CDT Yebes

TPS-COMPACT (AGILENT)

Performance verification tests

José M. Serna, Gabriel Gómez, Beatriz Vaquero

Observatorio de Yebes – IGN

CDT Technical Report 2018-16

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Introduction

Recently, Yebes Observatory has acquired a new pumping system (TPS-Compact from Agilent).

Supplier information:
Teratorr Technologies SL
Contact person: Carlos Elvira (c.elvira@teratorr.com)
Phone: +34 910 298 111
Mobile: +34 685 596 026
Calle Las Fábricas, 1 - local 12, 28923 Alcorcón, Madrid

This pumping system was selected in order to improve the current pumping capabilities achieved using the systems in use in the observatory for this application. TPS Compact pumping specifications are better.

The main objective of these device will be the pumping of the receivers during the cooling procedure. Because of its characteristics, it should be a good option for big volume receivers as the Tri-band receiver and the VGOS Broadband receiver.

Following Yebes observatory recommendation, FGI from Finland, has also acquired one of this pumping systems to be integrated with the new VGOS receiver that is under development at Yebes Observatory laboratories. This receiver will be installed in the new VGOS radio telescope in Metsahövi (Finland).

In this report the tests carried out to verify its correct performance are presented.

The main conclussion is that the system is not able to pump correctly the receivers so its use is not advised for this type of applications.

1. TPS-COMPACT specifications

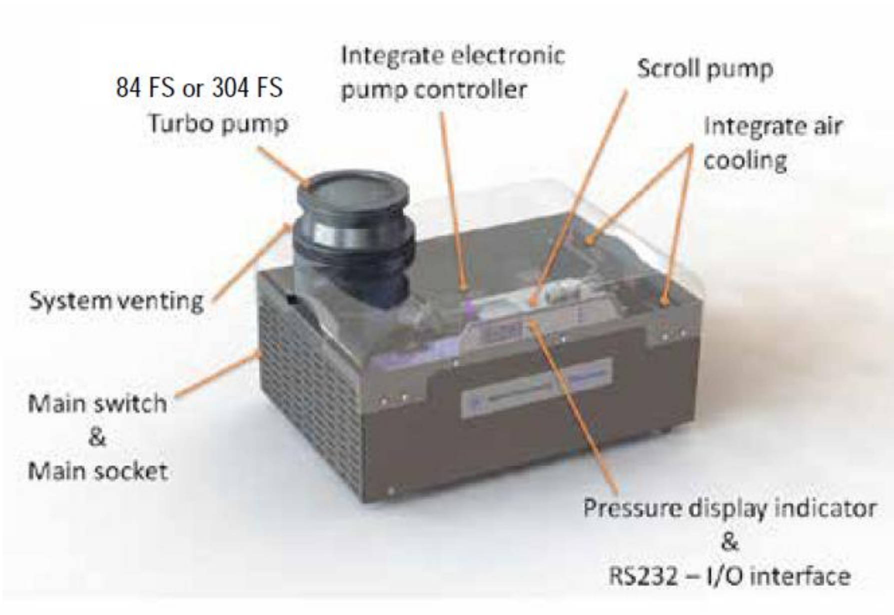

Figure 1: Agilent TPS COMPACT system

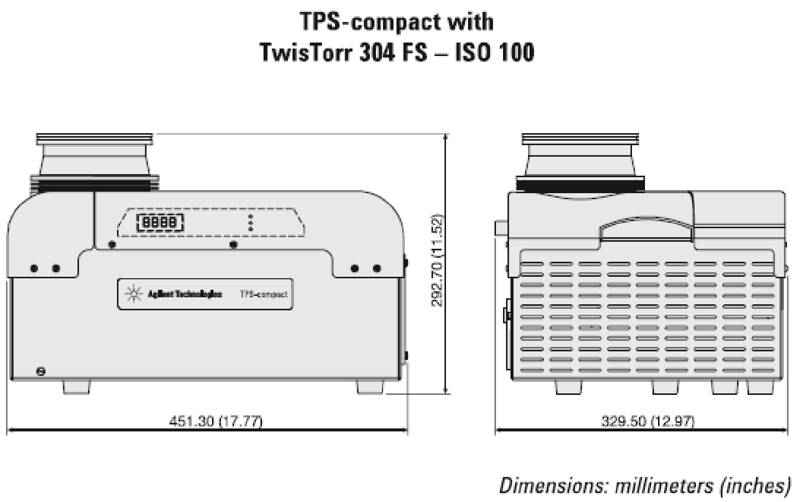

Figure 2: System dimensions

Features

- New generation TwisTorr 84 FS and 304 FS Turbomolecular Pumps
- IDP-3 Dry Scroll backing pump
- Compact, light, dry, clean and robust system
- Nominal voltage (90-240 V) - CE/CSA certified
- RS-232 or analogical communication
- Wide range vacuum gauge driving capability
- Large pressure data display
- Pressure driven set point, analog set point
- Wheels option available

Benefits

- Designed for demanding applications
- Cost-effective pumping solution
- Easy to use: plug and play system; easy PLC & PC interface
- Complies with world-wide safety standards
- Easy system pressure measurement; no external gauge reading unit needed
- Easy Tip-seal replacement (10 min)
- Excellent base pressure, down to 10^{-9} mbar
- Easy to be moved in small space
- Highest compression ratio for H_2/He

Technical Specifications

	Equipped with TwisTorr 84 FS	Equipped with TwisTorr 304 FS
Pumping speed	N_2: 57 l/s (ISO 63, with inlet screen)*	N_2: 180 l/s (with inlet screen)*
Base pressure**	1×10^{-9} mbar (CFF flanges) - 1×10^{-8} mbar (ISO flanges)	1×10^{-9} mbar (CFF flanges) - 1×10^{-8} mbar (ISO flanges)
Pumpdown time (15 lt volume)	46 sec (100 mbar); 104 sec (1 mbar); 160 sec (1×10^{-4} mbar); 210 sec (5×10^{-5} mbar); 400 sec (1.3×10^{-5} mbar)	80 sec (16 mbar); 110 sec (3 mbar); 155 sec (6×10^{-5}); 200 sec (1×10^{-5})
Turbo pump rotational speed	80,000 RPM	60,000 RPM
Start-up time	144 sec.	150 sec.
Operating ambient temperature	5 °C to 35 °C	5 °C to 35 °C
Input voltage and frequency	115 Vac 60 Hz or 220-240 Vac 50/60 Hz	115 Vac 60 Hz or 220-240 Vac 50/60 Hz or 100 Vac 50/60 Hz
Maximum input power	260 VA	310 VA
Bakeout temperature	120 °C at inlet (CFF flanges) - 80 °C at inlet (KF/ISO flanges)	120 °C at inlet (CFF flanges) - 80 °C at inlet (ISO flanges)
Communication	RS232 - Analogical I/O	RS232 - Analogical I/O
Weight	16.7 kg (36.8 lbs)	20.1 kg (44.3 lbs)

* *Pump nominal speed: TwisTorr 84 FS N_2: 67 l/s; Twistorr 304 FS N_2: 250 l/s*
** *According to standard DIN 28 428.*

Table 1: TPS COMPACT specifications (TwisTorr 304 FS)

1.1. T_PLUS software pumping monitoring.

With J5 connector, when turning on the pumping system only backing pump starts pumping.

T-Plus software only detects the system once it is ON.

- Open T_Plus software.
- Serial mode.
- Open control panel.
- file/load readings/TPS_readings.vrc (it is on the desktop).
- Data logger.
    - Setting sampling rate: 30 seconds.
    - Show data Log dialog.
    - Select file name to record (press square bottom with dots).
    - Start log.
- Start turbopump.

Stop monitoring when turbopump frequency is 0Hz.

2. Comparison with other pumping systems in use in the observatory

TPS Compact, Twistorr 304FS (Agilent)	
Pumping speed backing pump at 50 Hz, scroll	3,6m^3/h
Pumping speed for N_2	180 l/sec
Ultimate pressure	1E-08mbar
weight (kg)	20,1
Price	8837,5

Figure 3: TPS Compact (Agilent)

HiCube 80 Eco (Pfeiffer)	
Pumping speed backing pump at 50 Hz	0,9m^3/h
Pumping speed for N_2	67 l/sec
Ultimate pressure	<1E-7mbar
weight (kg)	17 - 12.1
Price	4425

Figure 4: Hicube 80 Eco (Pfeiffer)

DUO3 (Pfeiffer)	Turbo V81 (Varian=Agilent)
2.5m^3/h	77l/sec

Figure 5: DUO3 (Pfeiffer) + Turbo V81m (Varian)

Analyzing the basic specifications of the three different systems, it can be concluded that the system TPS-Compact is the most powerful one.

So pumping the receiver with this system should be faster and with a better final vacuum.

