENTE EN FROID *Cold down*	Passed	
RENDEMENT / *Efficiency*	Passed	

DECISION : *DECISION :* **CONFORME** / *PASS* ☑ **NON CONFORME** / *FAIL* ☐	**OBSERVATIONS :** *COMMENTS :*

	ESSAI / ***TEST***	**Responsable** / ***Manager***	**A.Q.** / ***Q.A.***		
NOM / ***NAME***	B Renzetti	F. Delcayre	JL. David		
DATE / ***DATE***	16/10/06	16/10/06			
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 : C4 554 FV1
Bearing conditions required : NORMAL

CASE	EXTREME 1	EXTREME 2	
INPUTS			
Load	0	30	N
On	Brake	Turbine	Bearing
Equivalent pressure difference on the shaft	0	2	10^5Pa
OUTPUTS			
Inlet bearing pressure	15.14	15.13	10^5Pa
Outlet bearing pressure	2.61	2.62	10^5Pa
Turbine outlet pressure (1)	2.85	2.69	10^5Pa
Brake pressure (2)	2.80	4.65	10^5Pa
Pressure difference = (2) – (1)	0.05	2.03	10^5Pa
Speed	11	11	H_Z
Passed/failed	passed	passed	

TEST REPORT

5.2 THRUST AND JOURNAL BEARINGS TEST, HIGH SPEED

(Items 6.2 of procedure)

Cartridge number : C4 554 FV1
Bearing conditions required : NORMAL

MODE	MINIMAL	NOMINAL	MAXIMAL	
INPUTS				
Turbine outlet design pressure (1)	6.1	5.2	4.1	10^5Pa
Brake design pressure (2)	5.8	7.3	8.8	10^5Pa
Δ = 2-1	-0.3	2.1	4.7	10^5Pa
OUTPUTS				
Inlet bearing pressure		15.23	15.14	10^5Pa
Outlet bearing pressure		2.47	2.54	10^5Pa
Turbine outlet test pressure (1)		2.52	2.53	10^5Pa
Brake test pressure (2)		4.76	7.27	10^5Pa
Δ = (2) – (1)		2.26	5.17	10^5Pa
Speed		2544	1720	Hz
Passed	passed	passed	passed	

TEST REPORT

5.3 THRUST AND JOURNAL BEARING TEST,HIGH SPEED

(Items 6.2 of procedure)

Cartridge number : C4 554 FV1
Bearing conditions required : ALARM AND STOP

BEARING CONDITIONS	**ALARM**	**STOP**	
Mode	Nominal	Nominal	
INPUTS			
Turbine design outlet pressure (1)	5.2	5.2	10^5Pa
Brake design pressure (2)	7.3	7.3	10^5Pa
Δ = 2-1	2.1	2.1	10^5Pa
OUTPUTS			
Inlet bearing pressure		14.59	10^5Pa
Outlet bearing pressure		2.52	10^5Pa
Turbine outlet test pressure		2.55	10^5Pa
Brake inlet pressure		4.66	10^5Pa
Δ = 2-1		2.11	10^5Pa
Speed		2542	Hz
Passed		passed	

TEST REPORT

5.4 CRITICAL SPEEDS AND SHAFT VIBRATIONS

(Items 6.3 of procedure)

Cartridge number : C4 554 FV1
Bearing conditions required : STOP

INPUTS					
	1st RIGID MODE		2nd RIGID MODE		
Calculated peak freq.	800		1000		H_z
OUTPUTS					
Measured critical speeds	BEGIN.	END	BEGIN.	END	
		800		1600	H_z
Sound level estimation	B		B		
Time within the mode (> 3 ')	3		3		Min
Inlet bearing pressure	15.11		15.11		10^5Pa
Outlet bearing pressure	2.55		2.55		10^5Pa
Fail/pass	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 554 FV1
Bearing conditions required : NORMAL

INPUTS		
Nominal speed (Hz)	Maximum speed (Hz)	Over speed (Hz)
2542	2700	2802
OUPUTS		

