

 DIVISION TECHNIQUES AVANCEES		<b>PROCES-VERBAL D' ESSAI</b> <b>TEST REPORT</b> <b>CRYOGENIC TURBO EXPANDER</b>			N° : C 4023 NT 9 (0) Folio : 1 / 11 Folio :											
AFFAIRE : KSTAR JOB :			N° : T02 N° :		Fiche Suiveuse n° : Inspection traveller n° :											
Identification du matériel : C5 <i>Material identification :</i>		N° : 604 FT1	Quantité / <i>Quantity</i> : 1 Lot / <i>Batch</i> :													
Fournisseur/Fabricant : <i>Supplier / Manufacturer :</i> <b>AIR LIQUIDE</b>		Organisme de Contrôle : <i>Inspected by :</i> D2TI	Lieu : <i>Location :</i> <b>Sassenage</b>		Phase : <i>Phase :</i>											
Documents de référence : <i>Reference documents :</i> PROCEDURE : D4444-PO-2			Instruments de contrôles utilisés : <i>Inspection instruments used :</i> <table border="1" data-bbox="874 745 1548 1064"> <thead> <tr> <th>Type / <i>Type</i></th> <th>N° de Gestion/<i>Control n°</i></th> </tr> </thead> <tbody> <tr> <td>Test bed</td> <td>504 9999 100</td> </tr> <tr> <td></td> <td></td> </tr> <tr> <td></td> <td></td> </tr> <tr> <td></td> <td></td> </tr> </tbody> </table>				Type / <i>Type</i>	N° de Gestion/ <i>Control n°</i>	Test bed	504 9999 100						
Type / <i>Type</i>	N° de Gestion/ <i>Control n°</i>															
Test bed	504 9999 100															
<b>MESURES</b>		<b>RESULTATS</b>	<b>OBSERVATIONS</b>													
PIVOTERIE / <i>BEARINGS</i>		Passed														
VITESSES CRITIQUES <i>Critical speeds</i>		Passed														
SURVITESSE / <i>Overspeeds</i>		Passed														
DESCENTE EN FROID <i>Cold down</i>		Passed														
RENDEMENT / <i>Efficiency</i>		Passed														
<b>DECISION :</b> <i>DECISION :</i> CONFORME / <i>PASS</i> <input checked="" type="checkbox"/> NON CONFORME / <i>FAIL</i> <input type="checkbox"/>			<b>OBSERVATIONS :</b> <i>COMMENTS :</i>													
	<b>ESSAI / <i>TEST</i></b>	<b>Responsable / <i>Manager</i></b>	<b>A.Q. / <i>Q.A.</i></b>													
<b>NOM / <i>NAME</i></b>	L. Pelosi	F. Delcayre	JL. David													
<b>DATE / <i>DATE</i></b>	04/04/06	05/04/06														
<b>SIGNATURE / <i>VISA</i></b>																

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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 : C5 604 FT1

Bearing conditions required : NORMAL

CASE	EXTREME 1	EXTREME 2	
<b>INPUTS</b>			
Load	0	554	N
On	Brake	Turbine	Bearing
Equivalent pressure difference on the shaft	0	28	10 <sup>5</sup> Pa
<b>OUTPUTS</b>			
Inlet bearing pressure	13.88	13.96	10 <sup>5</sup> Pa
Outlet bearing pressure	1.99	2.05	10 <sup>5</sup> Pa
Turbine outlet pressure (1)	1.86	1.94	10 <sup>5</sup> Pa
Brake pressure (2)	2.05	17.84	10 <sup>5</sup> Pa
Pressure difference = (2) – (1)	0.19	15.9	10 <sup>5</sup> Pa
Speed	12	12	Hz
Passed/failed	passed	passed	

TEST REPORT

**5.2 THRUST AND JOURNAL BEARINGS TEST, HIGH SPEED**

(Items 6.2 of procedure)

Cartridge number : C5 604 FT1

Bearing conditions required : NORMAL

MODE	MINIMAL	NOMINAL	MAXIMAL	
<b>INPUTS</b>				
Turbine outlet design pressure (1)	6.1	5.2	4.2	10 <sup>5</sup> Pa
Brake design pressure (2)	8.1	10.2	12.2	10 <sup>5</sup> Pa
$\Delta = 2-1$	2.0	5.0	8.0	10 <sup>5</sup> Pa
<b>OUTPUTS</b>				
Inlet bearing pressure	13.94	14.0	13.85	10 <sup>5</sup> Pa
Outlet bearing pressure	2.09	2.1	2.05	10 <sup>5</sup> Pa
Turbine outlet test pressure (1)	2.02	2.05	2.09	10 <sup>5</sup> Pa
Brake test pressure (2)	4.03	7.01	10.24	10 <sup>5</sup> Pa
$\Delta = (2) - (1)$	2.01	4.96	8.15	10 <sup>5</sup> Pa
Speed	2186	1814	1649	Hz
Passed	passed	passed	passed	

TEST REPORT

**5.3 THRUST AND JOURNAL BEARING TEST, HIGH SPEED**

(Items 6.2 of procedure)