3. Tests and results with FGI pumping system

3.1. Test setup

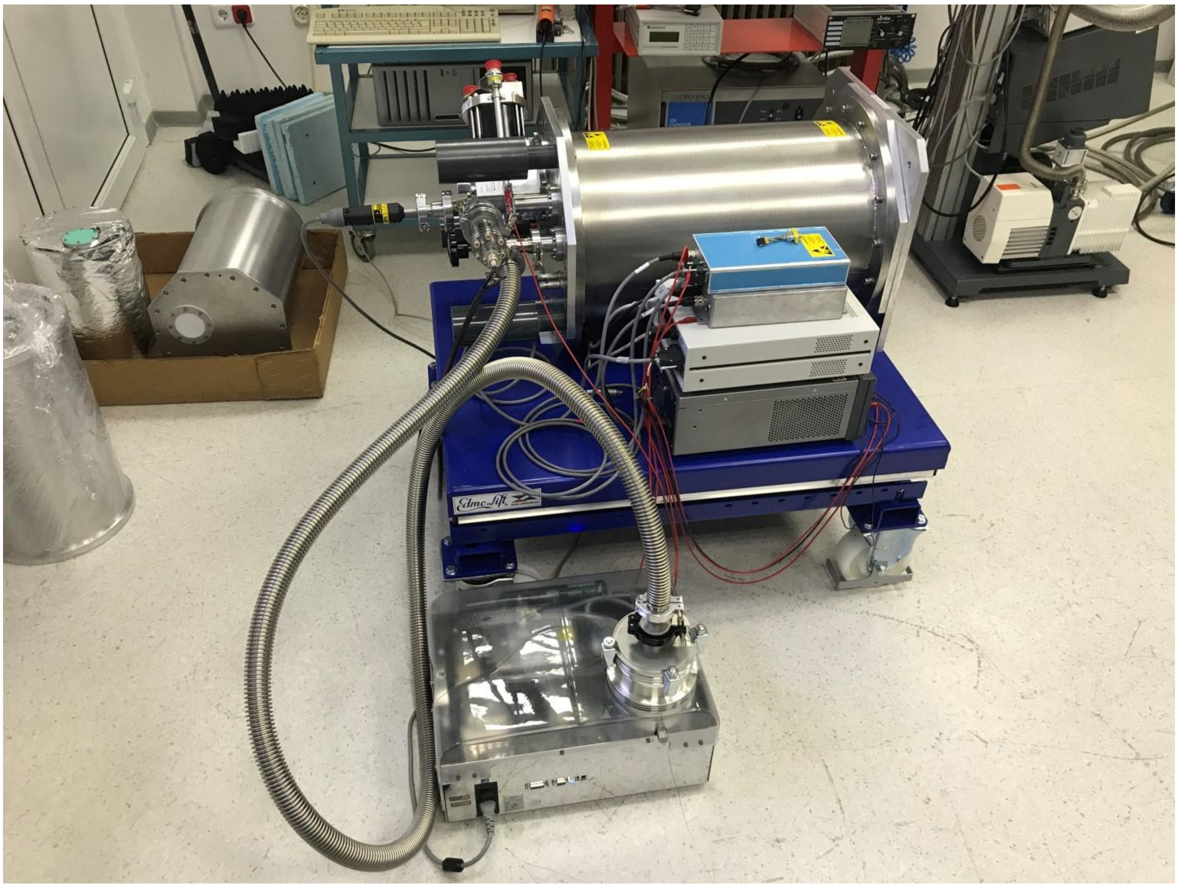

Figure 6: Test setup with receiver, pumping system and accessories

The system to pump is a VGOS receiver. At the bottom plate there is a KF25 manual valve. The connection between the dewar and the pumping system is made by means of a KF25 vacuum pipe.

Before starting the tests, the setup of the pumping system was carefully done, following in detail the user´s manual indications:

- Installation of the pumping system interface for KF40.
- Installation of the Agilent T-Plus control software.
- Running the pumping system for 48 hours in soft start mode (with a blind cover).

There are not leakage problems in the dewar. It was measured and also verified with a leakage detector system.

The dewar consists of three main parts: stainless steel cylinder and aluminum top and bottom covers. At the top cover the vacuum window is installed.

The dewar lower flange has several inputs/outputs for different uses:

- Cold head connection: to place the cold head in the right position.

- Two apertures with transitions for the vacuum control (pressure sensor and vacuum valve).
- Three Fisher hermetic connectors for the housekeeping control and monitoring, and amplifiers biasing.
- Four SMA hermetic connectors for the RF signals (calibration inputs and RF outputs).

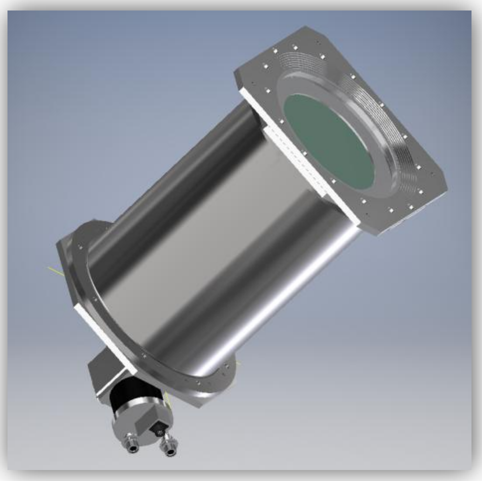

Figure 7: Receiver 3D model

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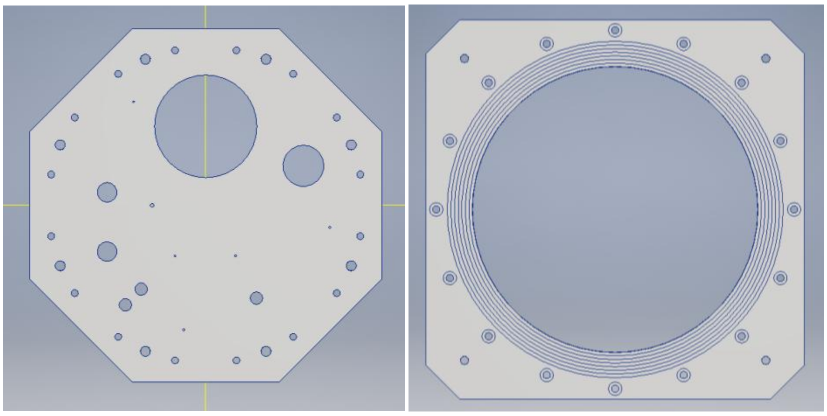

Figure 8. Dewar design: cylinder bottom and top covers.

Inside the dewar, at the bottom cover, there is an aluminum plate to carry out the transition between room temperature DC wiring and the cryogenic wires, using DB connectors.

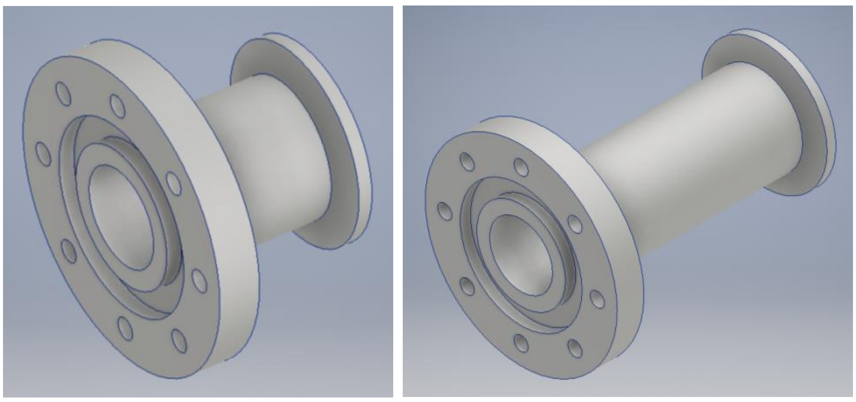

Figure 9. Vacuum flanges design (for electrovalve and vacuum transducer)

O-rings: main specifications and locations are presented in the table below:

Viton Seals	Type	d_1 (mm)	d_2 (mm)	Reference	Qty
Sumitomo Cold Head - bottom flange	OR VI	142	3	503.328	1
Vacuum case - bottom and top flanges	OR VI	365	5	304.143	2
Top flange 1 - Mylar	OR VI	365	5	304.143	1
Top flange 2 - Mylar	OR VI	385	5	673.715	1
Vacuum flanges - bottom flange	OR VI	28	4	670.265	2
SMA and K connectors flange - bottom flange	OR VI	58.42	2.62	305.517	3

Table 2: Vacuum seals Epidor.

The vacuum window goal is to allow transition (physical, electromagnetic and vacuum) between the signal and the QRFH feed. For this receiver, a vacuum window made of Mylar (Polyethylene terephthalate film, thickness 0.5 mm) was selected.

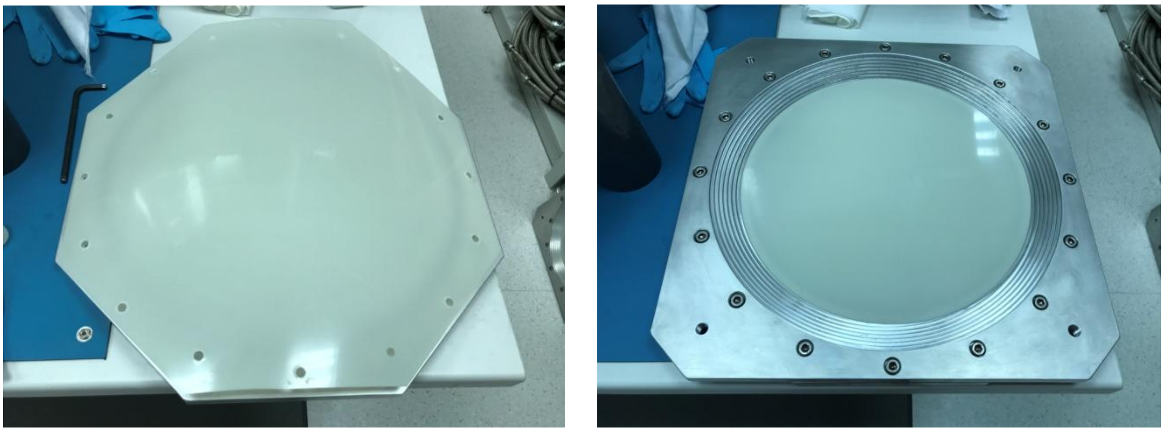

Figure 10. Vacuum window

3.2. Test results

TEST 1

- Without J5 connector.
- Without PC connection.
- Starting directly from atmospheric pressure with backing pump + turbo-pump.
- Soft start OFF.
- Maximum turbo frequency is 900Hz (reduced from 1010Hz), because with 1010Hz the turbopump power is too much during previous tests.