BEARING TEST CONDITIONS

BEARING GAS PRESSURE (10^5Pa)		BEARING GAS TEMPERATURE (°C)		BEARING GAS FLOW RATE (g/s)
SUPPLY	RETURN	SUPPLY	RETURN	
15.14	2.56	19.9	37.4	3.30

TURBINE TEST CONDITIONS

TURBINE PRESSURE (10^5Pa)		TURBINE TEMPERATURE (K)		TURBINE FLOW RATE (g/s)
SUPPLY	RETURN	SUPPLY	RETURN	
10.30	2.58	286.3	237.9	12.5

BRAKE TEST CONDITIONS

INLET BRAKE PRESSURE 10^5 Pa	OUTLET BRAKE TEMPERATURE °C
4.77	52.1

TEST RESULTS

ROTATION SPEED H_z	STEADY STATE	OVERSPEED STATE DURATION (mn)	COMMENTS	
			FAIL	PASS
2807	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 554 FV1
Bearing conditions required : normal
Nominal speed :

	AMBIENT	MEDIUM	+10 %	NOMINAL	-10 %	
Target outlet temperature	280	150	36	33	30	K
TURBINE :						
Inlet pressure	6.65	9.34	15.24	16	15.96	10^5Pa
Outlet pressure	2.55	2.62	4.17	4.34	4.47	10^5Pa
Inlet temperature	275.7	181.6	53.6	44.5	41.5	K
Outlet temperature	241.4	149.8	37.8	32	30	K
Flow	7.9	14.1	42	48.1	49.4	g/s
U_1/ Co	0.30	0.33	0.60	0.64	0.65	
η s	39	44	73	70	69	%
BRAKE :						
Inlet pressure	2.91	4.78	6.69	6.86	6.95	10^5Pa
Outlet temperature	42.3	50.4	56.2	55.7	54.6	°C
BEARING :						
Inlet pressure	15.14	15.20	15.24	15.23	15.23	10^5Pa
Outlet pressure	2.53	2.52	2.55	2.53	2.52	10^5Pa
Inlet temperature	19.9	20.1	18	18.4	18.1	°C
Outlet temperature	38.1	36.8	12.9	7.4	4.9	°C
Inlet flow	3.24	3.31	3.34	3.32	3.30	g/s
SPEED :	2521					Hz
Number of start up/shut down	3				3	
Fail/pass	passed	passed	passed	passed	passed	

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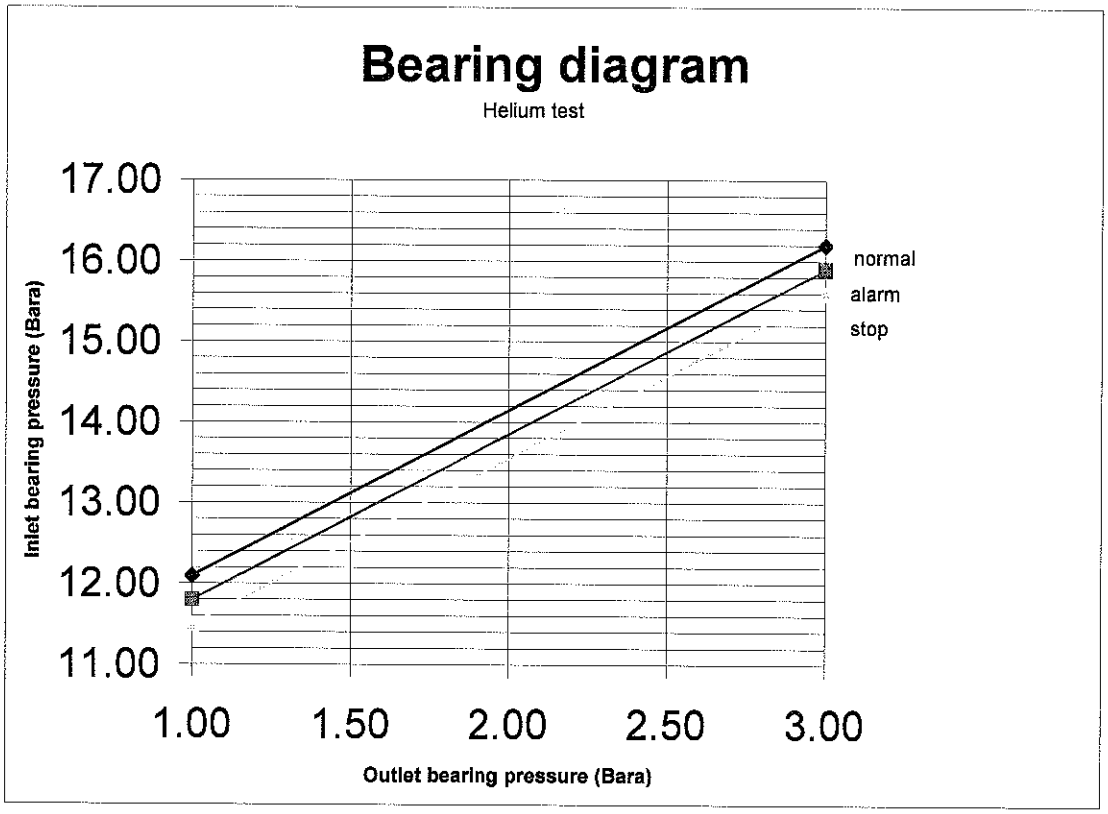
AIR LIQUIDE DIVISION TECHNIQUES AVANCEES	**DIAGRAMME PIVOTERIE** ***GAS BEARING DIAGRAM***	**N° :C4023-NT-9 (0)** Folio : 10 / 11 *Folio* :

