

TVC Facility Description

The aim of the TVC test facility is the simulation of thermal vacuum conditions (e.g. space environment in open space and sun exposure). The vacuum chamber is made of stainless steel and offers an inner diameter of 880 mm and a length of 1,200 mm (volume: approx. 0.7 m³).

The temperature of the hardware under investigation is adjusted by means of temperature controlled copper plate(s) mounted inside the vacuum chamber, and – if required – by heating the chamber wall. Process plates are heated electrically, the cooling is performed by liquid nitrogen (LN2: T = -196 °C). General specifications of this plate type are:

- Available dimensions: 1,000x700 mm², 500x500 mm².
- 60x50 mm grid of M6 threads for sample fixation
- Maximum heating rate 5-6 K/min
- Maximum operating temperature +250 °C (short time), +200 °C (continuous)
- Maximum cooling rate ~ 5-6 K/min
- Minimum operating temperature -185 °C in vacuum
- Various copper shields for improved thermal homogeneity available
- For specific applications 2 heating/cooling plates may be used in parallel, either in sandwich configuration or mounted in two stages for larger amount of test items

The TVC test rig is attached to a clean room classified as ISO7. The front door is inside the clean room, the external equipment like vacuum pumps, cooling systems, TQCM, and data processing systems, are located outside. Figure 1 shows overview images of the TVC test rig, the following sections describe the single sub-systems in detail.

Chamber Setup

To allow the connection of measurement devices for the characterisation of the test object (e.g. thermocouples, Si-diode sensors, motors, etc.) and to connect the cooling and heating devices the chamber is equipped with the following flanges:

- 4xCF40, 2xCF63, 2xCF100 and 1xCF200 flanges on the front door placed in the clean room
- 4xCF40, 4xCF63, and 1xCF200 flange on the back side
- 1xCF200, 2xCF150, 2xCF63 and 4xCF40 on the circumference of the chamber.

Vacuum Generation and Control

A vacuum pressure of 10⁻⁶ mbar can be achieved. Alternatively, it is possible to perform tests in defined gas atmosphere (e.g. 100 mbar N₂). Various non-corrosive gases at pressures below ambient can be used for the testing. The following equipment is used to maintain and control the pressure:

- Rotary vane pump Adixen ACP40 (oil-free multistage Roots pump)
- Turbo pump Pfeiffer Hi Pace 1200 (1000 l/s)
- Rough vacuum gauge Pfeiffer TPR 018 (Pirani gauge head)
- High vacuum gauge Pfeiffer IKR 060 (inverted magnetron gauge)
- Pressure control Pfeiffer RVC300/EVR 116 valve/APR250 gauge

All pressure measurement cells are calibrated by manufacturer. Additional calibration on customer request may be done on customer's expense at Pfeiffer Vacuum; expect lead time of ~ 2 weeks.

Temperature Measurement and Control

To achieve the required temperature on the hardware, two Eurotherm temperature controllers are available. They allow the definition of complex temperature profiles which can be completed automatically. The temperature is measured by thermo-sensors at several positions inside the TVC. For each setup all thermo-sensors are calibrated using an Ametek CTC-650 calibration furnace that is regularly calibrated by its manufacturer.

The following equipment is used:

- 4x Eurotherm 2416 - 2x for process plates, 1x for chamber wall heating, 1x for cold plate
- Up to 32 thermocouples type K (\varnothing 0.5 mm), regularly calibrated in house
- On request: 20 PT100, \varnothing 2.0 mm, measurement performed by Keithley 2700 Multimeter

Additionally, the chamber wall may be heated to a temperature of up to 125 °C using a heating band wrapped around the chamber circumference, for improving temperature homogeneity of a bake-out.

Additional Support Equipment

- For trapping condensable matter, a cold plate with approximately 200x200 mm size is installed. The standard operation temperature is -50 °C; the minimum operation temperature is -180 °C.
- To assess the amount of material evaporated from the sample during the thermal vacuum test a TQCM (Temperature-controlled **Q**uartz **C**rystal **M**icrobalance) with 6 MHz quartz is used. The temperature is typically kept at -20 °C, but may be operated at lower temperatures, too.
- For RGA analysis (**R**esidual **G**as **A**nalysis) a quadrupole mass spectrometer can be attached to the chamber.
- For specific applications the measurement of electrical properties (e.g. electrical resistivity, voltage, current) is required. For this purpose a Keithley 2700 Multimeter equipped with Keithley 7700 multiplexer is available. Up to 20 channels may be read out simultaneously. This device is also used to read the PT100 temperature sensors (if installed).
- To test the performance of moving parts (e.g. potentiometers, slip rings ...) under space environment, a drive train can be mounted on the TVC chamber. It is equipped with servo or stepper motors and different torque gauges.
- All devices listed above are controlled by PC. The TherESA software to control all devices and to record all parameters has been developed at AAC.