Time (min)	P (mbar)	Turbo Freq (Hz)	Turbo P (W)	Turbo state
0	ATM			
3	100			
4	29			
5	11			
6	4,7			
7	2,1			
8	9,3E-01			
9	7,6 E-01			
10	6,7 E-01			
11	5,5 E-01			
12	4,4 E-01			
13	3,5 E-01			
14	**4,3 E-01**	During the complete process, strange noise in the backing pump (see video)		
15	4,1E-01			
16	3,5E-01			
17	**3,7E-01**			
18	**4,4E-01**	Connect PC to the pumping system		
721Hz 70W Autotuning STOP pumping system				

Table 3: test 1 results

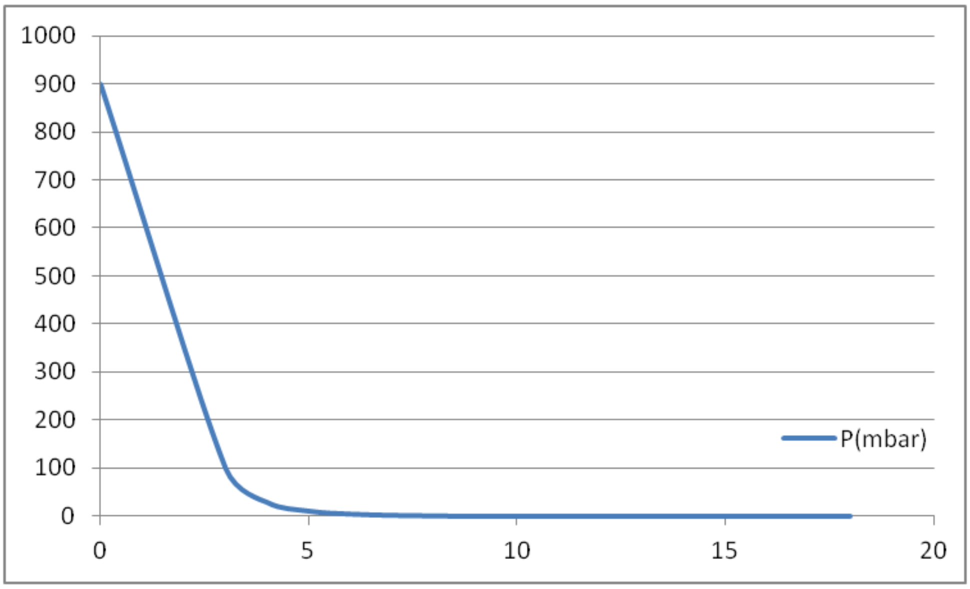

Figure 11: test result (Pressure)

The pumping system is not able to pump the receiver.

With this same setup, the receiver was pumped with the HiCube 80Eco system and the DUO3+Turbo V81M system and it was pumped correctly.

TEST 2

- With J5 connector (stop turbo pump from the beginning).
- With PC connection.
- Starting only with backing pump from atmospheric pressure.
- Soft start OFF
- Maximum turbo frequency is 900Hz (reduced from 1010Hz).

Time (min)	P (mbar)	Turbo Freq (Hz)	Turbo P (W)	Turbo state
0	ATM	Without strange noise in the backing pump		
3	120			
4	34			
7	5,2			
9	3,2			
11	2,5			
15	1,8			
16	1,7	TURBOPUMP ON		
17	1,2	283	33	Ramp
18	3,7E-01	450	61	Ramp
19	2,6 E-01	610	70	Ramp
20	2,2 E-01	780	71	Ramp
21	2,1 E-01	900	57	Normal
22	1,9 E-01	900	31	Normal
24	1,7 E-01	900	35	Normal
48	1,2E-01	900	54	Normal
65	**1,5E-01**	**790**	**70**	**Autotuning**
Strange noise in the backing pump System switch off				

Table 4: test 2 results

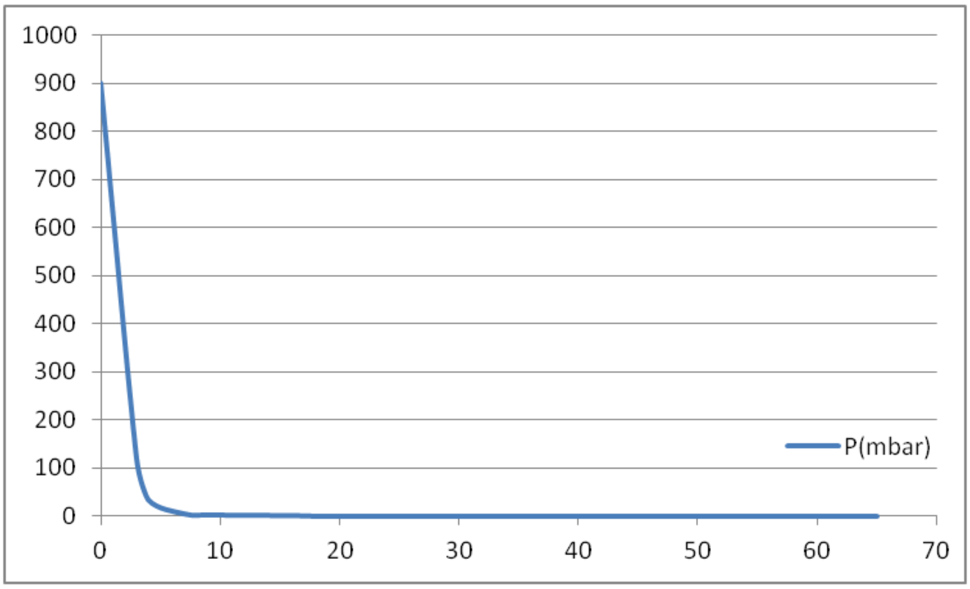

Figure 12: test result (Pressure)

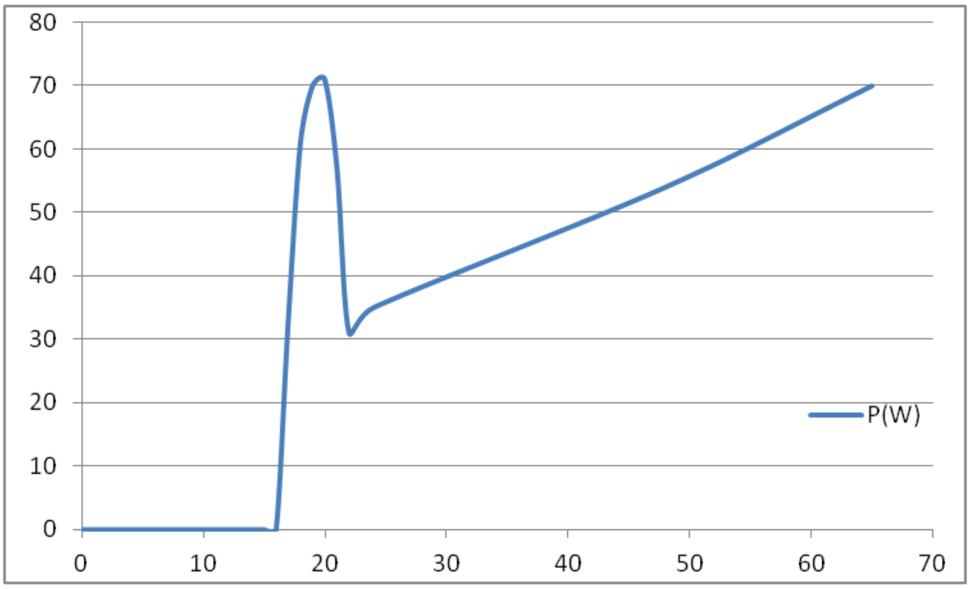

Figure 13: test result (Power)

The pumping system is not able to pump the receiver.

With this same setup, the receiver was pumped with the HiCube 80Eco system and the DUO3+Turbo V81M system and it was pumped correctly.

In order to complete this tests, because of the negative results, it was decided to carry out other complementary tests.

TEST 3: with SS reinforced PVC vacuum pipe

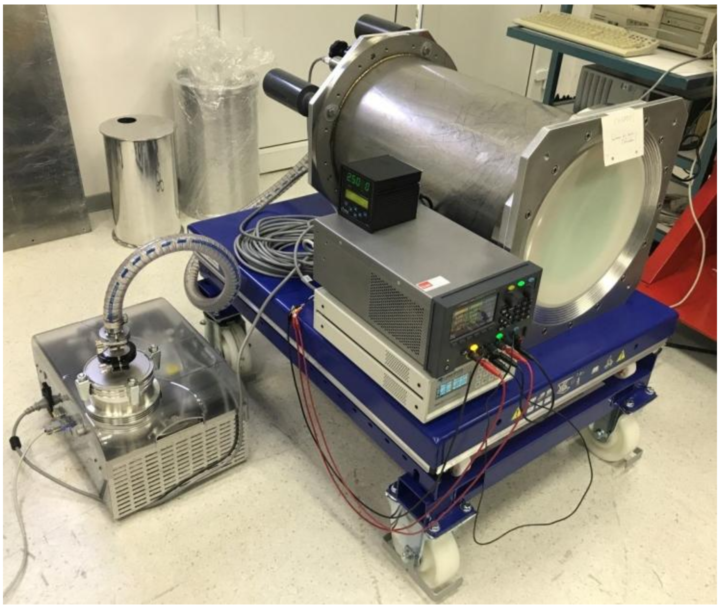

Figure 14. Previous setup but with a SS reinforced PVC pipe

- FGI pumping system (SN: IT18194006).
- Start from atmospheric pressure just with backing pump.
- Soft start Off.