AFFAIRE / *JOB* :KSTAR N° :

Identification du matériel / *Material identification* : C4 554 FV1

APPLICATION : ☐ Site Client/*Customer* ☑ DTA Test



NOM / *NAME*	F. DELCAYRE				
DATE / *DATE*	02/10/06				
SIGNATURE / *VISA*					
VERSION / *ISSUE*					

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TEST REPORT

5.7 EFFICIENCY VERSUS U1/CO

(Items 6.7 of procedure)

Cartridge number : C4 554 FV1

INPUTS — TURBINE PROCESS CONDITIONS

GAS	PRESSURE 10^5Pa		TEMPERATURES K		FLOW kg/s	ENTHALP. DROP kJ/kg		η s	ROTATION SPEED Hz	REFRIG. POWER Watt	INLET WHEEL PRESS. 10^5Pa
	INLET	OUTLET	INLET	OUTLET		Δ Hs	Δ Hr	Δ Hr/ Δ Hs			
He	20.53	5.18	47.4	33	59.0	107.5	77.4	0.72	2542	4566	11.6

OUTPUTS — TURBINE TEST CONDITIONS

GAS	PRESSURE 10^5Pa		TEMPERATURES K		FLOW kg/s	ENTHALP. DROP KJ/kg		η s	ROTATION SPEED Hz	REFRIG. POWER Watt	INLET WHEEL PRESS. 10^5Pa
	INLET	OUTLET	INLET	OUTLET		Δ Hs	Δ Hr	Δ Hr/ Δ Hs			
He	15.24	4.17	53.6	37.8	42	115.175	84.034	0.73	2580	3530	7.13

BEARING TEST CONDITIONS

GAS	PRESSURE 10^5Pa		TEMPERATURES °C
	SUPPLY	RETURN	
He	15.23	2.55	In : 18 Out : 12.9

BRAKE TEST CONDITIONS

GAS	PRESSURES 10^5Pa		TEMPERATURE °C	
	INLET	OUTLET	INLET	OUTLET
He	6.69			56.2

TEST RESULTS

DIAM. WHEEL mm	TIP VELOCITY U_1 m/s	SPOUTING VELOCITY C_o m/s	U_1/ Co	η s	COMMENTS	
		SUPPLY	RETURN		FAIL	PASS
35.75	289.7	479.7	0.60	73 %		X

UTILITY FLOW RATE

GAS BEARING SUPPLY g / s	BRAKE SUPPLY g / s	SEAL GAS g / s	RETURN g / s
	INLET	OUTLET	OUTLET
3.34	0.25	0.25	4.08