Cleaning Procedure

The step-by-step procedures, how tests are performed in the TVC rig can be found in the according test specifications and in the test procedures available at AAC. However, one common step to prepare the test rig for the tests is the cleaning procedure. For all operations performed in the clean room, cleanroom smocks and cleanroom snoods should be worn during cleaning operations and for handling the hardware.

The chamber and all installed support equipment are being wiped with IPA using non-linting cleanroom tissues. In specific cases, other permitted solvents may be used, too. The cleanliness is tested and documented by performing wiping tests: The tissue is soaked with IPA and the inner side of the CF flange where the water-cooled turbo-molecular pump is mounted, is wiped. The tissue is put into a sample bag and the sample bag is stored in plastic sheets together with the project's process slip. Also a contamination protocol is stored.

Chamber Bakeout

The amount of molecular organic contaminants (MOC) is most efficiently reduced by chamber bake-out under vacuum. This is typically done in two stages:

- Facility Cleaning Bake-Out:
 - Standard temperature 165 °C on process plate(s), 125 °C on chamber wall
 - Duration at least 24 hours
 - Target value $<<1 \times 10^{-5}$ mbar
- Blank Bake-Out
 - Temperature and duration depending on customer specification
 - Duration typically 72h
 - Target vacuum $<1 \times 10^{-5}$ mbar (typically $<3 \times 10^{-6}$ mbar)
 - Optional: TQCM monitoring
 - Installation of MOC / PFO samples (to be provided by customer)



**Figure 1: Overview of TVC Thermal Vacuum Chamber:
up: view from clean room, down: view from laboratory.**

Table of Equipment

To summarise the information given above, Table 1 lists the equipment used at the TVC test rig.

Table 1: List of used equipment for TVC test rig

Equipment	Type	Ser.Nr	Remark
Rotary vane pump	Adixen ACP40	666681	
Turbo pump	Pfeiffer Hi Pace 1200	15703606	
Rough vacuum gauge	Pfeiffer TPR 018	44244014	Pirani gauge head
High vacuum gauge	Pfeiffer IKR 060	44243822	Inverted magnetron gauge head
Vacuum Monitor	Balzers TPG 300	86546-900CT	Controller for TPR and IKR gauges
Vacuum Controller	Pfeiffer RVC300	PFI 00792	Controller for EVR116 valve/ APR280 or APR250 piezo sensors
Vacuum control valve	Pfeiffer EVR 116	44236052	Electro-mechanical gas dosing valve (e.g. N ₂ , CO ₂ , Ar)
Vacuum gauge	Pfeiffer APR 250	44187039	Piezo transducer, 1-1,300 mbar
Temperature Controllers	2x Eurotherm 2416	FC1344001983 FC1344001984	
Multimeter	Keithley 2700	4045974	with Keithley 7700 multiplexer
PT100 thermo-elements	OMEGA Thinfilm RTD Element F3105	n/a	Installed on customer request
TQCM Sensor Unit	BeamTec / McVac Inc. Twin Sensor Head Model MV-700-009S	n/a	6 MHz crystal
TQCM Controller	Colnatec EON-LT	20160812AAC	
RGA	ThermoScientific Smart IQ+	1703-01-182-3	Quadrupol mass spectrometer, range: 0-200 amu
Calibration furnace	Ametek CTC-650 B RS232	620568-00905	



List of Consumables

The standard consumables are listed in Table 2 below:

Table 2: Permitted consumables in the TVC test rig

Consumable	Quality	Vendor / Article ID#
<u>Cleaning fluids:</u> <ul style="list-style-type: none"> • 2-Propanol (mostly used) • Acetone • Ethanol • n-Pentane 	AnalaR NORMAPUR ACS/REAG.PE/REAG.USP IR grade TechniSolv reinst AnalaR NORMAPUR zur Analyse	VWR Chemicals Roth Lactane VWR Chemicals VWR Chemicals
<u>Cleaning Tissue:</u> <ul style="list-style-type: none"> • Cleanroom Wipes 	Spec-Wipe® 4	VWR Collection Art.-No. 115-0036
<u>Mounting samples / thermo-sensors:</u> <ul style="list-style-type: none"> • Kapton tape 	ECSS-Q-ST-70-02C passed (each new batch tested at AAC)	RS-Components Art.-No. 436-2778
<u>Purging / Venting:</u> <ul style="list-style-type: none"> • Nitrogen (standard) • Argon (on request) • Carbon dioxide (on request) 	Grade 5.0, 99.999% Grade 5.0, 99.999% Grade 3.0, 99.9%	Messer Austria
<u>Thermal Shielding / Homogenisation:</u> <ul style="list-style-type: none"> • Aluminium foil • Multi-layer isolation (up to +150 °C) 	OTS MLI Coolcat 2	various suppliers RUAG Space Austria

Please note: Other consumables may be used if agreed on between AAC and Customer.