Time	P (mbar)	Freq(Hz)	Power(W)	Mode	Notes
0	Atm				
1	380				
2	140				
3	55				
4	24				
5	11				
6	7				
7	4,5				
8	3,5				
9	2,8				
10	2,4				
15	1,6				
20	**1,33**	**Turbopump ON**			
21	9,1E-01	280	34	Ramp	
22	3,5E-01	430	54	Ramp	
23	1,8E-01	617	70	Ramp	
24	1,57E-01	790	72	Ramp	
25	1,43E-01	919	69	Autotuning	
26	**1,34E-01**	**1010**	**61**	**Normal**	
30	1,13E-01	1010	38	Normal	
60	7,7E-02	1002	69	Autotuning	
90	6,6E-02	1010	32	Normal	11:10 AM
133	1	726	69	Autotuning	11:53 AM
Not able to maintain the pumping status					

Table 5: Test results

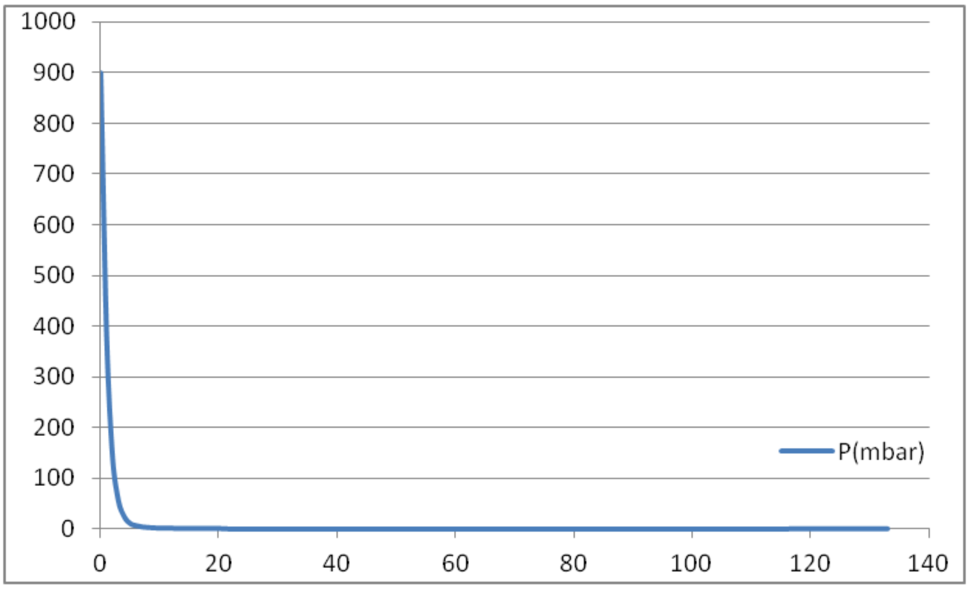

Figure 15: test result (Pressure)

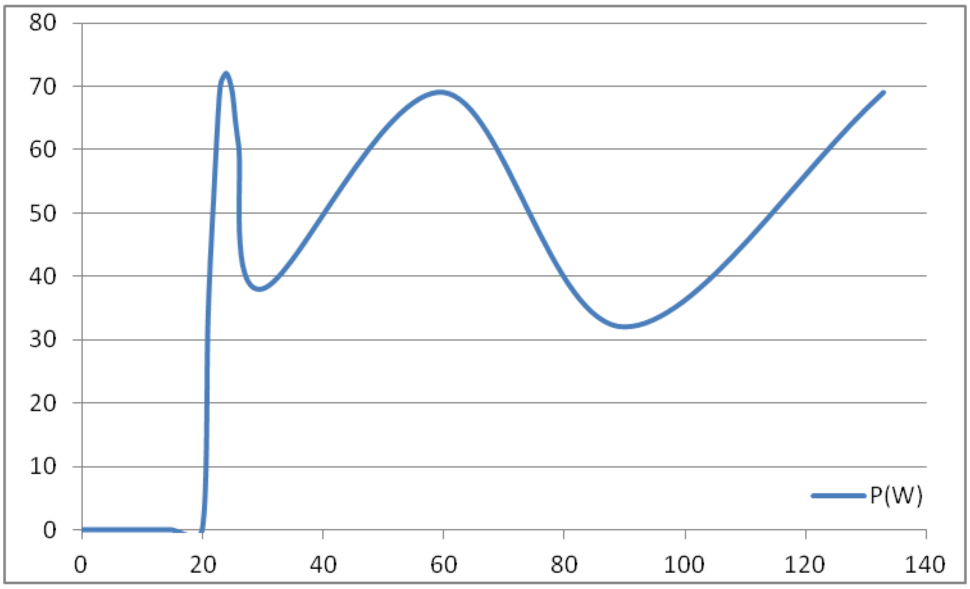

Figure 16: test result (Power)

TEST 4: with turbopump low speed option

- Start from atmospheric pressure just with backing pump.
- Soft start Off.
- **LOW SPEED OPTION** (turbopump max. frequency = **900Hz**). Parameter [001]=1.
- Monitoring file available (turbopump parameters).

Time	Δt (min)	P (mbar)	Freq(Hz)	Power(W)	Mode	Notes
12:00	0	Atm				
12:10	**10**	**2,2**	**Turbopump ON**			
12:12	12	3E-01	400	50	Ramp	
12:14	14	1,2E-01	790	72	Ramp	
12:15	**15**	**1,1E-01**	**900**	**47**	**Normal**	
12:20	20	8,7E-02	900	24	Normal	
12:40	40	6,3E-02	900	20	Normal	
13:15	75	5,2E-02	900	24	Normal	
13:55	115	4,56e-02	900	17	Normal	
14:25	145	4,26E-02	900	**45**	Normal	
02/08/2018						
08:47		8,3E-02	900	61	Normal/Autotuning	
STOP PUMPING						

Table 6: Test results

- **between normal and autotuning continuously.**
- **between low power and 70W.**
- **No error code.**
- **temp turbopump increasing.**

Even reducing the turbopump maximum speed to 900Hz, the pumping system is not able to pump correctly the receiver.

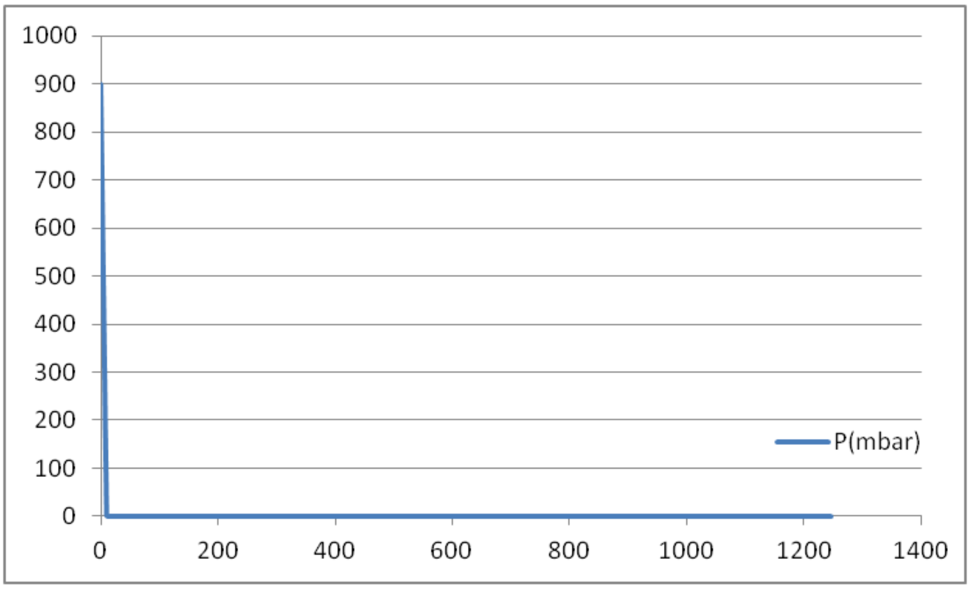

Figure 17: test result (Pressure)

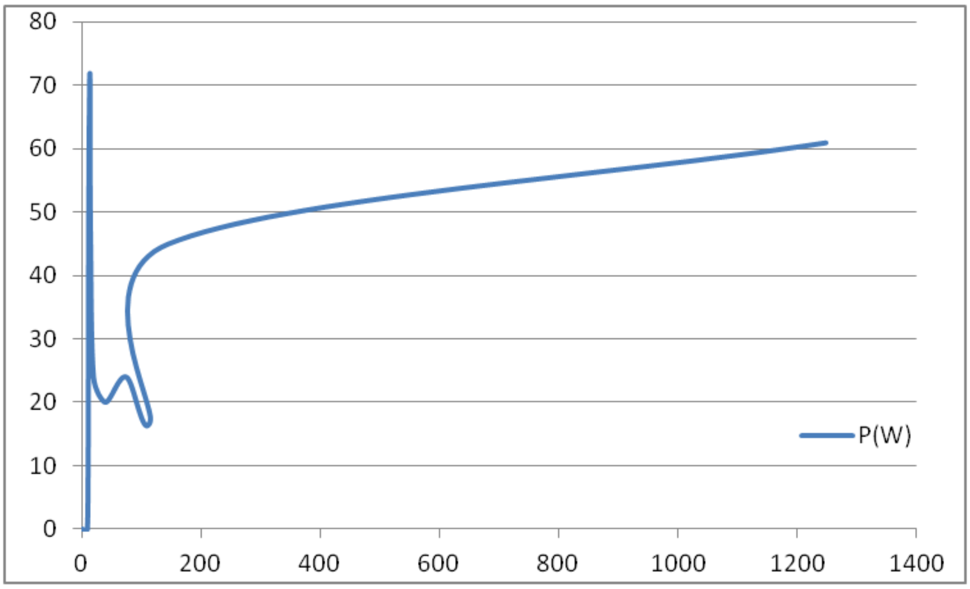

Figure 18: test result (Power)