Cartridge number : C5 604 FT1

Bearing conditions required : ALARM AND STOP

BEARING CONDITIONS	ALARM	STOP	
Mode	Nominal	Nominal	
<b>INPUTS</b>			
Turbine design outlet pressure (1)	5.2	5.2	10 <sup>5</sup> Pa
Brake design pressure (2)	10.2	10.2	10 <sup>5</sup> Pa
$\Delta = 2-1$	5.0	5.0	10 <sup>5</sup> Pa
<b>OUTPUTS</b>			
Inlet bearing pressure		12.88	10 <sup>5</sup> Pa
Outlet bearing pressure		2.15	10 <sup>5</sup> Pa
Turbine outlet test pressure		2.13	10 <sup>5</sup> Pa
Brake inlet pressure		6.14	10 <sup>5</sup> Pa
$\Delta = 2-1$		4.01	10 <sup>5</sup> Pa
Speed		2049	Hz
Passed		passed	

TEST REPORT

**5.4 CRITICAL SPEEDS AND SHAFT VIBRATIONS**

(Items 6.3 of procedure)

Cartridge number : C5 604 FT1

Bearing conditions required : STOP

INPUTS					
	1 <sup>st</sup> RIGID MODE		2 <sup>nd</sup> RIGID MODE		
Calculated peak freq.	820				Hz
OUTPUTS					
Measured critical speeds	BEGIN.	END	BEGIN.	END	Hz
Sound level estimation	A		A		
Time within the mode (> 3 ')					Min
Inlet bearing pressure	13.51		13.51		10 <sup>5</sup> Pa
Outlet bearing pressure	2.19		2.19		10 <sup>5</sup> Pa
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 : C5 604 FT1

Bearing conditions required : NORMAL

INPUTS				
Nominal speed (Hz)		Maximum speed (Hz)		Over speed (Hz)
2024		2150		2230
OUPUTS				
BEARING TEST CONDITIONS				
BEARING GAS PRESSURE (10 <sup>5</sup> Pa)		BEARING GAS TEMPERATURE (°C)		BEARING GAS FLOW RATE (g/s)
SUPPLY	RETURN	SUPPLY	RETURN	
13.94	2.1	14.6	27.9	12.85

**TURBINE TEST CONDITIONS**

TURBINE PRESSURE (10 <sup>5</sup> Pa)		TURBINE TEMPERATURE (K)		TURBINE FLOW RATE (g/s)
SUPPLY	RETURN	SUPPLY	RETURN	
6.45	2.09	239.7	187.7	53.6

**BRAKE TEST CONDITIONS**

INLET BRAKE PRESSURE 10 <sup>5</sup> Pa	OUTLET BRAKE TEMPERATURE °C
6.05	55.4

**TEST RESULTS**

ROTATION SPEED Hz	STEADY STATE	OVERSPEED STATE DURATION (mn)	COMMENTS	
			FAIL	PASS
2237	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 : C5 604 FT1

Bearing conditions required : normal

Nominal speed :

	AMBIENT	MEDIUM	+10 %	NOMINAL	-10 %	
Target outlet temperature	280	180	78	71	64	K
<b>TURBINE :</b>						
Inlet pressure	3.43	8.16	11.92	12.72	12.0	10 <sup>5</sup> Pa
Outlet pressure	2.1	3.33	5.12	5.2	5.23	10 <sup>5</sup> Pa
Inlet temperature	249.9	215.4	100.6	95.4	82.1	K
Outlet temperature	238.3	176.0	78.4	72.8	64.0	K
Flow	31.2	70.6	145.4	156.1	158.5	g/s
<b>BRAKE :</b>						
Inlet pressure	6.11	8.34	9.99	10.08	10.04	10 <sup>5</sup> Pa
Outlet temperature	20.6	51.7	57.5	60.5	55.4	°C
<b>BEARING :</b>						
Inlet pressure	13.51	13.9	13.97	14.02	13.8	10 <sup>5</sup> Pa
Outlet pressure	2.19	2.12	2.17	2.13	2.11	10 <sup>5</sup> Pa
Inlet temperature	14.7	16.5	15.6	17.1	16.1	°C
Outlet temperature	17.2	26.2	21.3	21.1	17.5	°C
Inlet flow	10.52	11.71	11.1	10.94	10.57	g/s
<b>SPEED :</b>	1170	2012	2016	2050	1908	Hz
Number of start up/shut down	<del> </del>	3	<del> </del>	<del> </del>	3	
Fail/pass	passed	passed	passed	passed	passed	



DIAGRAMME PIVOTERIE  
GAS BEARING DIAGRAM

N° :C4023-NT-9 (0)