TEST 5

- Start from atmospheric pressure just with backing pump and pump for 24 hours with <u>heaters and regenerators activated</u> (+6V@112mA, +25V@486mA).
- After 24 hours, switch ON turbopump and pump for other 24 hours.
- Serial mode.
- Soft start Off.
- **LOW SPEED OPTION** (turbopump max. frequency = **900Hz**). Parameter [001]=1.
- Monitoring file available (turbopump parameters): fgi_test3.xlsx
- T1=Tint, T2=Tcold, T3=Tfeed, T4=Tlna

Time	Δt (min)	P (mbar)	Freq(Hz)	Power(W)	Mode	Notes
9:30	0	894	302.7 - 302.9 - 302.8 - 303K			
9:31	1	400				
9:32	2	150				
9:33	3	60				
9:34	4	24				
9:35	5	11				
9:36	6	6				
9:37	7	4				
9:40	10	1,9	304 - 305 - 303 - 305K			
10:40	70	4,93E-01	308 - 313 - 311 - 314K			
11:40	130	5,13E-01	311 - 318 - 316 - 318K			
12:40	190	5,46E-01	313 - 323 - 320 - 323K			
13:40	250	6,14E-01	314 - 326 - 324 - 327K			
14:40	310	7E-01	315 - 329 - 326 - 329K			
03/08/2018						
08:35	23 h	9,3e-01	320 - 338 - 335 - 338K			
			ACTIVATE TURBOPUMP, Switch off heaters			
8:39	0	1,08	When activating turbo, P increases a bit			
8:40	1	1	275	34	Ramp	
8:41	2	5,8E-01	467	60	Ramp	
8:42	3	2,2E-01	617	69	Ramp	
8:43	4	1,63E-01	765	71	Ramp	
8:45	**6**	**1,4E-01**	**900**	**54**	**Normal**	
8:49	10	1E-01	900	36	Normal	
8:51	12	9,45E-02	900	26	Normal	
	31	9,9E-02	900	46	Autotuning	
	40	2E-01	740	70	Autotuning	

Table 11: Third vacuum test results

The pumping system is not able to pump correctly.

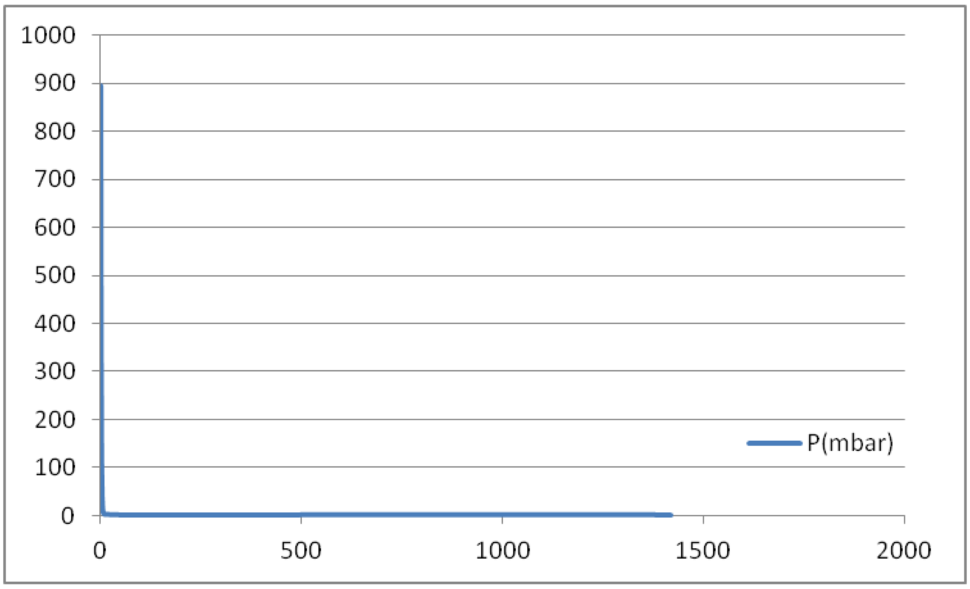

Figure 19: test result (Pressure)

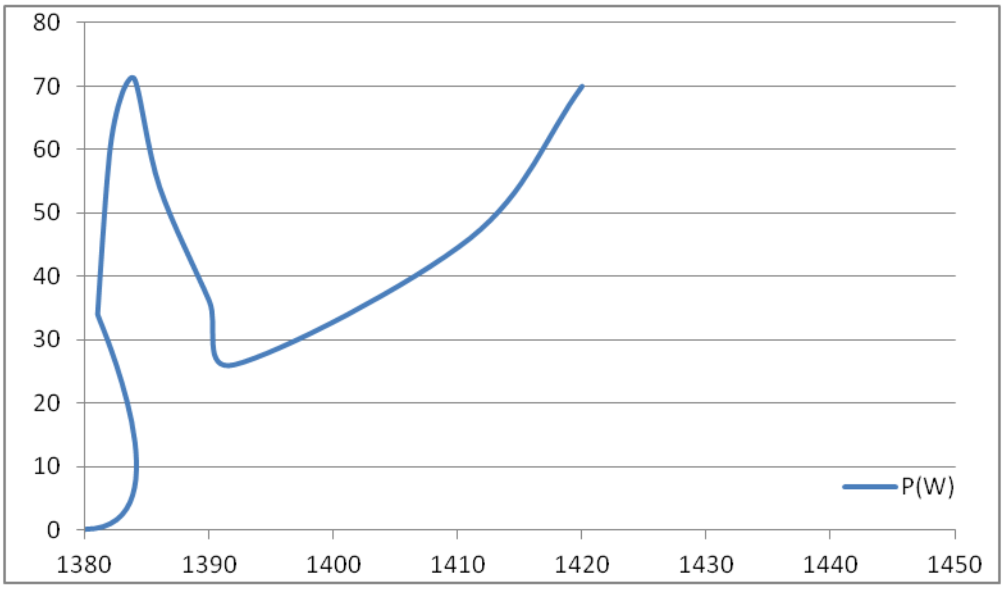

Figure 20: test result (Power)

4. Tests and results with Yebes pumping system

Similar tests were carried out using the pumping system acquired by Yebes Observatory with similar negative results.

This pumping system is currently under study at Agilent laboratories (for five weeks now, still without results).

5. Tests with other pumping systems

Just for verification, the same VGOS receiver was pumped using two of the pumping systems usually used at Yebes Observatory.
The test results are indicated below.

5.1. Pfeiffer Hicube 80 Eco

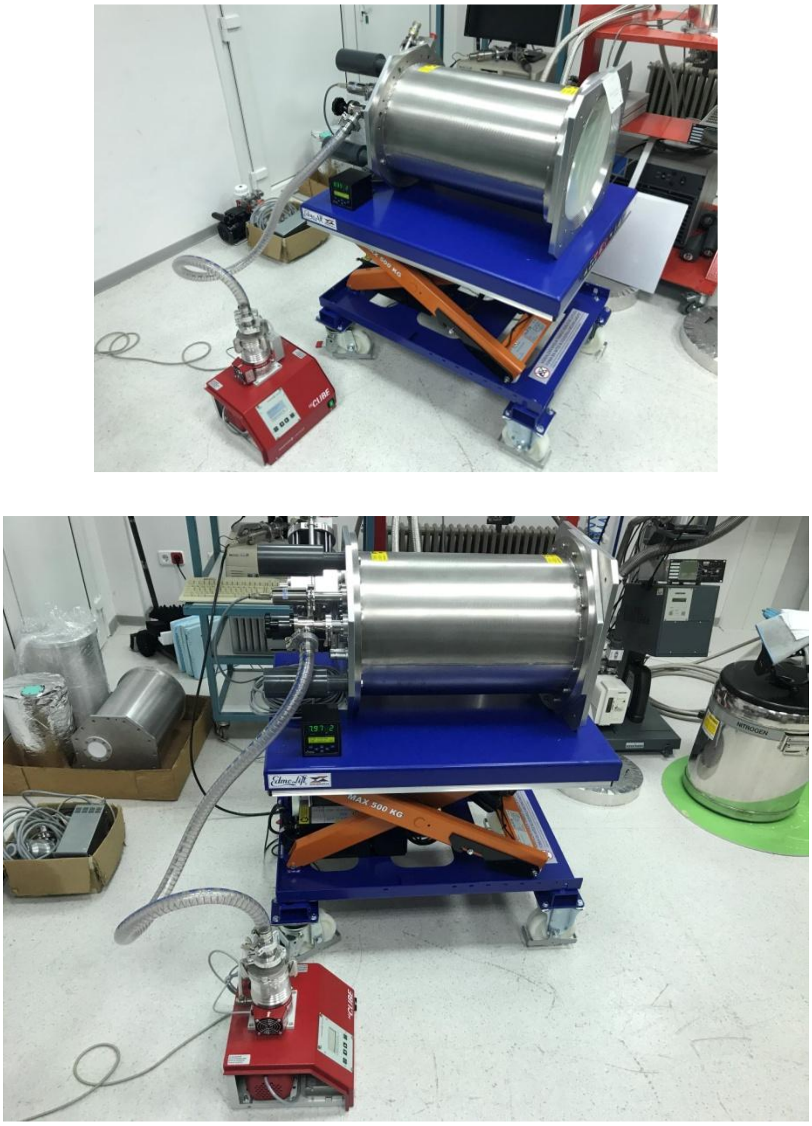

figure 21: FGI VGOS rx with Hicube 80 Eco

- Start only with backing pump from atmospheric pressure.
- When vacuum≈4mbar, start turbopump.
- Maximum turbo frequency is 1500Hz.
- SS reinforced PVC pipe between receiver and turbopump.

Test 6

Time (min)	P (mbar)	Turbo Freq (Hz)	Turbo P (W)
0	Atm		
1	720		
2	585		
3	480		
4	390		
5	324		
7	222		
11	108		
14	68		
16	60		
30	12		
45	5,6		
60	4,1	**Start turbopump**	
61	3,1	730	77
62	1,4	895	77
63	1,2E-01	1100	77
64	5E-02	1500	21
65	3,5E-02	1500	20
90	1,9E-02	1500	16
110	1,68E-02	1500	16
130	1,4E-02	1500	15

Table 12: test results

The pumping system is able to pump the receiver.

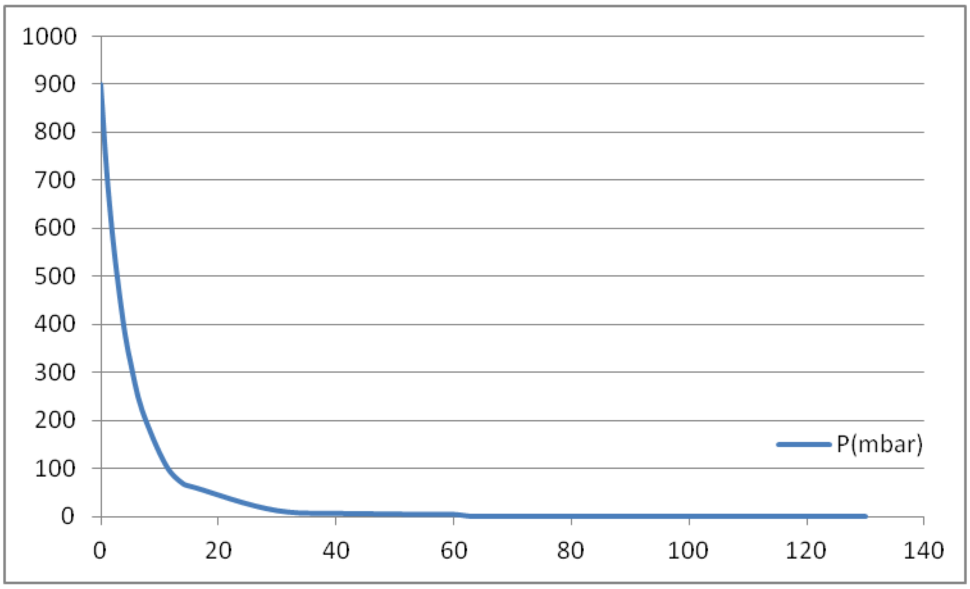

Figure 22: test result (Pressure)

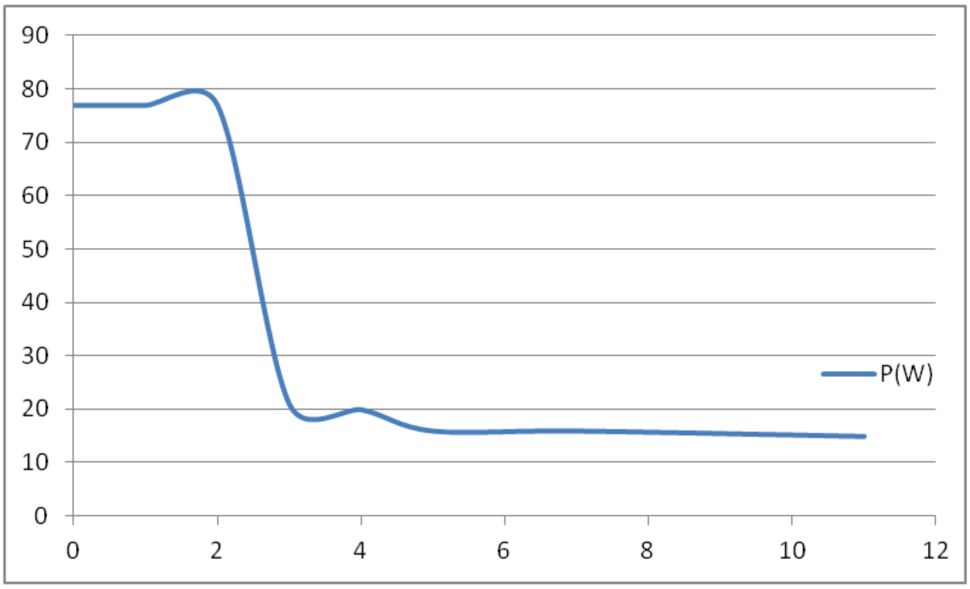

Figure 23: test result (Power)

5.2. DUO3 + Turbo V81m

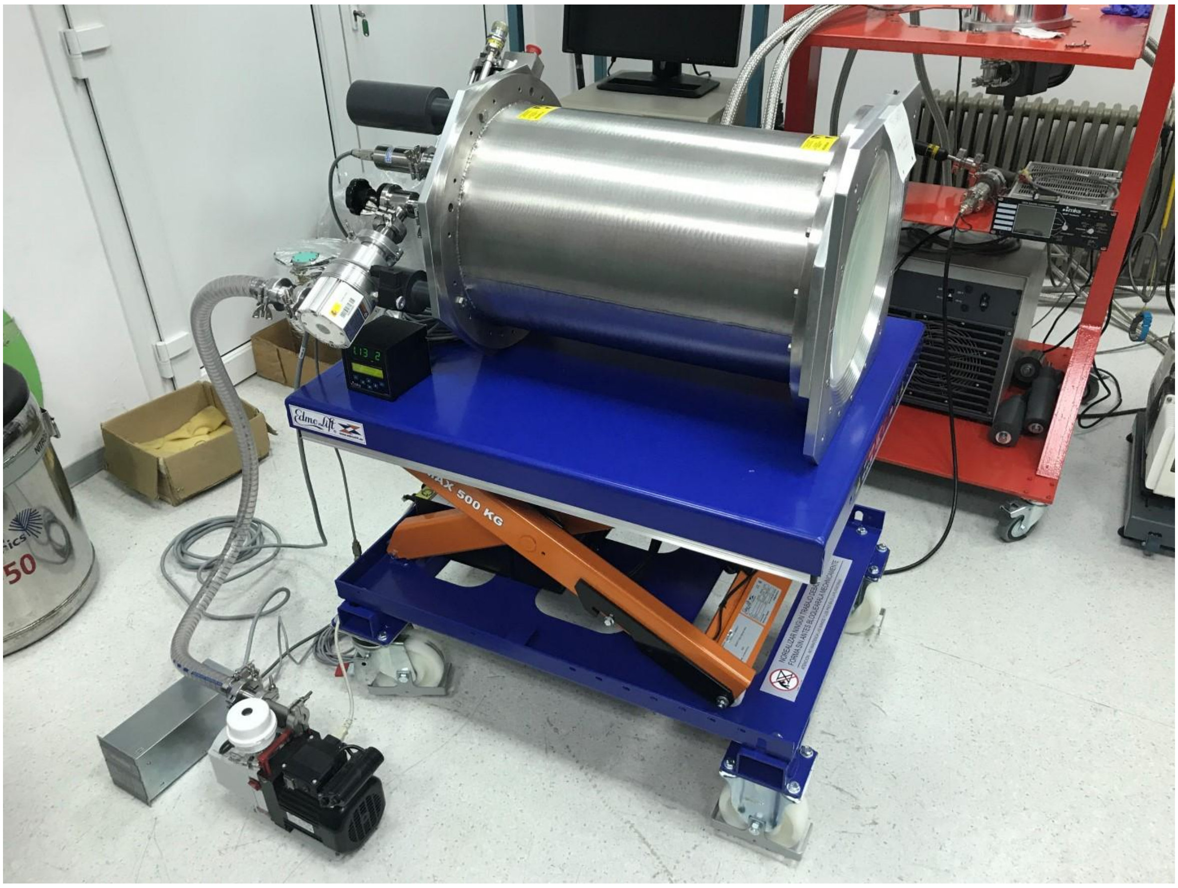

figure 24: FGI VGOS rx with DUO3 + Turbo V81m

- Start directly with backing pump and turbopump from atmospheric pressure.
- Maximum turbo frequency is 1350Hz.
- SS reinforced PVC pipe between turbopump and backing pump.

Test 7

Time (min)	P (mbar)	Turbo Freq (Hz)	Turbo P (W)
0	Atm	**Start turbopump**	
1	400	219	20
2	170	317	27
3	65	485	42
4	25	746	65
5	6	1100	53
6	1E-01	1180	51
7	2E-02	1350	11
54	3.5E-03	1350	7
75	2.96E-03	1350	7

Table 13: test results

The pumping system is able to pump the receiver.