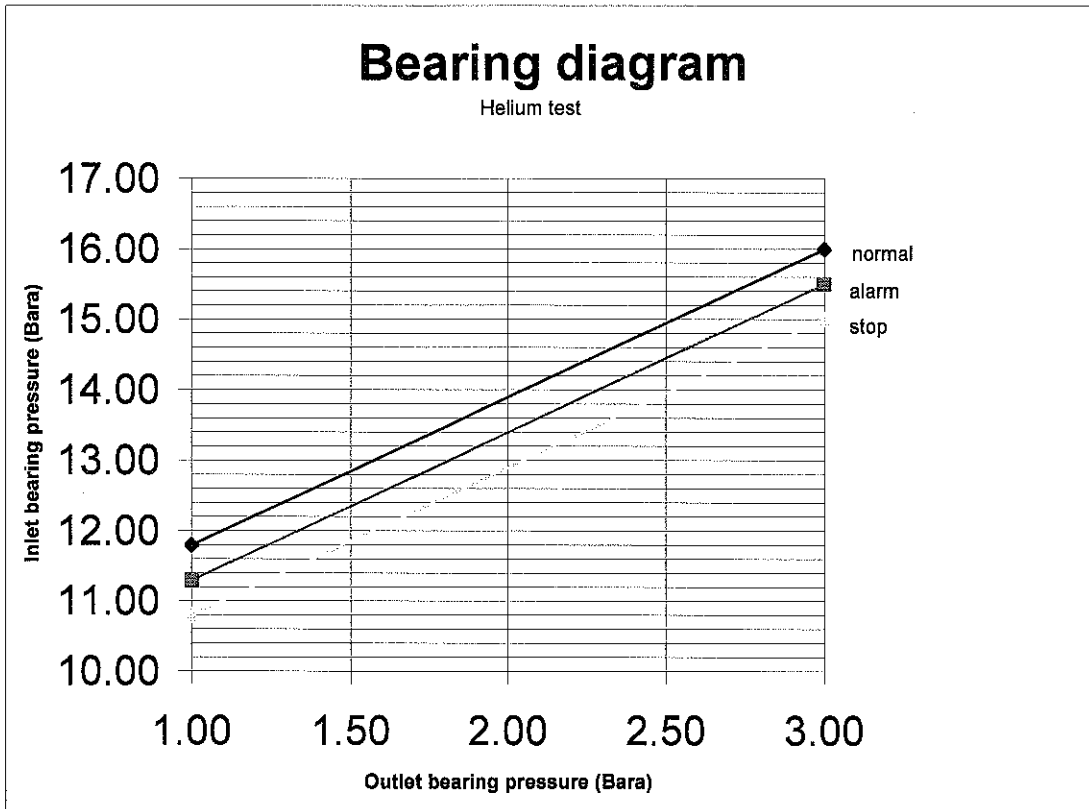
Folio : 10 / 11  
Folio :

AFFAIRE / JOB :

N° :

Identification du matériel / Material identification : C5 604 FT1

APPLICATION :  Site Client/Customer  DTA Test



NOM / NAME	F. DELCAYRE				
DATE / DATE	04/04/06				
SIGNATURE / VISA					
VERSION / ISSUE					

**TEST REPORT**

**5.7 EFFICIENCY VERSUS U1/CO**

(Items 6.7 of procedure)

Cartridge number : C5 604 FT1

**INPUTS**

**TURBINE PROCESS CONDITIONS**

GAS	PRESSURE 10 <sup>5</sup> Pa		TEMPERATURES K		FLOW kg/s	ENTHALP. DROP kJ/kg		$\eta$ s	ROTATION SPEED Hz	REFRIG. POWER Watt	INLET WHEEL PRESS. 10 <sup>5</sup> Pa
	INLET	OUTLET	INLET	OUTLET		$\Delta$ Hs	$\Delta$ Hr				
He	13.18	5.17	92.8	72.9	162.0	152.8	116.2	0.76	2024	18817	8.7

**OUTPUTS**

**TURBINE TEST CONDITIONS**

GAS	PRESSURE 10 <sup>5</sup> Pa		TEMPERATURES K		FLOW kg/s	ENTHALP. DROP KJ/kg		$\eta$ s	ROTATION SPEED Hz	REFRIG. POWER Watt	INLET WHEEL PRESS. 10 <sup>5</sup> Pa
	INLET	OUTLET	INLET	OUTLET		$\Delta$ Hs	$\Delta$ Hr				
He	12.72	5.2	95.4	72.8	156.1	151.15	119.6	0.791	2050	18666	8.23

**BEARING TEST CONDITIONS**

GAS	PRESSURE 10 <sup>5</sup> Pa		TEMPERATURES °C
	SUPPLY	RETURN	
He	14.02	2.13	In : 17.1 Out : 21.1

**BRAKE TEST CONDITIONS**

GAS	PRESSURES 10 <sup>5</sup> Pa		TEMPERATURE °C
	INLET	OUTLET	
He	10.19	10.08	60.5

**TEST RESULTS**

DIAM. WHEEL mm	TIP VELOCITY U <sub>1</sub> m/s	SPOUTING VELOCITY C <sub>0</sub> m/s		U <sub>1</sub> /C <sub>0</sub>	$\eta$ s	COMMENTS	
		SUPPLY	RETURN			FAIL	PASS
55	354.03	549.82	0.64	0.64	79.13%		X

**UTILITY FLOW RATE**

GAS BEARING SUPPLY g / s	BRAKE SUPPLY g / s	SEAL GAS g / s	RETURN g / s
10.94	0.71	0.61	12.45