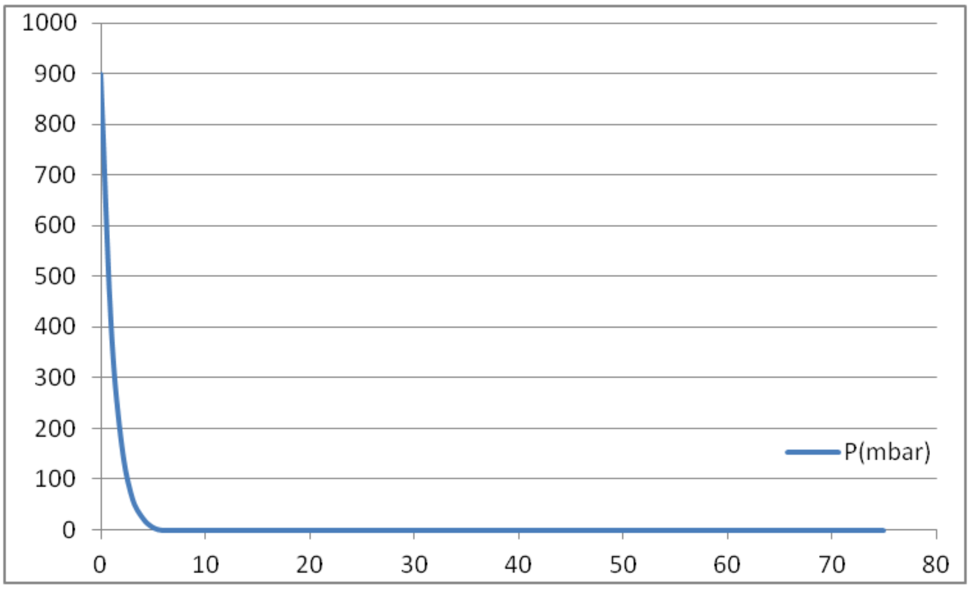

Figure 25: test result (Pressure)

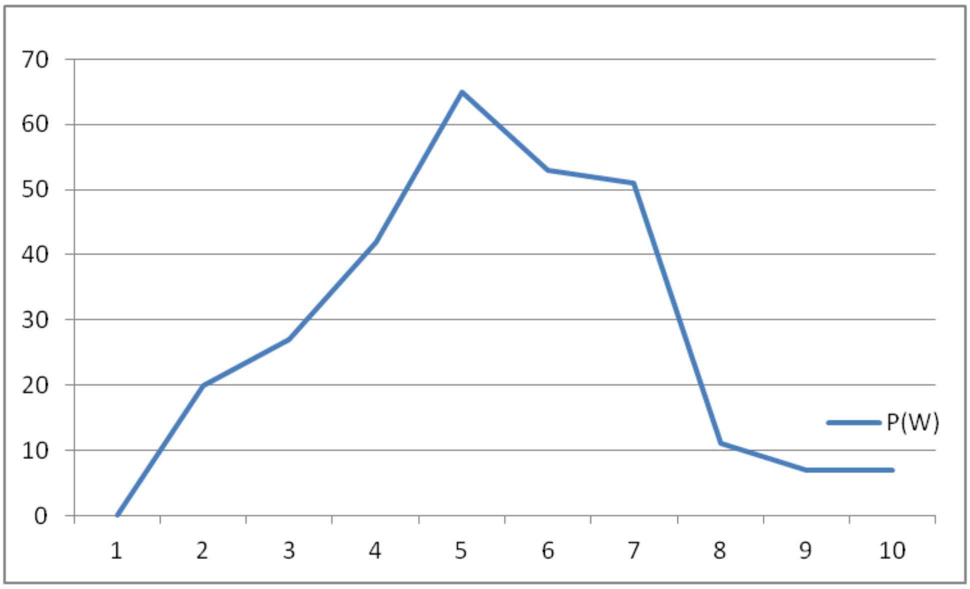

Figure 26: test result (Power)

6. Tests after reparation

TEST 8, after reparation at Agilent laboratories (FGI VGOS cryostat), 12/09/2018

- With J5 connector (stop turbo pump from the beginning).
- With PC connection. Start monitoring from T-plus software (instructions at the end).
- Starting only with backing pump from atmospheric pressure.
- Soft start OFF
- Maximum turbo frequency is 1010Hz (default value).

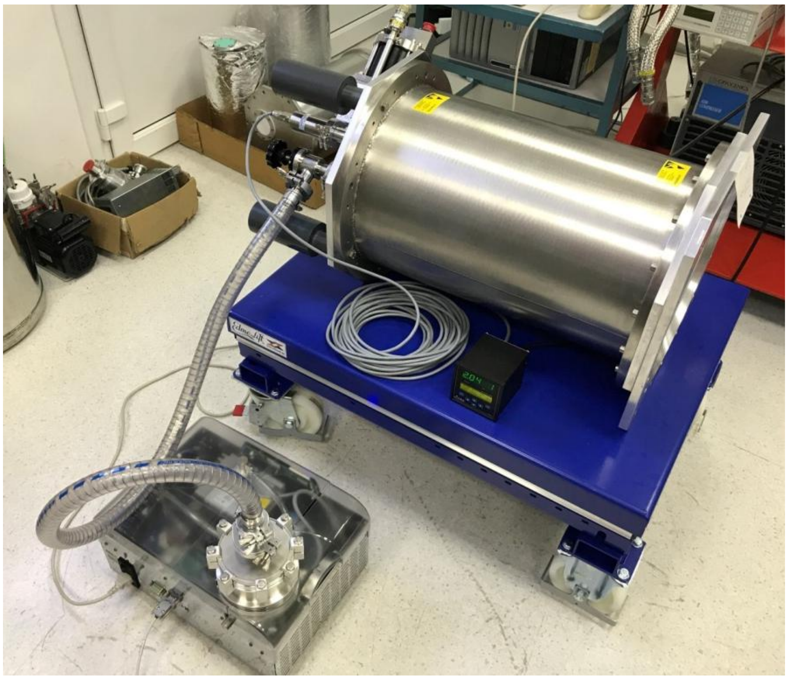

Figure 27: test setup

<table>
<tr><th>Time (min)</th><th>Pressure (mbar)</th><th>Turbo Freq (Hz)</th><th>Turbo Power (W)</th><th>Turbo state</th></tr>
<tr><td>0</td><td>905</td><td colspan="3" rowspan="12">Only backing pump</td></tr>
<tr><td>1</td><td>425</td></tr>
<tr><td>2</td><td>150</td></tr>
<tr><td>3</td><td>63</td></tr>
<tr><td>4</td><td>25</td></tr>
<tr><td>5</td><td>11</td></tr>
<tr><td>6</td><td>6</td></tr>
<tr><td>7</td><td>4</td></tr>
<tr><td>8</td><td>2,8</td></tr>
<tr><td>9</td><td>2,2</td></tr>
<tr><td>10</td><td>1,8</td></tr>
<tr><td>20</td><td>7,5E-01</td></tr>
<tr><td>22</td><td>7,3E-01</td><td colspan="3">Start turbopump</td></tr>
<tr><td>23</td><td>4E-01</td><td>260</td><td>34</td><td>Ramp</td></tr>
<tr><td>24</td><td>7E-02</td><td>440</td><td>55</td><td>Ramp</td></tr>
<tr><td>25</td><td>5E-02</td><td>660</td><td>70</td><td>Ramp</td></tr>
<tr><td>26</td><td>4,6E-02</td><td>860</td><td>72</td><td>Ramp</td></tr>
<tr><td>27</td><td>4,4E-02</td><td>1010</td><td>60</td><td>Normal Operation</td></tr>
<tr><td>28</td><td>4,3E-02</td><td>1010</td><td>24</td><td>Normal Operation</td></tr>
</table>

30	4,1E-02	1010	23	Normal Operation
51	3,12E-02	1010	21	Normal Operation
70	2,26E-02	1010	20	Normal Operation
115	2,24E-02	1010	18	Normal Operation
160	1,94E-02	1010	15	Normal Operation
230	1,66E-02	1010	15	Normal Operation
1345	7,5E-03	1010	32	Normal Operation
Stop turbopump: it takes 15 minutes to 0Hz				
Switch off pumping system				

Final vacuum is not very good...

*** Power a little high (between 20 and 40W), there were moments with V=72V. 15W only for some time.**

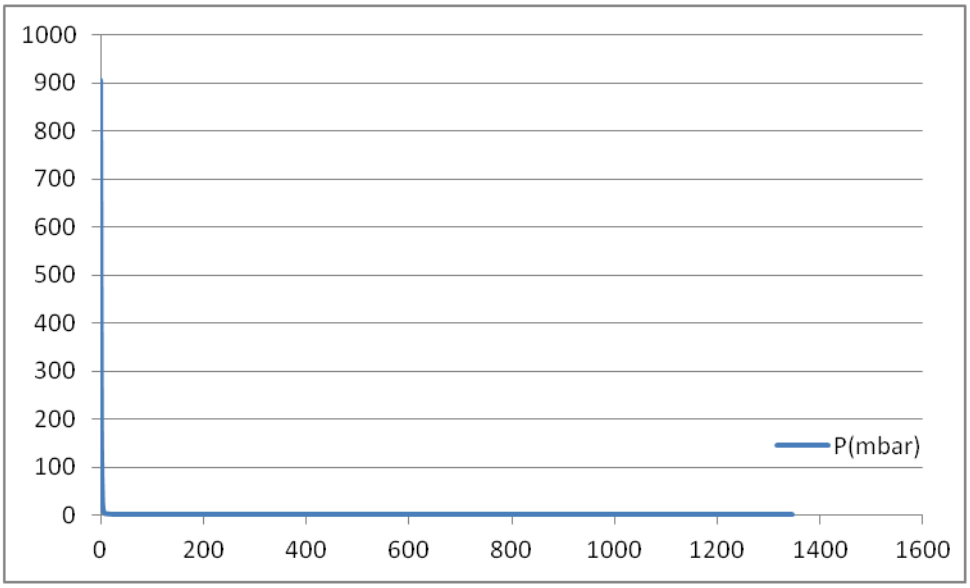

Figure 28: test result (Pressure)

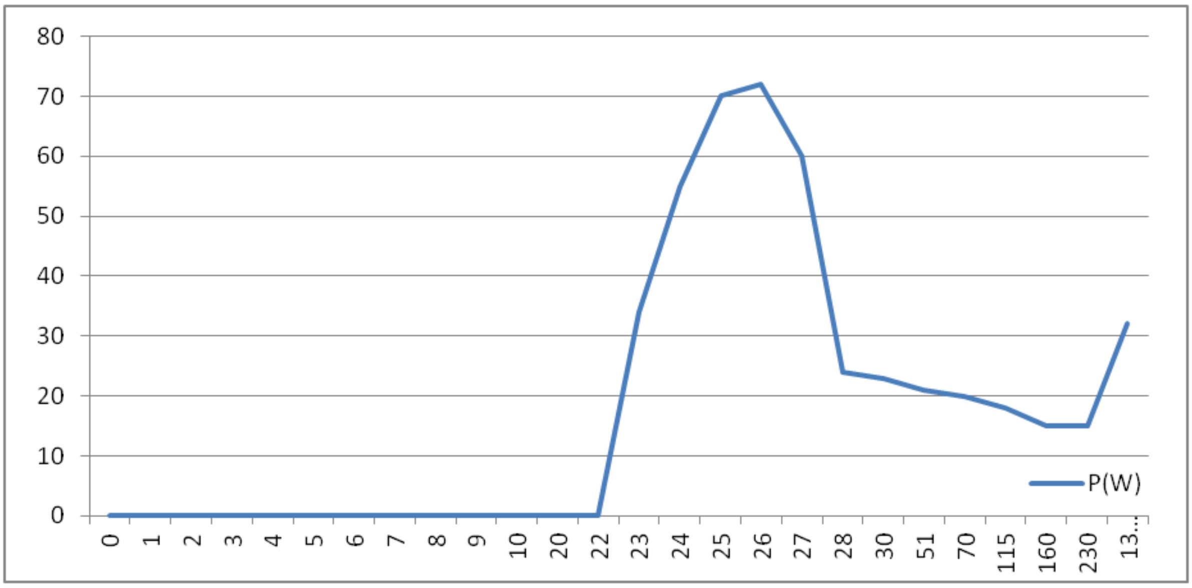

Figure 29: test result (Power)

TEST 9, after reparation at Agilent laboratories (FGI VGOS cryostat), 17/09/2018

- With J5 connector (stop turbo pump from the beginning).
- With PC connection. Start monitoring from T-plus software (instructions at the end).
- Starting only with backing pump from atmospheric pressure.
- Soft start OFF
- Maximum turbo frequency is 1010Hz (default value).

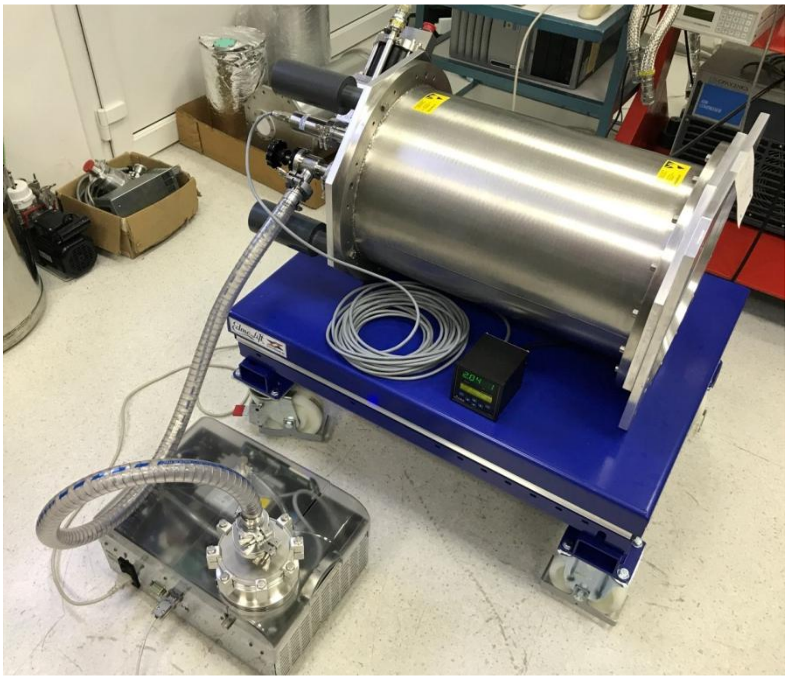

Figure 30: test setup

Time (min)	Pressure (mbar)	Turbo Freq (Hz)	Turbo Power (W)	Turbo state
0	887	Only backing pump		
1	290			
2	121			
3	44			
4	18			
5	8.5			
6	4.9			
7	3.4			
8	2.52			
9	1.97			
10	1.7			
20	7.55E-01			
22	7.11E-01	Start turbopump		
23	4.4E-01	261	34	Ramp
24	8.4E-02	443	57	Ramp
25	6.1E-02	689	70	Ramp
26	5.6E-02	867	72	Ramp
27	5.36E-02	1010	63	Normal Operation
28	5.1E-02	1010	22	Normal Operation
30	4.93E-02	1010	23	Normal Operation

51	3.74E-02	1010	21	Normal Operation
70	3.29E-02	1010	18	Normal Operation
115	2.68E-02	1010	17	Normal Operation
160	2.33E-02	1010	26	Normal Operation
230	1.97E-02	1010	45	Normal Operation
306	1.72E-02	1010	56	Normal Operation
1365	1.5E-02	890	70	(Status code 3)
Stop turbopump: it takes 5 minutes to 0Hz				
Switch off pumping system				

* The test was started at 09:43 on 17th of September 2018 and ended on 18th of September 2018 at 08:4. From about 12:49 (17th of September) the consumed power of the turbopump starts to rise. Then at approximately 16:42 (17th of September) the rpm of the turbopump slow down from 1010 till the end of the test (See TPS-Test-2-17-09-2018.xlsx).

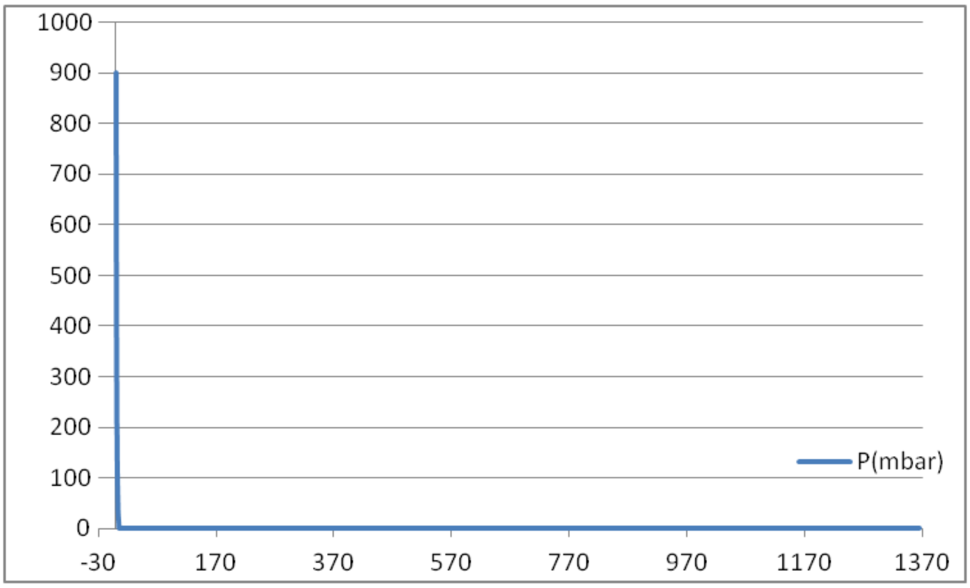

Figure 31: test result (Pressure)

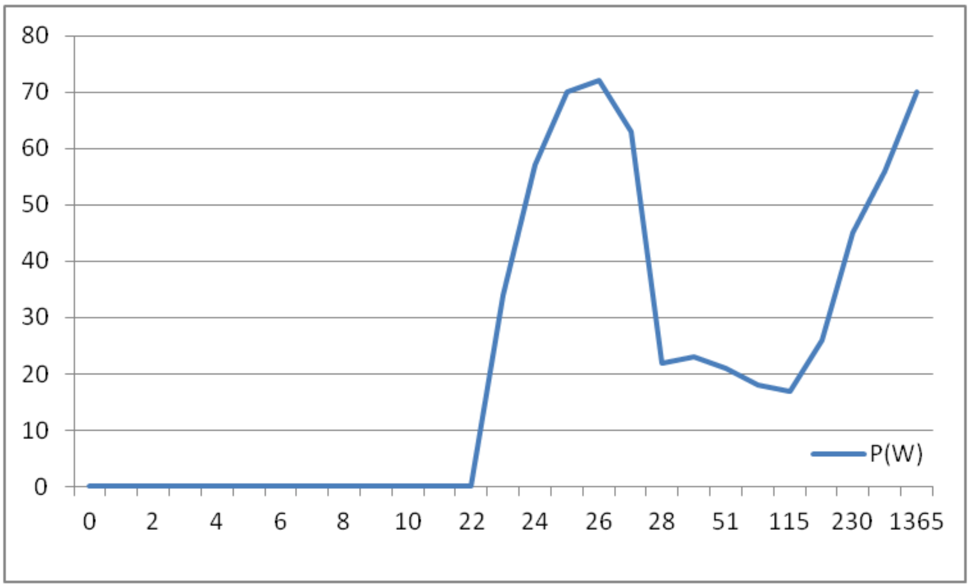

Figure 32: test result (Power)

7. Conclusions

Analyzing the basic specifications of the three different systems, it can be concluded that the system TPS-Compact is the most powerful one (looking only the specifications).
So pumping the receiver with this system should be faster and with a better final vacuum.

Before starting the tests, the setup of the pumping system was carefully done, following in detail the user´s manual indications:

- Installation of the pumping system interface for KF40.
- Installation of the Agilent T-Plus control software.
- Running the pumping system for 48 hours in soft start mode (with a blind cover).

There are not leakage problems in the dewar. It was measured and also verified with a leakage detector system.

After a negative test with the TPS-Compact system, it was always verified that, under the same setup, it was possible to pump the receiver with the other two available pumping systems (remember they both have lower pumping capabilities).

Similar bad results are obtained when using the pumping system acquired by Yebes Observatory.

The final conclussion is that the system is not able to pump correctly the receivers so its use is not advised for this type of applications.